



# INTER-YEAR COURSE OFFERING

## LANGUAGES

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ECTS Credits: 2  
MANDATORY

All students must attain at least a CEFR B2 level in French to graduate. French is offered at beginner, intermediate, and advanced levels. Students are placed into the appropriate level based on a French test taken at the beginning of the year.

Students who are francophones will take a different foreign language. The offering changes from one year to the next, but typically includes courses like Spanish, Italian, German, and Chinese.

## HUMANITIES AND SOCIAL SCIENCES FALL OFFERING

Students must take at least one HSS course per year in the first two years. The course offer is shared among students from all years.

### Geopolitics of cyberspace HSS102

L. Pétiinaud

The aim of the course is to approach a wide variety of subjects related to geopolitics and cybersecurity, cyber defense and cyberspace. To understand the intricate relationships between these concepts, the course studies their definition and the changing meaning of these words in both space and time. We will first address the question of the evolving nature of geopolitics as a method and as a historically changing field of study, but also a renowned tool of geopolitical studies: maps. We will then apply geopolitics to the complex concept of cyberspace through multiple case studies.

The course also reviews the many aspects of cyberspace and cybersecurity where

States are not the central actor. The emergence of numerous private actors also raises questions in the political field (Internet giants and their relationships to governments or the EU) and in the military and defense domains (non-State actors including terrorist groups, and their role in cyber conflicts).

After this overview, the course will cover specific and detailed case studies in order to analyze the interactions between geopolitical conflicts and the specificities of cyberspace: disinformation, “geopolitics of infrastructures”, and the geopolitical dimension of the so-called emerging technologies.

ECTS Credits: 2

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Syllabus

# HUMANITIES AND SOCIAL SCIENCES FALL OFFERING

## Violence: An Introduction to Moral and Political Philosophy **HSS103**

T. Sentis

ECTS Credits: 2

This course serves as an introduction to some major concepts and theories in moral and political philosophy, building on the notion of violence. The aim of the course is to define violence and to shed light on its moral status and political use. The central problem concerns the relation between violence and justice: are violence and injustice equal? Is violence necessarily unfair? Can violence be of any good? Is any injustice a form of violence?

Violence will be examined under its political aspect in relation to power and domination: contemporary subjects will be addressed, such as state violence and protests, terrorism and war, as well as symbolic and economic violence.

## Tech and Law **HSS213**

A. Side

ECTS Credits: 2

This course is a practical introduction to intellectual property law, information and technology law, designed especially for engineers and business people. It is a global approach, which helps students creating a new and strategic way of thinking when building or working on tech projects, by using law as a tool.

The moral aspect of the subject will be studied in relation to suffering, recognition and vulnerability: violence will be understood in the context of race, gender and class and in the light of contemporary issues such as sexual violence, environmental violence and animal exploitation.

This course should help students to get familiar with philosophical methods like following a critical approach, elaborating concepts and discussing texts from Plato to the present day, in an effort to understand contemporary problems in the light of philosophy.

This course also gives students a better understanding of the legal implications of technology law and of the future challenges they will have to face while working in the tech industry.

## Introduction to Sustainable Architecture and Urbanism **HSS212**

V. Fraigneau

ECTS Credits: 2

Understanding the emerging initiatives and theories in architecture and urbanism helps support a sustainable and desirable habitability of territories, by giving attention to their dynamic agencies. We introduce strategies and perspectives in architecture and urban planning to understand their transformation, their modes of installation and aesthetics. We'll explore urban stratifications,

interrelations, infrastructure and mobility networks, urban recycling, the place of nature in the city, local and frugal design thinking. We'll understand what sustainability really is in architecture and urban practice through critique, theory, and the actions and thoughts of major figures promoting this attitude.

## HUMANITIES AND SOCIAL SCIENCES FALL OFFERING

### Masterpieces of Western Literature: Sea and Sailors **HSS301**

I. de Vendevre

ECTS Credits: 2

This course proposes a fuller understanding of the role played by the sea and seafarers in literature from Homer and The Odyssey up to the twentieth century.

The sea is not only a backdrop in literature. In many masterpieces of the Western canon, the sea is at the very heart of narrative development. It is a place that puts the human will to the test, thus revealing the true nature of men, for better or for worse. More often than not, the sea features as a living being, a character per se.

Oceans have provided opportunities for adventure, discovery, the pursuit of wealth, and encounters with other civilisations. The sea and seafarers have played a decisive part in cultural exchange, political conquest, and scientific knowledge.

Studying them, we shall be carried into a history of crime, war, and death. We shall also find them functioning as pervasive metaphors in metaphysics and poetry, in music and painting.

The sea is the habitat of fascinating, awe-inspiring creatures that connect the natural with the supernatural. The sea is probably the best example of a threshold (in the twofold sense of limes and limen), of a border that keeps some people out and allows others in. It can also mark the frontline where holidaymakers enjoy – or not – the summer through life on the beach, an invention of the late-nineteenth century.

Based on multidisciplinary analyses, this course aims to discuss the multifarious aspects of the sea and of sailors in fiction.

## HUMANITIES AND SOCIAL SCIENCES SPRING OFFERING

### French Identity **HSS151**

P-M. Renaudeau

For students with little or no previous knowledge of French culture/language.

This course aims to define French identity from a historical, geographical, cultural and political point of view. Political science methods will be used to address three questions:

› The social construction of French Identity as seen through France's history and geography.

› French identity as a social model and national model claiming a universal dimension.

› French identity facing globalization. The purpose will be to be able to analyze the French context and understand its specificities.

ECTS Credits: 2

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Syllabus

# HUMANITIES AND SOCIAL SCIENCES SPRING OFFERING

## Introduction to Film Studies HSS251

J. Degenève

ECTS Credits: 2

This course will provide tools to analyse every genre of movie. More precisely, four aspects will be addressed: story, staging, frame and montage.

The purpose will be to be able to find and defend ideas, without forgetting the emotions experienced.

## Major Issues in Today's World and the Place of France HSS101

N. Rousselier

ECTS Credits: 2

**For students holding French Bac or having previously studied French History**

This course is designed to give a broad and comprehensive view of the political and social place of France in today's globalized world. Two themes will be addressed this year in order to understand the originality of French Politics. First, we will study the question of the French democracy and its difficulties. French Politics have gone through many different poli-

tical regimes (Monarchy under different styles, two Bonapartist Empires, five different forms of Republic, Vichy's Dictatorship) and recurrent upheavals from the Revolution of 1789 to the "Gilets Jaunes" of 2018. It is this "French instability" which is at the core of the first part of the course. Secondly, the course will address issue of the French Secularism, "laïcité à la française". It was historically and is still today one of the great challenges of French society and the French democracy.

## Philosophy: Science and Technology HSS202

J. Chalier

This course introduces students to foundational concepts in the philosophy of science. It asks the question of the relationship of philosophy to science and technology throughout history, examines some examples of encounters between

science and philosophy with an emphasis on their social and political context and encourages students to exercise their own judgement on contemporary issues in philosophy of science.

ECTS Credits: 2

## Social Media and Society HSS252

A. Claesson

Have social media changed our societies for the better? Or have they worsened already existing social problems (or created new ones)?

This course offers a sociological perspective on the role of online platforms in our political landscape and invites students to

question the role of digital technologies in relation to traditional media outlets in our democracies. It will cover issues such as mis- and disinformation, "filter bubbles", online harassment, and the role of private companies in our public sphere.

ECTS Credits: 2



# YEAR 1 COURSE OFFERING FALL SEMESTER

# MATHEMATICS

## Linear Algebra MAA101

N.Perrin

ECTS Credits: 5  
MANDATORY

Linear Algebra is a fast-paced course which provides students with an overview of the most useful techniques of linear algebra. Upon completion of this course, students will fully understand the funda-

mental concepts of vector spaces, dimension, linear systems, and determinants, and how they apply to problems in other fields of the Bachelor program.

## Introduction to Analysis MAA102

F. Pacard

Introduction to Analysis is an introductory-level mathematical analysis course that provides a well-balanced approach between calculus and foundational notions. It is designed to equip students with the fundamental analytical tools required in all scientific fields. This course introduces students to the key concept of limits which can be studied in many

different frameworks. In particular, this course covers the theory of real valued and complex valued sequences as well as infinite series. The course also covers the study of continuous and differentiable functions. The course culminates with the notion of Taylor series which is a powerful tool for many interesting and deep results in mathematics.

ECTS Credits: 5  
MANDATORY

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Syllabus

# INTRODUCTION TO MAJORS

## Introduction to Economics EC0101

Y. Koriyama, J-B. Michaud

ECTS Credits: 5  
MANDATORY

Introduction to Economics provides students with the foundational concepts of economics. The course begins with the investigation of the individual behavior of households and firms. Subsequently, students review and develop a thorough understanding of the concepts of supply and demand, before investigating how markets function. The course also covers imperfect competition and other market failures, as well as macroeconomic aggregates and the role of the central bank.

**Required reading:** Principle of Economics by N. Gregory Mankiw

## Physics I: Mechanics And Heat PHY101

S. Ramanarivo

Physics I introduces students to the fundamentals of classical mechanics and thermodynamics. Classical mechanics surveys the physics of motion from the ground up, learning the basic principles of physical laws and their application to the behavior of objects. It covers kinematics (motion), dynamics (forces and Newton's laws), energy, linear and angu-

lar momentum, and harmonic oscillators. The course then introduces general principles of thermodynamics: temperature, kinetic theory of ideal gas, heat and heat transfer, and entropy. Upon completion of this course, students will master key physical concepts, which will serve in the Math-Physics double major and to explain everyday phenomenon.

ECTS Credits: 5  
MANDATORY

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# METHODOLOGY

## Introduction to Computer Programming CSE101

B. Smith

ECTS Credits: 5  
MANDATORY

Computer Programming introduces students (with or without previous programming experience) to the fundamentals of computer programming in Python, with applications across the sciences. In this course, students will explore fundamental algorithms and data structures, up to and including binary trees, using a mixture of procedural, recursive, and

object-oriented techniques. Upon completion of this course, students will have a solid foundation in the culture and practice of modern programming, and the basic skills to solve real-world problems using efficient, well-written programs and open-source tools. These foundations will be extended and completed in CSE102 and CSE103.

## Maths in Practice: How to Write Maths LAB102

J. Sabin

ECTS Credits: 2  
MANDATORY

How to Write Mathematics introduces the central notions needed to pursue advanced mathematics, such as elementary logic (e.g. quantifiers, different methods of proof), sets, numbers and functions.

The goal is to provide the right tools and concepts to properly write and understand a mathematical argument, which will be a key component of the whole three years of the Bachelor program.

## Maths in Practice : Calculus LAB101

L. Guin

Maths in Practice I enables students to develop the basic practical mathematical skills that will be largely used in the program. It starts by a refresher training before tackling more advanced concepts, using a hands-on pedagogy.

The concepts to be covered are elementary functions and their derivations and integrations, vector calculus, coordinate systems, integration and simple differential equations.

ECTS Credits: 1  
MANDATORY

## Discovery Labs LAB103

C. Baroud, Y. Laplace, A. Guell

In the Discovery Lab sessions, students will discover basic experimental techniques, data analysis and interpretation, and documentation of experimental work.

Examples will cover harmonic oscillators, forces and equilibrium, kinematics and collisions, waves and chemistry.

ECTS Credits: 2  
MANDATORY

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Syllabus

# TRANSVERSE COURSES

## Overall presentation

Transverse teaching in the bachelor program includes courses in humanities and social sciences, foreign languages, personal development and sports, for a total of 5 ECTS per semester. At each of the four first semesters, a student must follow a foreign language class counting for 2 ECTS, either a course in Humanities and Social Sciences or a seminar on personal development counting for 2 ECTS each, and two hours of monitored sport activities per week counting for 1 ECTS.

The courses in humanities and social sciences, were presented above, those in foreign languages are to be chosen within a global catalog of classes provided by the corresponding department. The seminars on personal development for the fall semester of year 1 are described hereafter.

## The Art of Decision Making PDV101

A. Mortureux

We will review how our goals and values interact in decision making, what obstacles might hinder the process, look at

how to overcome them giving tools that enable us to act and move forward in life.

ECTS Credits: 2

## A Healthy Mind in a Healthy Body PDV 102

J. Lefebvre

In this unit, students will focus on health (sports, diet, sleep, mental preparation via the TOP...)

During several sessions, students are given some theoretical and practical tools about the four pillars: physical activity

including sports; diet and nutrition; sleep and alertness; mental preparation via the Tactics to Optimize the Potential. These tools will enable them to improve their health, to manage their stress in their current life or before/during an exam.

ECTS Credits: 2



# YEAR 1 COURSE OFFERING SPRING SEMESTER

# MATHEMATICS

## Discrete Mathematics MAA103

F. Alouges

ECTS Credits: 5  
MANDATORY

**Prerequisites:** LAB102

Discrete Mathematics introduces students to combinatorics, arithmetics and probability (on finite sets) with examples and applications such as graphical modelling and generating functions. It also presents

some more conceptual algebraic subjects. In particular students explore the notion of group. This prepares them for later questions related to symmetry (including those arising in physics) and number theory.

## Integral and Differential Calculus MAA105

J. Bettinelli

ECTS Credits: 5  
MANDATORY

**Prerequisite:** MAA102

Integral and Differential Calculus develops students' skills in two crucial analytical tools: Integration and Differential Equations. The approach to Integration employed in this course is Riemann's integral, a foundational mathematics theory.

The course also introduces students to two important and related topics covered in the Bachelor program: Taylor expansions (a tool for function approximation) and differential equations which is required to understand basic physical problems (trajectories, populations, etc.).

## Introduction to Numerical Analysis MAA106

M. Breden

Mandatory for the double major Math/CS.

**Prerequisites:** MAA102

The aim of Introduction to Numerical Analysis is to provide students with practical knowledge of basic mathematic algorithms and computer programming. Computational Mathematics covers seve-

ral notions such as representation of numbers, complexity of algorithms, interpolation of functions, numerical integration, optimization, error analysis, etc. A significant portion of the course will be devoted to implementation and experiments using Jupyter Notebooks with Python.

ECTS Credits: 3

## INTRODUCTION TO MAJORS

### Advanced Programming CSE102

P-Y. Strub

ECTS Credits: 5  
MANDATORY

Prerequisite: CSE101

Advanced Programming is the continuation of the previous semester's course (CSE101). We will continue to lay the foundations of modern computer science, while developing more sophisticated programming techniques in Python. At the end of this course, students will have

the fundamental analytical and programming skills to solve everyday problems in the sciences more efficiently and effectively. They will also be prepared to continue learning other programming languages and paradigms, and the theoretical foundations of computer science itself.

## METHODOLOGY

### Maths in Practice: Vector and Fourier Analysis LAB151

B. Goutéraux, K. Le Hur

In this course, we introduce vector and Fourier analysis from a hands-on, application-oriented perspective. Vector analysis spans the differentiation and integration of vectors in two and three-dimensional space, eventually culminating with Green's theorem in the plane and its higher-dimensional generalization, Stokes' theorem. Changing gears, we introduce the concept of Fourier series, which give an approximation of periodic functions as an infinite sum of cosines and sines.

We conclude the course with a gentle introduction to Fourier transforms, viewed as a limit of Fourier series in the limit of infinite periodicity. Besides their intrinsic mathematical interest, these tools are widely used in Physics (Electromagnetism, Fluid mechanics, Quantum mechanics...), signal processing and areas of Economics (cycle analysis in financial markets and business models).

ECTS Credits: 2  
MANDATORY

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Syllabus

# COMPUTER SCIENCE

## Introduction to Algorithms CSE103

I. Mackie

ECTS Credits: 2 Mandatory for the double major Math/Computer Science

**Prerequisite:** CSE101

An algorithm is a sequence of instructions that allows us to solve a problem using a finite number of steps; as such, algorithms formalize the notion of what it means to “compute”. We study algorithms to know what can actually be computed, in theory and in practice, and to find out how efficiently it can be done. Introduction to

Algorithms is an initiation into the art and science of algorithms. This course will train students in how to think about algorithms, how to rigorously compare different algorithms and predict their performance, and how to apply this knowledge to solve computational problems efficiently.

# ECONOMICS

## Topics in Economics EC0102

G. Barrows, B.Schmutz

Mandatory for the double major Math/ Economics

Topics in Economics provides an overview of how the concepts in economic analysis are applied through the real-life examples of scientific research in economics. Students will learn how theoretical and empirical methods in economics

are employed in the analysis of diverse subjects, such as economic growth, environmental regulation, public policy, networks, firms’ behaviors, etc. Topics are chosen from the themes in the frontier of economic research.

ECTS Credits: 5

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# PHYSICS

## Physics II: Electromagnetism and Light PHY104

S. Corde

ECTS Credits: 5 **Mandatory for the double major Math/Physics**

**Prerequisites:** PHY101

Physics II: Electromagnetism and Light provides an overview of numerous physics concepts related to the description of light and of electromagnetic phenomena.

This course introduces the concept of fields in physics, in particular with the electric and magnetic fields, and develops students' understanding of electrostatics, magnetostatics, electromagnetic induction, geometrical and wave description

of light. In addition, students explore concepts such as Coulomb's law, Lorentz force, Gauss' law, Ohm's law, Faraday's law, and others.

Upon completion of the course, the students will understand how the classical field theory of electromagnetism with the set of Maxwell equations can describe in a unified way many physical phenomena, from the propagation of light to electrostatics, magnetostatics and induction.

## Beginner's Physics Lab II PHY106

Y. Laplace

ECTS Credits: 2 **Mandatory for the double major Math/Physics**

In the Beginner's Physics Lab sessions, students will have the opportunity to apply the physics knowledge they have acquired in PHY104 in five distinct lab sessions of 4-hour duration. Students will learn basic experimental techniques, data analysis and interpretation, and documentation of experimental work.

Students will cover, in-depth, the measurement of the speed of light, the measurement of the specific charge ( $e/m$ ) of the electron, the photoelectric effect and the measurement of the Planck constant, as well as the Franck-Hertz experiment.

# ELECTIVES

## Biology BI0101

C. Le Clainche

ECTS Credits: 3 **Required for the Biology minor**

Biology is a molecular and cellular biology course, which provides all the concepts required for a scientific understanding of living systems. This course aims both at preparing students for the biology option,

which is available in the Mathematics & Computer Science and Mathematics & Physics majors, and at raising awareness about socio-economic issues related to biology, such as health, ethics or bioengineering.

## General Chemistry CHE101

A. Auffrant

ECTS Credits: 3 **Required for the Chemistry minor**

General Chemistry (CHE101) covers fundamental concepts of atomic structure, and bonding within molecules. It also describes intermolecular interactions and their consequences regarding macroscopic properties. Students also explore the notion of orbital.

CHE101 aims to develop students' fundamental knowledge in chemistry for their study of reactivity aspects in higher-level courses.

## Mathematical Modeling MAA107

V. Bansaye, T. Mastrolia

ECTS Credits: 3 **Prerequisites:** MAA101, MAA102

Mathematical Modeling introduces some basic mathematical models that find applications in mechanics, physics (for example mechanical systems), biology (popula-

tion dynamics) and economics (pricing, contract theory). In particular, this course introduces some techniques such as Markov chains and ordinary differential equations with a hands-on approach.

## Web Programming CSE104

D. Rohmer

**Prerequisite:** CSE101

Web Programming introduces the languages, tools, and techniques specific to develop web-based applications. Students will develop a solid understanding of contemporary, dynamic and responsive website development following the current standards.

This is a hands-on practical course focusing on HTML/CSS and JavaScript language, as well as introducing server programming with PHP. At the end of the course, students will be able to program from scratch their own dynamic website.

ECTS Credits: 3

## Applied Physics PHY107

S. Starikovskaia

**Recommended previous course:** PHY101, LAB101

Applied Physics provides a combination of lectures and seminars with a clear aim to show the link between advanced engineering and high-level physical/mathematical education.

The course will cover selected questions based on fluid mechanics, thermodynamics, optics, electricity and magnetism. Background obtained during courses of general physics and mathematics will be

used to understand the principles of rocket propulsion, engines for hypersonic flights, peculiarities of mass-spectrometry in physics/chemistry and biology, the link between optical spectroscopy, molecular analysis and quantum mechanics etc. As a result of the course, students should be able to look at applied physics problems combining deep knowledge in mathematics and physics and to be able to formulate to resolve a set of estimates giving the idea about mechanisms involved in the considered phenomena.

ECTS Credits: 3

# TRANSVERSE COURSES

## Overall presentation

Transverse teaching in the bachelor program includes courses in humanities and social sciences, foreign languages, personal development and sports, for a total of 5 ECTS per semester. In the first four semesters, student must follow a foreign language class counting for 2 ECTS, for 2 ECTS again either a course in Humanities and Social Sciences if the student has followed a seminar on personal development for the previous semester or a seminar on personal development if he had not, and two hours of monitored sport activities per week counting for 1 ECTS.

The courses in humanities and social sciences, were described above, those in foreign languages are to be chosen within a global catalog of classes provided by the corresponding department. The seminars on personal development for the spring semester of year 1 are described hereafter.

## Meeting a Professional PDV103

B. Destremau

In this unit, the students will interview a professional of their choice and present what they have learnt to their peers, coaches and the head of personal development or other academic staff who will assess their presentation. Discussion will follow. It will help all students better their

communication skills and reflect upon academic and career choices.

ECTS Credits: 2

The unit will start with tutorials on how to network and getting started with LinkedIn.

## The art of decision making PDV104

A. Mortureux

We will review how our goals and values interact in decision making, what obstacles might hinder the process, look at

how to overcome them giving tools that enable us to act and move forward in life.



# YEAR 2 COURSE OFFERING FALL SEMESTER

# MATHEMATICS

## Reduction of Endomorphisms MAA201

E. Balzin

ECTS Credits: 5  
MANDATORY

**Prerequisite:** MAA101

Reduction of Endomorphisms introduces students to more conceptual algebraic subjects. More precisely, students explore the fundamental structures of algebra including groups, rings, and fields. Topics covered in this course are designed to pre-

pare students for later questions related to symmetry (including those arising in physics) and number theory. This course also covers the study of polynomials, including their application, to further develop techniques acquired from linear algebra.

## Topology and Multivariable Calculus MAA202

Y. Bonthonneau

ECTS Credits: 5  
MANDATORY

**Prerequisite:** MAA105

This course is divided into two parts, the first one more theoretical than and setting the foundations of the second one. The theoretical part covers the fundamen-

tals of topology of normed vector spaces and of topology in finite dimension. The second part, more computational, covers differentiation and integration in several (real) variables.

## Introduction to Probability MAA203

G. Conforti

Mandatory for the double major Math/Economics

**Prerequisites:** MAA105

This course covers a wide-range of important notions in probability theory and focuses in particular on discrete

and continuous random variables with examples in modelling. A particular emphasis is put on how to perform and use computer simulations.

## Introduction to Statistics MAA204

D. Métivier

Mandatory for the double major Math/Economics

**Prerequisite:** MAA203

This course is an introductory course in statistics, with complements in probability. Topics include displaying and des-

cribing data, multivariate distributions, Central Limit Theorem and introduction to statistical inference (estimators, confidence intervals and hypothesis testing).

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ECTS Credits: 3

ECTS Credits: 3

# COMPUTER SCIENCE

## Object-oriented Programming in C++ CSE201

S. Mover, S. Redon

ECTS Credits: 5 Mandatory for the double major Math/CS

The goal of this course is to introduce students to the C++ programming language, and the object-based view of software design. C++ is one of the most widely-used programming languages in the world, especially for system-level programming. Much of its power derives from its use of objects, packets of data and functionality that model things and concepts in the real world.

## Design and Analysis of Algorithms CSE202

C. Enea

ECTS Credits: 5 Mandatory for the double major Math/CS

**Prerequisite:** CSE103

Algorithms are at the heart of all computation. Building on the algorithms the introduced in CSE103, this course provides a solid foundation in modern algorithmics. Students develop a deeper

knowledge of the fundamental algorithms, an understanding of how they work, and an appreciation of how to implement them efficiently. They also learn how to reduce other problems related to these fundamentals.

# ECONOMICS

## Intermediate Microeconomics ECO201

M. Nunez

Mandatory for the double major Math/Economics

**Prerequisites:** ECO101, ECO102

Intermediate Microeconomics focuses on the study of consumer and producer decisions and interactions. It also introduces the students to decision-making under uncertainty and basic portfolio theory, market equilibrium and general equilibrium of the economy, monopolistic and oligopolistic competition among firms and other forms of strategic interac-

tion studied in Game Theory. Additional issues are reviewed, including conditions for market efficiency, public goods, the effect of strategically used private information, market failures and their remedies, etc.

**Textbook:**

› *Intermediate Microeconomics: A Modern Approach* by Hal R. Varian.

## Intermediate Macroeconomics ECO202

G. Lukyanov

Mandatory for the double major Math/Economics

**Prerequisites:** ECO101, ECO102

Intermediate Macroeconomics focuses on both the business cycle and long-term growth. The goal is to understand the relationship between key macroeconomic variables; namely, consumption, investment, money supply, interest rate, inflation, unemployment, and GDP growth.

Students investigate the role of monetary and fiscal policy, while reviewing international issues, such as the behavior of exchange rates and capital flows.

**Textbook:**

› *Macroeconomics* by Olivier Blanchard  
› *Macroeconomics* by N. Gregory Mankiw.

# PHYSICS

## Classical Mechanics PHY201

JM. Allain

ECTS Credits: 5 Mandatory for the double major Math/Physics

**Prerequisites:** PHY101

This course introduces students to the Lagrangian and Hamiltonian mechanics. Starting from the concepts of Newtonian mechanics, the course extends these concepts to a more systematic description of the mechanics, adapted to complex systems. The course will mostly use examples from the dynamics and vibrations of mechanical systems, with progressively increasing complexity. Examples from other fields of physics will be also proposed (electromagnetism, astrophysics, chaos...)

After a reminder of the classical concepts of point mechanics, the course extends these concepts to the Lagrangian formalism and to the least action principle. The Lagrangian formalism will be used to describe the mechanics of rigid bodies. Lagrangian formalism will then be extended to the Hamiltonian mechanics which is at the core of quantum physics and other modern theories in physics.

We will also present some extensions of Lagrangian and Hamiltonian mechanics to other fields of physics.

Upon completion of this course, students master equations and principles in analytical mechanics. They will be able to discuss the relevance of the chosen model, as well as derive and solve simple models taken from their environment.

Main concepts covered: Fundamental law of dynamics; kinetic and potential energy. Linearized equations of motion, dynamics of linear coupled oscillators. Constraints and generalized coordinates, D'Alembert principle, Hamilton principle, Euler-Lagrange equations of motion, conservations of energy and momentum. Rigid body, center of mass, Euler angles, Moment of inertia and inertia tensor, Euler equation of motion. Equations of Hamilton, conservation theorem.

## Wave Optics and Radiation PHY202

J. Faure

Mandatory for the double major Math/Physics

**Prerequisites:** PHY101, PHY104

This course focuses on the description of light as a wave phenomenon. The course starts by reviewing the concepts of waves and oscillations in simple systems. It then turns to the way light is emitted by matter and covers dipole radiation, black body radiation as well as emission and absorption of light by atoms. The latter will be an opportunity to discuss the quantum behavior of matter and to introduce the electronic structure of atoms in a phenomenological manner. Light waves are then described in detail, with a focus on scattering, reflection and refraction at interfaces and polarization. The concept of coherence is developed along with its spectacular experimental manifestations in interferences and diffraction.

Concrete examples and illustration of these phenomena will be given throughout the lectures, so that students, by the end of the course, should be able to explain why the sky is blue and the sun a bright yellow, how the fingerprint detection system of a smartphone works and more.

With this course, students will acquire a deeper physical understanding of wave phenomena, including the basic concepts of wave optics and light emission. They will master the analytical skills needed to solve basic problems in physical optics and wave physics in general.

## PHYSICS

### Advanced Lab I PHY203

C. Baroud, F. Cadiz, Y. Laplace

ECTS Credits: 3 **Mandatory for the double major Math/Physics**

**Recommended previous courses:**  
LAB101, PHY106

In Advanced Lab I, students have the opportunity to apply the physics knowledge they acquired in PHY201 and PHY202. It consists of 7 distinct lab sessions of 4 hours each. It provides an in-depth study of a wide range of physical phenomena such as electronics wave-optics (diffraction, interference and polarization of light), and the mechanics of solid bodies.

Upon course completion, students will have acquired advanced experimental skills allowing them to set up, carry out and analyze critically experiments in physics and mechanics.

## ELECTIVES

### Cell Biology BIO201

C. Le Clainche

**Required for the Biology minor**

**Prerequisite:** BIO101

Cell Biology introduces students to the mechanisms that cells use to regulate the physical properties of their dynamic architecture, to produce force and move, to compartmentalize and transport proteins, to regulate growth and death, and to communicate with their environment. The course focuses on human cells, and emphasis is placed on human diseases where appropriate. Upon course completion, students have a comprehensive

understanding of the function and architecture of cells.

Because experimentation is at the heart of progress in cell biology, 50% of classes contain practical work, completed over the course of the semester. The intention is to allow students to develop their knowledge in the subject area, to acquire sound scientific reasoning, and to become familiar with the main techniques of modern cell biology, like quantitative microscopy imaging and computer-assisted data analysis.

# ELECTIVES

## Introduction to Reactivity CHE201

A. Guell

ECTS Credits: 3 **Required for the Chemistry minor**

**Prerequisite:** CHE101

This course is an intermediate-level chemistry course that allows students to develop the tools to analyze a chemical

transformation. In particular, students explore why, how and at which rate substances react. This interactive course explores these topics through lectures, tutorials and labs.

## Algorithms for Discrete Mathematics MAA205

L. Gérin

ECTS Credits: 3 **Mandatory for the minor Computational Mathematics**

**Prerequisites:** MAA101, MAA103, CSE101

The purpose of this course is to use computer science and programming to solve problems in Discrete Mathematics, and vice versa.

The main objectives of the course are:

- › Learning to use various tools (recursivity, symbolic computing, graphs, matrices...) to deal with complex problems.

› Using computer programming and experimentation to help prove theorems.

› Improving intuition in pure and applied Mathematics.

Discrete Mathematics happen to offer a lot of aspects that lend themselves to computer experimentation. Topics may include: graphs and adjacency matrices, number theory, logic, analysis of algorithms, dynamical systems, elementary probability...

The course will mainly consist of practical labs in Python.

## Logic and Proofs CSE203

D. Rohmer

Logic and Proofs is an introduction to logic, a science that deals with the principles of validity of demonstration. Its goal is to familiarize students with formal methods for representing arguments and reasoning about them. This encompasses

propositional calculus, first-order logic, and deduction systems, as well as the related technologies (e.g. automated provers, proof assistants) for building mechanized proofs. No prior knowledge in logic is required.

ECTS Credits: 3

# TRANSVERSE COURSES

## Overall presentation

Transverse teaching in the bachelor program includes courses in humanities and social sciences, foreign languages, personal development and sports, for a total of 5 ECTS per semester. In the first four semesters, student must follow a foreign language class counting for 2 ECTS, for 2 ECTS again either a course in Humanities and Social Sciences if the student has followed a seminar on personal development for the previous semester or a seminar on personal development if he had not, and two hours of monitored sport activities per week counting for 1 ECTS.

The courses in humanities and social sciences, were described above, those or in foreign languages are to be chosen within a global catalog of classes provided by the corresponding department. The seminars on personal development for the spring semester of year 1 are described hereafter.

## A Healthy Mind in a Healthy Body PDV201

J. Lefebvre

In this unit, students will focus on health (sports, diet, sleep, mental preparation via the TOP...)

Discover and develop the 4 pillars to improve your well-being and health capi-

tal: physical activity, diet, sleep and mental preparation.

Students will prepare and present a practical restitution dealing with the main notions learnt.

ECTS Credits: 2

## Volunteering PDV202

B. Destremau

In this unit, students will be involved as a group, volunteering to meet and work with all kind of partners outside the university context. The aim is to

strengthen one's skills in terms of group work but also to develop strong values such as open-mindedness, generosity and self-confidence.

ECTS Credits: 2

## Genius – online mentoring PDV205

A. Rosa

Create and set up a series of fun sciences online workshops in English (games/activities/presentations) targeting French

high school students from underprivileged backgrounds. Main goal: fight against social inequalities.

ECTS Credits: 2



# YEAR 2 COURSE OFFERING SPRING SEMESTER

# MATHEMATICS

## Euclidean and Hermitian Spaces MAA206

T. Gauthier

ECTS Credits: 5  
MANDATORY

**Prerequisite:** MAA201

Euclidean and Hermitian Spaces continues the study of linear maps between vector spaces, started in MAA101. The goal is to obtain simple and efficient models for these applications up to suitable changes of coordinates. The concept of duality is initially introduced in the

general context of mere vector spaces. Then, the focus is put on vector spaces enjoying a richer structure, namely prehilbert spaces, which is available in most applications (*e.g.* in solid mechanics or in quantum mechanics). The geometry of these spaces, as well as their important transformations (*e.g.* normal or unitary maps) is also discussed.

## Series of Functions, Differential Equations MAA207

E. Di Nezza

ECTS Credits: 5  
MANDATORY

**Prerequisite:** MAA202

Series of Functions, Differential Equations (MAA207) builds upon the topology notions studied in Topology and multivariable calculus (MAA202) to allow for a more profound study of functions. Examining functions as limits of simpler ones (*e.g.* for approximation problems) is made possible in a rigorous manner thanks to topological ideas. This

provides the possibility of using crucial tools in many scientific fields; the most striking one being Fourier series (first designed to solve the heat equation and now ubiquitous in science and, in a hidden manner, in daily life). The second part of the course deals with a wide array of differential equations, permitting students to better understand complex physical questions.

## Numerical Linear Algebra MAA208

T. Pichard

Mandatory for the double major Math/CS

ECTS Credits: 3

**Prerequisite:** MAA106, MAA201

This course covers the very important topic of numerical linear algebra. Starting with recalling linear algebra's basic concepts (*i.e.* vectors, matrices, addition and multiplication), we quickly concentrate on methods for solving linear systems. Students study typical direct and iterative methods together with their practical implementation. This permits them to compare the methods in terms of complexity depending on the size of

the problem to solve. The emphasis is put on the practical resolution of the problems and the theory that is required to understand the behavior of the methods considered. Subtle notions such as condition number, order of convergence, etc. are covered and explained. The course finishes with a project which is defended in-class during the last week of the semester. Students are evaluated based on this their project presentation, a report, and coursework.

# COMPUTER SCIENCE

3 Mandatory courses among all CS courses available for the double major Math/CS

## Machine Learning CSE204

J. Read

ECTS Credits: 5

**Prerequisites:** CSE101, CSE102 and CSE201

Machine learning is an increasingly important topic and is involved in many of the recent advances of artificial intelligence in science and industry. This course covers the main paradigms and algorithms in this area, including classic regression methods, neural networks (and deep and convolutional networks), decision tree and ensemble approaches, kernel

methods, clustering and representation learning, and a brief look at reinforcement learning. Emphasis is put both on building solid theoretical foundations as well as being able to master a complete machine-learning pipeline from data pre-processing to model testing and evaluation from a practical viewpoint. We work with Python and scientific libraries such as Numpy and Scikit-Learn. The main grading component is a team project, and a few in-class quizzes and assignments.

## Computer Architecture CSE205

F. Zappa Nardelli

ECTS Credits: 5

**Prerequisite:** CSE201

This course investigates the design and organization of computers at their lowest level.

This encompasses computer hardware, and also the operating systems that provide an interface between most programs we write and use with the underlying machine and its network.

## Introduction to Formal Languages CSE206

E. Haucourt

**Prerequisites:** CSE203

This course introduces different concepts in automata theory and formal languages, including formal proofs, deterministic

and non-deterministic automata, regular expressions, regular languages, context-free grammars and languages, and Turing machines.

ECTS Credits: 3

## Introduction to Networks CSE207

T. Clausen

This course will introduce students to the architecture and skeleton required for implementing a protocol – and part

of that will include creating multiple threads, and synchronized queues.

ECTS Credits: 3

# ECONOMICS

## Introduction to Econometrics ECO203

L. Recuero Virto, A. Uhlendorff

ECTS Credits: 5 **Mandatory for the double major Math/Economics**

**Prerequisite:** ECO101, ECO102

Introduction to Econometrics introduces the most common ways to study and analyze economic data, with a focus on emphasizing data analysis for empirical causal inference. Topics include randomized trials, regression, instrumental variables, differences-in-differences, and

regression discontinuity designs. Students also learn how to study datasets through practical examples.

**Textbook:**

- › *Introductory Econometrics: A Modern Approach* by Jeffrey M. Wooldridge
- › *Basic Econometrics* by Damodar N. Gujarati and Dawn C. Porter

## Introduction to Finance ECO204

H. Dastarac

ECTS Credits: 5 **Mandatory for the double major Math/Economics**

**Prerequisite:** ECO101, ECO102, ECO201

This course introduces to basic issues regarding the financial system, i.e. markets and institutions intermediating saving and investment. After an informal description of the financial system, it

starts with basic asset pricing, continues with corporate finance theory (Modigliani-Miller theorem and its deviations), then turns to the study of banking, insurance and financial markets. Whenever possible, it connects theory with contemporary issues.

## Topics in History of Economic Thought Since 1945 ECO205

B. Cherrier

ECTS Credits: 3

**Mandatory for the double major Math/Economics**

**Prerequisite:** ECO101, ECO102

This topics course is based on teamwork in which students work in groups of four or five to further explore economics

issues. In particular, students discuss current events, create and test economic models, while developing and analyzing computer simulations.

# PHYSICS

## Classical Electrodynamics PHY204

A. Couairon

ECTS Credits: 5 Mandatory for the double major Math/Physics

**Prerequisites:** PHY104, PHY105

Classical electrodynamics is an important pillar of physics given that it led to numerous scientific and technological developments since the 19th century. This course aims to provide students with an introduction to the principles and behaviors of dynamical electric and magnetic systems, and a theoretical foundation in classical field theory. It builds upon the knowledge acquired in PHY104 and begins with reminders in electrostatics and magnetostatics, before moving on to a more formal presentation of Maxwell's equations in magnetic and dielectric media including local and integral forms, conservation laws, potential formulations and Gauge transformations. Applications of the electromagnetic theory such as free or guided propagation, optical phenomena or the emission of radiation by moving charges are presented as key concepts illustrating the development of modern technology. The course concludes with an introduction to relativistic electrodynamics and its covariant formulation.

Upon completion of this course, students will master the fundamental principles

in classical electrodynamics. They will be able to understand the origin of Maxwell's equations in magnetic and dielectric media and their essential consequences. Besides deriving and solving simple models illustrating the main concepts, they will also be able to understand the physical principles governing everyday life and modern technological systems, from wave propagation phenomena to optical fibers, to antennas and electrical engines.

Topics covered in this course include: electrostatics, potential problems in 3D, boundary value problems, Poisson's equation, multipole expansion; conservation laws; dia-para-ferro-magnetism, induction laws; field energy; displacement current; solution to Maxwell's equations in vacuum, superconductivity (London theory); plane electromagnetic waves; waveguides and resonators; radiating systems; special theory of relativity; relativistic kinematics; Lorentz transforms of Fields; 4 vectors, covariant formulation of electromagnetism; radiation by moving charges; synchrotron radiation; Cherenkov radiation.

## Introduction to Quantum Physics PHY205

A. Specka

Mandatory for the double major Math/Physics

**Prerequisites:** PHY101, PHY104, PHY105, PHY202

**Recommended previous courses:** PHY103, PHY106, PHY107, PHY201

Quantum physics is the theoretical framework for the description of nature at the atomic length scale and below. According to our present knowledge, it encompasses the most fundamental physical theory, and is the basis for everyday applications like semi-conductor electrons, lasers, medical imaging to name only a few. In this course, students discover quantum physics through the formalism of Schrödinger's wave mechanics, and learn to describe simple, non-relativistic quantum phenomena, mainly in one dimension, by applying mathematics of classical waves to which they have become familiar. Subsequently, they are introduced to the quantum-mechanical formalism of which the central notion is the quantum state. Students also become familiar with the underlying mathemati-

cal structures, Hilbert spaces and Hermitian operators, and discover the quantum description of known classical systems and concepts such as free motion, the harmonic oscillator and angular momentum. The course also allows students to explore purely quantum phenomena that have no classical counterpart, such as the electron spin, and a brief overview on quantum communication may be provided. Throughout the course, the abstract theory will be illustrated by historic experimental evidence and modern applications whenever appropriate.

Upon completion of this course, students will be able to explain the conceptual difference between classical and quantum behavior, and solve simple one- or two-dimensional problems of quantum mechanics in the framework of wave mechanics. Furthermore, they will be able to wield the abstract formalism of quantum states in Hilbert spaces, and to apply it on simple quantum systems.

# PHYSICS

## Waves in Fluids, with Examples from Geophysics PHY206

R. Plougonven

### Prerequisites:

PHY101, PHY102, PHY201, PHY202

The course provides an introduction to waves in fluids. A necessary first step is to derive a minimal set of equations for fluid motions. In consequence, the course constitutes a partial introduction to fluid mechanics, restricted to inviscid fluids. One goal of the course is to demonstrate how one proceeds to obtain wave solutions starting from a physical description of a system and its equations of motion. Two families of waves are derived and examined in detail: acoustic waves and surface gravity waves. These serve to discuss key notions regarding waves: the methodology to obtain wave solutions, the dispersion relation and its implica-

tions, the phase and group velocity, the polarization relations. The above constitutes the core of the course. In complement and as openings to other topics, the three last sessions discuss nonlinearity, different families of waves present in the atmosphere and ocean, and propagation into an inhomogeneous medium.

At the end of the course, the students will understand how to obtain, in a given system, wave solutions if they exist, and how to characterize a family of waves. The illustrations, for acoustic waves and for geophysical waves, will have introduced general culture elements regarding music and musical instruments, and certain oceanic and atmospheric motions.

## Advanced Lab II PHY207

F. Cadiz

Mandatory for the double major Math/Physics

### Recommended previous course: PHY203

In Advanced Lab II, students have the opportunity to apply the physics knowledge they have acquired in 7 distinct lab sessions of 4 hours each. PHY207 provides an in-depth study of a wide range of physical phenomena such as fundamental and applied wave-optics (Fourier optics,

Michelson interferometry), atomic physics (the Balmer series), thermodynamics (the Rüchardt experiment, the Stirling engine) as well as fluid mechanics. Upon completion of this course, students will have acquired advanced experimental skills allowing them to set up, carry out and to critically analyze experiments in physics and mechanics.

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ECTS Credits: 3

1 Mandatory course to choose between PHY206 and PHY208 for the double major Math/Physics

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ECTS Credits: 3

Syllabus

## PHYSICS

### Atoms and Lasers PHY208

D. Suchet, E. Johnson

ECTS Credits: 3

1 Mandatory course to choose between PHY206 and PHY208 for the double major Math/Physics

**Recommended previous course:** PHY202

Light amplification by stimulated emission of radiation (laser) holds a unique place in the heart of physicists. Lasers are at the same time a spectacular manifestation of a quantum phenomenon, a powerful and versatile tool ranging from industrial applications (laser processing, telemetry...) to fundamental research (spectroscopy, cold atoms...) and a remarkable workbench to acquire a better understanding of key concepts in physics.

This course is an introduction to light-matter interactions through the intricate relationship between atoms and lasers. Importantly, this course will build on experimental situations, and introduce models with increasing complexity to explain the observed results. As the basic component of a laser is a source of light, the course will start with basic spectroscopy, and several atomic models will be considered (Bohr model, Einstein coefficients, Schrodinger model, etc.). The emission of continuous laser light by such atoms will be described from both a classical (effective medium)

and semi-classical (population inversion) perspective. The mirror will then be turned back on the atoms, and several applications of laser light revealing the behavior of atoms will be discussed (Light, Stark and Zeeman shift, Rabi oscillations etc.). Finally, some practical perspectives on advanced laser technologies and applications will be given.

This course will not add many new physical concepts, but rather show how results obtained in previous courses (especially in optics, classical and quantum mechanics) can be used. Upon completion of this course, students will have acquired key understandings concerning the bilateral interactions between laser devices and atoms. They will have understood the circumstances under which the emission of useful coherent light can be produced, and also the information that such light can provide when analyzing atomic systems. They will also be able to identify the relevance, necessity, and limitations that classical and quantum models display when analyzing problems in this field. They will also gain familiarity with some laser device technologies.

## ELECTIVES

### Molecular Genetics BIO202

PA. Defossez

ECTS Credits: 3

Required for the Biology minor

**Prerequisite:** BIO201

Molecular Genetics provides an in-depth understanding of the mechanisms by which living organisms store, express and transmit genetic information and the basis of human genetic diseases. Lectures will cover a range of topics, including the molecular aspects of DNA replication and transcription, translation of RNA into protein and gene regulations. This course will also cover the latest methodologies used in genomics analysis, like DNA sequencing.

Because experimentation is at the heart of progress in cell biology, 50% of classes contain practical work, completed over the course of the semester. The intention is to allow students to develop their knowledge in the subject area, to acquire sound scientific reasoning, and to combine the modern techniques in molecular genetics with computer-assisted data analysis.

# ELECTIVES

## Environment and Energy CHE202

A. Auffrant, A. Guell

ECTS Credits: 3 Required for the Chemistry minor

**Prerequisite:** CHE201

Environment and Energy is an intermediate-level chemistry course that explores topics such as chemistry in water (*i.e.*

acid/base, complexation equilibrium), electrochemistry, and selectivity in chemical transformations. This interactive course explores these topics through lectures, tutorials and labs.

## A First Step in Numerical Optimization MAA209

B. Bogosel

Mandatory for the minor Computational Mathematics

**Prerequisites:** MAA202, MAA208

Numerical optimization concerns the minimization or maximization of an objective function. It often relies on the computation of the gradient of this function. MAA209 covers several aspects of the classical methods that are used in such problems. For instance, the gradient methods (or steepest descent), the non-linear conjugate gradient methods will be seen. A particularly important topic

concerns the Newton-Raphson method, which extends the mono-dimensional Newton method to higher dimension. MAA209 follows MAA208, since linear algebra methods are heavily used. Applications to the computation of the Eigen elements of a matrix or to the resolution of non-linear systems of equations are also studied. As before, the course heavily uses practical sessions, which are taken under consideration for the grading.

ECTS Credits: 3

# TRANSVERSE COURSES

## Overall presentation

Transverse teaching in the bachelor program includes courses in humanities and social sciences, foreign languages, personal development and sports, for a total of 5 ECTS per semester. At each of the first four semesters, a student must follow a foreign language class counting for 2 ECTS, either a course in Humanities and Social Sciences or a seminar on personal development counting for 2 ECTS each, and two hours of monitored sport activities per week counting for 1 ECTS.

The courses in humanities and social sciences, were described above, those in foreign languages are to be chosen within a global catalog of classes provided by the corresponding department. The seminars on personal development for the fall semester of year 2 are described hereafter.

## Speech Contest PDV203

L. Ali-Messaoudi

In this unit, the students will be trained for and participate in a speech contest. The aim is to acquire oratory skills (pro-

nunciation, tone, body language, speaking in public) but also develop substance (rhetoric, argumentation).

ECTS Credits: 2

## Speech contest organization PDV204

L. Ali-Messaoudi

The purpose of this unit is to organize the Speech Contest final (publicity, evening sequencing, cocktail...). Students will

develop skills linked to event planning, organisation, communication, and budget management.

ECTS Credits: 2

## Sustainable development PDV206

E. Aziz, P. Perez-Lopez

This unit will be made of courses, conferences and case studies aiming to give an introduction to the concepts, history and evaluation of sustainability, and to the general framework of life cycle assessment.

ECTS Credits: 2

## Preparing for Graduate Studies PDV207

N. Dufort

This PDV will cover technical skills such as writing a report for publication, resumé writing, and how to write a good statement of purpose for graduate school applications. Students will also explore

personal topics like finding universities and programs that fit their aspirations and needs, as well as developing their networking skills and social media presence.

ECTS Credits: 2



# YEAR 3 COURSE OFFERING FALL SEMESTER

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Syllabus

# MATHEMATICS

## Measure and Integration MAA301

Y. Martel

ECTS Credits: 5  
MANDATORY

**Prerequisite:** MAA207

MAA301 proposes an introduction to the modern theory of integration. The first part of this course is focused on the construction of the Lebesgue integral, an extension of the Riemann integral to a class of functions much larger than the set of Riemann-integrable functions. With the Lebesgue theory of integration, pas-

sing to the limit in integrals of sequences of functions is an easy task which rests on the verification of a few essentially optimal assumptions. The end of the course offers an introduction to Lebesgue spaces and the Fourier transform, with applications to physics. The abstract theory of integration discussed at the beginning of this course provides the setting used in probability theory and stochastic analysis.

## Topology and Differential Calculus MAA302

K. Carrapatoso

ECTS Credits: 5  
MANDATORY

**Prerequisite:** MAA207

MAA302 is devoted first to the theory of metric and topological spaces in an abstract setting, including numerous examples of function spaces. We will then shift our focus towards Banach spaces, motivated by applications in optimization. Following this, the course will examine differentiable functions, smooth

functions, and their local properties. Restricting our attention to finite dimensional spaces, the course will conclude with an abstract theory of optimization, with applications in economics and physics: optimization without constraints and with constraints, and the well-known Lagrange multiplier theorem will all be studied in detail.

## Algebra and Arithmetics MAA303

M. Rosenbaum

At least 1 Mandatory course to choose between MAA303, MAA304 and MAA305 for the double major Math/CS.

Recommended for the double major Math/Economics

ECTS Credits: 3

**Prerequisite:** MAA206

MAA303 mainly focuses on general group theory. The first part of the course will be dedicated to the basic notions that one uses to study groups: normal subgroups, quotient group, simple groups... The second part of the course will focus on group actions. After introducing them, we will see a number of interesting applications in algebra, geometry and arithmetic, such as the so-called Sylow theorems.

At the very end of the course, we will move on from groups to other usual algebraic structures, such as rings and fields. This part of the course will only be a short introduction to ring and field theory. Extra material not covered during the course itself will be provided for those students who would like to go further and understand how groups, rings and fields are deeply related through the study of algebraic equations and Galois theory.

# MATHEMATICS

## Asymptotic Statistics MAA304

E. Moulines

ECTS Credits: 3

At least 1 Mandatory course to choose between MAA303, MAA304 and MAA305 for the double major Math/CS.

Recommended for the double major Math/Economics

First half of the semester

**Prerequisite:** MAA204

This course will open with a recap of convergences of random variables and convergences of distributions. The class will then investigate asymptotic statistics

(asymptotic properties of MLE, asymptotic confidence intervals, asymptotic test theory etc.) and information theory for statistics (efficiency, Cramer-Rao theory etc.). Finally, students will be given an introduction to Bayesian statistics.

## Probability: Stochastic Processes MAA305

T. Mastrolia

At least 1 Mandatory course to choose between MAA303, MAA304 and MAA305 for the double major Math/CS.

ECTS Credits: 3

Second half of the semester

**Prerequisites:** MAA203

This course introduces some fundamental properties on stochastic processes (in a discrete time framework), illustrated with examples in biology, economics and finance. We investigate the behavior of systems evolving step by step. As a gui-

deline for this course, the random walk is introduced first to emphasize fundamental interesting long time behavior properties. We then introduce the notion of conditional expectations and study two particular theories: martingales and Markov chains. The course concludes with the Brownian motion as a scaling limit of a random walk in continuous time.

# COMPUTER SCIENCE

## Functional Programming CSE301

X. Rival

ECTS Credits: 3 **At least one course to choose between CSE301, CSE303 and CSE307 for the double major Math/CS**

First half of the semester  
**Prerequisites:** CSE201 and CSE203

In this course, we will study functional Programming, and will learn how to take advantage of the features of modern functional programming languages. We will study in depth the notions of func-

tions (higher-order functions, closures), module systems (signatures, functors), and iterators. The practice sessions will be done in OCaml (but concepts presented in the course can be applied in many other languages such as Haskell, SML or JavaScript).

## Compilers CSE302

K. Chaudhuri

ECTS Credits: 5 **Mandatory for the double major Math/CS**

**Prerequisite:** CSE201

**Recommended previous course:**  
CSE206

Compilation is the process of transforming high-level programs and abstractions into the binary machine code used

in computer processors. This course introduces the principles and techniques of compilation, with parsers, interpreters, and translators, as well as topics in code optimization and semantic analysis. Students will build a compiler for a simple programming language.

## Computer Science Project CSE303

A. Couvreur

ECTS Credits: 3 **At least one course to choose between CSE301, CSE303 and CSE307 for the double major Math/CS one course to choose between CSE303 and MAA303 for the minor Computational Mathematics**

This course will give to the students the opportunity to design and implement a significant CS project.

In that perspective, the students will have to work in an organized and professio-

nal manner from conception to delivery, giving them the opportunity to apply all the knowledge they got from the previous courses.

## Constraint Logic Programming CSE307

ECTS Credits: 3 **At least one course to choose between CSE301, CSE303 and CSE307 for the double major Math/CS**

Second half of the semester  
**Prerequisite:** CSE203

The course will present the paradigm of Constraint Logic Programming from its logical foundations for programming with relations, to its current applications. From logic programming and the early days of artificial intelligence, towards the holy grail of programming simply by modelling, the students will learn how to

use a recent dialect of Prolog for relational databases, knowledge representation, automated deduction and combinatorial problem solving. The balance between declarative programming and efficiency, between clean semantics and expressiveness will be of particular interest, and will lead us into looking at how things work internally in a Prolog bytecode compiler (Warren Abstract Machine, indexing...) on practical examples.







# ELECTIVES

## Biology Practicals BIO301

L. Fioni

ECTS Credits: 3 **Required for the Biology minor**

**Prerequisite:** BIO201, BIO202

The primary goal of the Biology practicals is to provide an overview of the most recent techniques to complement the practicals of BIO201 and BIO202.

During this course, students will participate in research projects in the École Polytechnique laboratories where they will learn some of the most advanced techniques in biology under the supervision of researchers.

## Technological Tools for Chemistry CHE301

A. Guell

**Required for the Chemistry minor**

**Prerequisite:** CHE101

Chemistry strongly benefits from technological advances that accelerate the progress in the design and development of new compounds and materials, understanding their composition, properties and behavior. In this course, students explore the scientific basis and the technological features of the techniques/instruments employed on a daily basis in any cutting edge chemistry laboratory. Among these techniques, students review a set of spectroscopic tools (*e.g.* IR and

Raman spectroscopy, Mass spectroscopy, Nuclear Magnetic Resonance), nanocharacterization microscopes (*e.g.* Scanning Electron Microscopy, Scanning Probe Microscopy), separation techniques (*e.g.* HPLC), and analytical tools (*e.g.* X-Ray diffraction). The course includes a significant amount of experimental time in the laboratory where the techniques will be employed to resolve interesting and exciting chemical problems. A visit to the Synchrotron radiation facility Soleil may also be planned.

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Syllabus

# TRANSVERSE COURSES

Foreign languages and sports remain mandatory. Students may choose, at most, one other course in the following list or from the HSS course offering.

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## Diversity Report PDV301

B. Destremau

This course unit is designed to allow students to reflect upon their experience of diversity on campus. It includes rea-

ding and communicating on the students' experiences and reflections through a written report.

ECTS Credits: 2

## Active Volunteering PDV302

B. Destremau

This course unit is designed to allow students to acquire personal skills they will use in their future professional life. Since responsibility is paramount in professional life, the unit fosters and rewards community spirit as well as the students' commitment for the public good. Students will learn through experience

how to contribute to society. Being third year students, they will be expected to make personal choices and to take actions autonomously. The unit includes reflection and communication on the students' practices and experiences through a written report.

ECTS Credits: 2

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Syllabus



# YEAR 3 COURSE OFFERING SPRING SEMESTER

The semester begins with a mandatory Bachelor Thesis prepared during a research internship of 8 weeks minimum.

The subsequent classes have a shorter duration.

# MATHEMATICS

At least 2 Mandatory course to choose between MAA306, MAA307, MAA308 and MAA312 for the double majors Math/CS and Math/Physics

## Algebra and Geometry MAA306

E. Balzin

ECTS Credits: 4 Prerequisite: MAA202

The course “Topics in Differential Geometry” introduces basic and important objects which are widely used in mathematics and physics: vector fields and differential forms.

Firstly, we propose a geometric point of view on differential equations using the

language of vector fields, their integral curves and their flows. Secondly, we define differential forms and the exterior differentiation of such forms.

Many formulas used in physics (Gauss-Green-Riemann-Ostrogradski-Stokes) are naturally expressed and unified in those terms and will illustrate the course.

## Convex Optimization and Optimal Control MAA307

S. Amstutz

ECTS Credits: 4 Mandatory for the double major Math/Economics

Prerequisite: MAA202, MAA301 or MAA310

Convex Optimization and Optimal Control is composed of three connected parts. The first one lays the foundation of convex analysis in Hilbert spaces, and covers topics such as: convex sets, projection, separation, convex cones, convex functions, Legendre-Fenchel transform,

subdifferential. The second part deals with optimality conditions in convex or differentiable optimization with equality and inequality constraints, and opens the way to duality theory and related algorithms. The last part is an introduction to the optimal control of ordinary differential equations and discusses, in particular, the concepts of adjoint state, Hamiltonian and feedback law.

## Image Analysis MAA308

S. Allasonnière

When several pictures (obtained from a camera, a CT scan, etc.) of an object are available, registration refers to mathematical methods to combine those images. Registration is then an important first step to extract information from those images. This will introduce variational methods that play a central role in many scientific problems and in particular in image analysis.

Next, we will consider the problem of partitioning an image into different segments. These segments should be meaningful : an organ in a CT scan, an object in a picture. The lecture will cover a range of mathematical models and methods, such as regularization or level set methods.

ECTS Credits: 4

## Numerical Methods for ODEs MAA312

N. Spillane

Prerequisite: MAA207

In “Numerical Methods for ODEs”, we will introduce numerical scheme to simulate ordinary differential equations.

We will start by Euler schemes (explicit and implicit) and understand how the

notions of stability and consistency can be used to study these methods. We will then consider Runge-Kutta schemes and apply the different methods to particular applications, *e.g.* the N-body problem.

ECTS Credits: 4

# MATHEMATICS

## Measure and Integration – Condensed MAA310

I. Pasquinelli

ECTS Credits: 2

Mandatory and only open to students who have not followed MAA301 or an equivalent course.  
This course can replace two of the mandatory ECTS in Maths or in Economics.

First half of the semester

Students study the condensed version of the course MAA301, devoted to the modern theory of integration.

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## Topology and Differential Calculus – Condensed MAA311

Mandatory and only open to students who have not followed MAA301 or an equivalent course.  
This course can replace two of the mandatory ECTS in Maths or in Economics.

Second half of the semester

Students study the condensed version of the course MAA302, devoted mostly to the theory of metric and topological spaces in an abstract setting.

ECTS Credits: 2

133

Syllabus







# ECONOMICS

At least 12 ECTS to choose between ECO303 to ECO309 for the double major Math/Economics

## Introduction to Research Frontiers A, B ECO307, ECO308

G. Corcos

ECTS Credits: 2+2

This course introduces students to the research frontiers in economics. Each week, a researcher from the laboratory CREST would present a central topic of his/her research. Students are expected to see how researchers tackle problems using the tools and concepts developed

in economics. Topics include traditional microeconomics, macroeconomics, and econometrics, as well as recent interdisciplinary developments such as blockchain technology, and machine learning.

## Computational Economics ECO309

M. P. Winant

ECTS Credits: 4

This course is designed to provide economists with elements of modern scientific computing using the open-source Julia language. It covers several topics in numerical analysis and programming, and applies them to several economic

modeling fields (dynamic programming, macro modeling, IO models). Special emphasis is given to performance and reproducibility. Approximately half of the sessions will consist in hands-on tutorials.

# PHYSICS

## Thermodynamics and Statistical Physics PHY305

L. Palencia-Sanchez

Mandatory for the double major Math/Physics

ECTS Credits: 4

### Prerequisites:

PHY101, PHY201, PHY205

### Recommended previous course: PHY301

The most dramatic success of thermodynamics is to provide us with a universal description of macroscopic physical systems. It equally applies to systems as various as molecular gases, magnetic materials, stellar systems, and electromagnetic radiation to name a few. It was later realized that the laws of thermodynamics can be established from a statistical description. The statistical approach represented a genuine paradigm shift in our understanding of physical systems and paved the way to major advances in many fields. The aim of this course is to give a theoretical background to thermodynamics and statistical physics, as well

as applications in a variety of contexts, from classical to quantum.

The following subjects are expected to be treated:

- › Axiomatic thermodynamics (reminder and complements; laws 0-3, energy, entropy, universality)
- › Phase transitions
- › Statistical description of isolated systems
- › From isolated to open systems: The canonical Gibbs ensembles
- › Statistical physics of the ideal classical gas
- › Ideal quantum gases: fermions and bosons (Bose-Einstein condensation and Fermi seas)
- › Other applications of thermodynamics and statistical physics.

# PHYSICS

## Fluid Mechanics PHY306

S. Michelin

ECTS Credits: 4 One course to choose between PHY306 and PHY307 for the double major Math/Physics

**Prerequisite:** PHY101, PHY102, PHY105

**Recommended previous course:** PHY201, PHY206

The motion of fluids plays a critical role in many phenomena or processes that are the center of our daily life or engineering systems, ranging from the flight and/or propulsion of aircrafts and vessels, the generation of electricity from wind-turbines, the flow of blood in our arteries, the atmospheric and ocean circulations guiding our climate or microscopic flows in lab-on-a-chip systems. This course will provide the students the fundamental tools to model, understand and analyze the motion of such fluid flows in three dimensions, and evaluate the resulting forces on the bounding surfaces.

The material covered in this course will build upon several courses of the program including Mechanics and Heat (PHY101), Mathematical Methods for Physicists I and II (PHY102 and PHY105), Classical Mechanics (PHY201) and Waves and Heat Transfer in Geophysics (PHY206).

The following subjects are expected to be treated:

- › Eulerian description of motion of 3D flows
- › Mass and momentum conservation
- › Hydrostatic pressure
- › Viscosity and viscous stresses
- › Motion of a Newtonian fluid: Navier-Stokes equations
- › Non-dimensional analysis and scalings
- › Parallel and weakly-non parallel flows
- › Inviscid flows and potential flow theory
- › Vorticity
- › Introduction to boundary layers.

## Introduction to Subatomic Physics PHY307

E. Maurice

ECTS Credits: 4 One course to choose between PHY306 and PHY307 for the double major Math/Physics

**Prerequisites:** PHY204, PHY205

**Recommended previous courses:** PHY106, PHY301

The quest for finding the ultimate constituents of matter has revealed that matter has a nested structure quarks at scales that differ by many orders of magnitudes: atoms contain electrons and nuclei; nuclei are made up of nucleons, which in turn are composed of. Nowadays, particle physicists are more concerned with the fundamental laws that govern the interactions of elementary particles. The most emblematic question is “how do particles acquire mass”; and the discovery of the Higgs boson in 2012 is an important clue that we are on the right path to answering this question.

This course will give a pedestrian introduction to nuclear and particle physics,

illustrating in a balanced fashion theoretical underpinnings, experimental activities and technological aspects of subatomic physics. The basis for this course will be the PHY205 and PHY301 (introductory and advanced quantum physics) as well as PHY204 (theoretical electrodynamics).

The following subjects are expected to be treated:

- › the big picture of the structure of matter and the great discoveries
- › nuclear binding energy; nuclear models (droplet model; fermi-gas model); isotopic spin
- › particle accelerators and colliders
- › decay of elementary and subatomic particles
- › scattering experiments: nucleus, nucleons, quarks
- › the nonrelativistic quark-model and the magnetic moment of the nucleons
- › neutrino oscillations.

# ELECTIVES

## Biomedicine BIO302

A. Goutéraux

ECTS Credits: 3 **Required for the Biology minor**

The biomedicine course will include a series of lectures covering the molecular and cellular mechanisms of diseases and therapeutic strategies to treat them. In parallel, students will actively partici-

pate to research performed in laboratories of École Polytechnique on campus. All research topics are related to biomedicine.

## Mastering the Synthesis and Transformation of Molecules CHE302

T. Cantat

ECTS Credits: 3 **Required for the Chemistry minor**

**Prerequisite:** CHE201

Mastering the transformation of organic matter is key to tackle societal challenges such as the synthesis of new pharmaceutical drugs, the design of functional polymers and the recycling of wastes to value-added products. CHE302 is an intermediate-level chemistry course that introduces the reactivity and transformation of organic chemicals, based on quantum chemistry. From the des-

cription of the electronic structures and bonding interactions in molecules (using molecular orbitals and Hückel theory), the transformation of organic and inorganic compounds is introduced, as well as the reactivity of organic functionalities (carbonyls, alkenes and aromatics) and the concepts of catalysis. This interactive course explores these topics through lectures, tutorials and labs.

## Project in Numerical Methods MAA313

M. Breden

During this course, students are asked to study and then present a scientific paper. There will be several scientific papers to choose from, which broadly speaking will be concerned with problems related to mathematical modeling and simulations. Each presentation requires not only a deep understanding of the considered

paper, but also a practical implementation related to the content of the article. Students are free to focus on more specific parts or even to explore different ideas that might be of their own. This course therefore requires a lot of autonomy and personal investment.

ECTS Credits: 3

# TRANSVERSE COURSES

Foreign languages and sports remain mandatory. The students may choose at most one other course in the following list.

## Fundamentals of Organizations MIE301

P. Acosta

ECTS Credits: 2

Fundamentals of Organizations is an introductory course to the main theories that are useful to understand current problems within organizations. This course seeks to contribute to the development of students as actors that understand the complexity of the organizational world. Organizations are everywhere and students are and will be surrounded by organizations in their professional and personal life. Through the analysis of organizational theories, students will reflect on questions such as what is an

organization? What constitutes it? What function do they fulfill within a society? What are their key components and processes? How are organizations structured? Upon completion of this course, students will demonstrate their ability to apprehend an organizational situation and to understand typical human and organizational problems in various industries and contexts. Course materials include written case studies, videos and simulations.

## Diversity Report PDV303

B. Destremau

This course unit is designed to allow students to reflect upon their experience of diversity on campus. It includes reading and communicating on the students'

experiences and reflections through a written report. Only students who did not take this unit in semester 5 may register.

ECTS Credits: 2

## Active Volunteering PDV304

B. Destremau

This course unit is designed to allow students to acquire personal skills they will use in their future professional life.

Since responsibility is paramount in professional life, the unit fosters and rewards community spirit as well as the students' commitment for the public good.

Students will learn through experience how to contribute to society. Being third

year students, they will be expected to make personal choices and to take actions autonomously. The unit includes reflection and communication on the students' practices and experiences through a written report.

Students who registered for Active Volunteering in semester 5 may register again, but for a different project.

ECTS Credits: 2