YEAR 3
COURSE OFFERING
Fall Semester

MATHEMATICS

Measure and Integration MAA301

Y. Martel

ECTS Credits: 5
MANDATORY

Prerequisite: MAA202

MAA301 is devoted to the modern theory of integration. After first constructing the Lebesgue integral, and explaining how it improves the Riemann integral, a major part of the course will be devoted to discovering the power and ease of use of this tool. Applications in probability theory will then be briefly described. The course will finally provide an introduction to Lebesgue spaces and the Fourier transform, in order to demonstrate the usefulness of the theory for applications in physics and economics.

Topology and Differential Calculus MAA302

K. Carrapatoso

ECTS Credits: 5
MANDATORY

Prerequisite: MAA202

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.

At least 1 Mandatory course to choose between MAA 303, MAA 304 and MAA305 for the double major Math/CS, MAA 303 and MAA 304 Recommended for the double major Math/Economics

Algebra and Arithmetics MAA303

D. Izquierdo

ECTS Credits: 3

Prerequisite: MAA104
MAA303 focuses on general group theory, ring theory and field theory. The first course objective is to describe group actions and geometric applications, as well as the notion of Sylow subgroups. The second part of the course develops general commutative ring theory, looking specifically at applications for the arithmetic of integers. The last aim of the course is to introduce students to the theory of field extensions, and the Galois theory of algebraic equations.

Asymptotic Statistics MAA304

E. Moulines

ECTS Credits: 3

First half of the semester
Prerequisites: MAA203, MAA204
MAA304 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

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 guideline 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
1 or 2 mandatory course(s) to choose between CSE301, CSE307 and CSE302 for the double major Math/CS for at least 5 ECTS

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 functions (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
1 or 2 mandatory course(s) to choose between CSE301, CSE307 and CSE302 for the double major Math/CS for at least 5 ECTS

Prerequisite: CSE201, CSE207
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

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

ECTS Credits: 3
Mandatory for the double major Math/CS,
1 Mandatory course to choose between CSE303 and MAA303 for the minor Computational Mathematics in the double major Math/Economics

Constraint Logic Programming CSE307

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.

ECTS Credits: 3
1 or 2 mandatory course(s) to choose between CSE301, CSE307 and CSE302 for the double major Math/CS

ECONOMICS

Advanced Microeconomics ECO301

J. Combe

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

In Advanced Microeconomics (ECO 301), we build on the ECO 201 course to go beyond the competitive equilibrium setting and elicit new causes of market failures. We aim to study how the presence of incomplete and asymmetric information affects the standard analysis of microeconomic theory. The starting point is that the presence of asymmetric information leads to market failures and open the question of how to regulate and appropriately design markets to solve or reduce these failures. We will present the basics of two important theories and methods which have been the core of the modern microeconomic analysis since 1970: the signaling games and the mechanism design. The students will learn the tools to analyze markets and interactions in the presence of incomplete and asymmetric information. They will learn how to develop policy tools and how to design markets to mitigate the issues induced by the information structure.

More specially, we will cover the following topics:

- Chapter 1: Game theory under incomplete information (1)
- Chapter 2: Asymmetric Information, Signaling and Application to the Insurance Market (2)
- Chapter 3: The Principal Agent Model (3)
- Chapter 4: Auctions and Mechanism Design (4)
- Chapter 5: Market Design and Matching

The mathematical treatments are rigorous but not as much as at the graduate level. This course will be thus most useful as a preparation for formal graduate studies in Economics.

Textbooks:

- Osborne, M. J., & Rubinstein, A. (1994). *A course in game theory*. MIT press (Chap 2 & 11)
- Jehle, G. A., & Reny, P. J. (2001). *Advanced Microeconomic Theory* (Chap 7, 8 & 9)
- Laffont, J. J., & Martimort, D. (2009). *The theory of incentives: the principal-agent model. Princeton university press* (Chap 2 & 4)
- Krishna, V. (2009). *Auction theory*. Academic press (Chap 2 & 5)

Advanced Macroeconomics ECO302

E. Challe

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

This course builds on the Intermediate macroeconomics course (ECO202) and will cover both the short run (business cycles, crises, and stabilization policies) and the long run (the determinants of long-run economic growth). To be more specific, the course will cover the following topics:

Part I: Business cycles and stabilization policies (7 lectures)

- The New Keynesian model of aggregate demand and supply
- The propagation of business cycle shocks
- Conventional monetary and fiscal policies
- The liquidity trap and unconventional policies

Part II: Economic Growth (7 lectures)

- Growth facts and Solow reminder
- Immediate causes of economic development: human capital, physical capital, and technology
- The deep causes of economic development: geography, institutions, and culture
- Innovation and economic growth
- Economic growth and the environment

Textbooks:

- Edouard Challe, *Macroeconomic Fluctuations and Policies*, MIT Press, 2019
- Charles I. Jones and Dietrich Vollrath, *Introduction to Economic Growth*, W.W. Norton, 2013
- David Romer, *Advanced Macroeconomics*, McGraw Hill, 2019 (5th ed.)

A complementary reading list of policy and accessible research papers will be provided in due time.

PHYSICS

Advanced Quantum Physics PHY301

M. Ferrero

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

Prerequisite: PHY205

As its name suggests, this course is a sequel to PHY205 "Introduction to Quantum Physics". It will expand our view on three-dimensional quantum mechanical problems, by applying the formalism to the description of atoms and particles in a magnetic field. This includes also a deeper analysis of angular momentum, and its relation to rotational symmetry. We will discover approximation techniques for time-independent and time-dependent phenomena, and apply them to the detailed description of the hydrogen atom. The quantum-mechanical description of scattering will be introduced. Furthermore, we will study the notion of entanglement which is fundamental to quantum cryptography and quantum computing. The description of identical particles in quantum mechanics will build the bridge to the Pauli exclusion principle and the spin-statistics connection.

The following subjects are expected to be treated:

- The addition of angular momenta
- The notion of spin and magnetic resonance
- The hydrogen atom
- Approximation methods and time independent perturbation theory
- Entangled states, the EPR paradox and quantum information
- Particles in a magnetic field, Landau levels
- Identical particles and the spin-statistics connection
- Time-evolution and time-dependent perturbation theory
- Scattering theory.

Introduction to Condensed Matter Physics PHY302

JE. Wegrowe

ECTS Credits: 5
1 Mandatory course to choose between PHY302 and PHY304 for the double major Math/Physics

Recommended previous courses: PHY102, PHY107, PHY201, PHY204, PHY205, PHY206

Condensed matter physics deals with the description of the physical properties of matter when the interaction between its constituants are very strong. This is typically the case for materials and devices. It covers a very large field of knowledges that encompasses electric, thermal, chemical, magnetic, and mechanical properties, and all the combinations of these properties, in solids.

From the technological point of view, condensed matter physics have brought some major discoveries and new developments: electronic devices, sensors, actuators, transductors, power generation devices, energy storage, to name but a few.

This domain of physics is based on two different and complementary approaches. A first approach starts from the quantum microscopic constituants and describes statistically the macroscopic consequences. The second is a phenomenological macroscopic description based on general principles of thermodynamics and symmetries. The complementarity of both approaches will be established for systems at thermal equilibrium in the 6th semester lecture PHY305.

The goal of this lecture is to give an overview of the concepts, methods and applications, with a particular emphasis on the non-equilibrium thermodynamic approach of transport phenomena (electric, thermal, thermoelectric, magnetic…). The lectures are focused on the understanding of technologically important problems.

The following topics will be covered:

- Crystal structures and symmetries. Structural characterization of solids.
- Introduction to quantum theory of solids.
- Macroscopic approach: first principles of thermodynamics. Transport coefficients, and Onsager reciprocity relations. Conservation laws.
- Electric transport properties in metal and semiconductors. Thermoelectric effects. Hall effects, Nernst effects, magnetoresistance.
- Kinetics of magnetization: the Landau-Lifshitz-Gilbert equation, hysteresis loops and thermal activation.
- Kinetics of defects in solids.
- Standard anelastic solids (viscoelasticity).

PHYSICS

Advanced Lab III PHY303

Y. Laplace

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

Recommended previous courses: PHY203, PHY207

In Advanced Lab III, students have the opportunity to apply the physics knowledge they have acquired over the course of 6 lab sessions of 4 hours each. In PHY303, the students will discover a more autonomous style of experimentation. The lab sessions will be centered on modern physics and are expected to address several among the following subjects: quantum physics (*e.g.* Nuclear magnetic resonance), subatomic physics (*e.g.* Compton scattering, half-life of the muon), condensed matter physics (*e.g.* cristallography), modern optics (*e.g.* lasers) as well as solid mechanics (*e.g.* mechanics of deformable bodies). 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.

Solid Mechanics PHY304

M. Jabbour

Prerequisite:
PHY101, PHY102, PHY105
Recommended previous course:PHY201
Some knowledge of ordinary differential equations would be helpful.

We are surrounded by natural and man-made structures that deform when subjected to loadings. These structures span a wide spectrum of length scales, from suspension bridges and aircrafts all the way down to spider webs, human hair, micro-electro-mechanical systems, and cell membranes. In this course, we will focus on slender bodies, which by virtue of their elongated aspect can be modeled as curvilinear media. This simplified geometry allows us to present the fundamental concepts of the mechanics of deformable solids without recourse to the tensor formalism that is intrinsic to three-dimensional continuum mechanics. We will then solve problems and comprehend phenomena (such as the buckling of elastic beams) involving geometric and/or material nonlinearities that, in three dimensions, do not lend themselves to analytical treatment

We will cover the following topics:

- Geometry, deformation, and kinematics of curvilinear media
- External and internal forces and couples, equilibrium equations
- Constitutive relations, including rigid bars, extensible strings, and elastic rods
- Boundary value problems associated with various models: elastic strings, beams, and arcs
- Euler's elastica (and, time permitting, its boundary layer)
- Linear elasticity of slender bodies and its applications
- Stability of conservative systems (both discrete and continuous)
- Dynamics: wave propagation in elastic beams, forced and free vibrations of elastic rods.

ECTS Credits: 5
1 Mandatory course to choose between PHY302 and PHY304 for the double major Math/Physics

BIOLOGY

Biology Practicals BIO301

H. Myllykallio

ECTS Credits: 3
Required for the Biology minor

Prerequisite: BIO202

The primary goal of the Biology practicals is to provide an overview of the most recent techniques used by researchers in biology to complement the practicals of BIO201 and BIO202. During this course, students will rotate in several research laboratories of École Polytechnique where they will learn some of the most advanced techniques in microscopy and genetic manipulations under the supervision of researchers.

CHEMISTRY

Technological Tools for Chemistry CHE301

A. Guell

ECTS Credits: 3
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.

HUMANITIES AND SOCIAL SCIENCES

Masterpieces of Western Literature: Sea and Sailors HSS301

I. de Vendeuvre

ECTS Credits: 2
Eligible as a supplementary course

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.

PERSONAL DEVELOPMENT

Diversity Report PDV301

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.

ECTS Credits: 1
Eligible as a supplementary course

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: 1
Eligible as a supplementary course

YEAR 3
COURSE OFFERING
Spring Semester

MATHEMATICS

Algebra and Geometry MAA306

D. Renard

ECTS Credits: 4
At least 3 Mandatory courses to choose between MAA306, MAA312, PHY306 and PHY307 for the double major Math/Physics

Prerequisite: MAA206

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 langage 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

MAA307 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. The last part is an introduction to the optimal control of ordinary differential equations.

MAA307 complements MAA209 on the theoretical side, but MAA209 is not mandatory.

Image Analysis: Registration MAA308

S. Allassonnière

First half of the semester
Prerequisite: MAA206
Recommended previous course: MAA208
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 lecture introduce variational methods, that play a central role in many scientific problems, and in image analysis in particular.

ECTS Credits: 2

Mandatory for the double majors Math/Physics and Math/CS (except if replaced by MAA310)
At least 6 Mandatory courses to choose between MAA308 to MAA311 and ECO303 to ECO309 for the double major Math/Economics

Image Analysis: Segmentation MAA309

S. Allassonnière

Second half of the semester
Prerequisite: MAA308
In this lecture, 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, etc. The lecture will cover a range of mathematical models and methods, such as regularization or level set methods.

ECTS Credits: 2

Mandatory for the double majors Math/Physics and Math/CS (except if replaced by MAA311)
At least 6 Mandatory courses to choose between MAA308 to MAA311 and ECO303 to ECO309 for the double major Math/Economics.

Measure and Integration – Condensed MAA310

V. Humilière

First half of the semester
MAA310 is the condensed version of the course MAA301, devoted to the modern theory of integration.

ECTS Credits: 2

Mandatory for all students who have not followed MAA301 or equivalent course

MATHEMATICS

Topology and Differential Calculus – Condensed MAA311

I. Pasquinelli

ECTS Credits: 2

Second half of the semester

MAA311 is the condensed version of the course MAA302, devoted mostly to the theory of metric and topological spaces in an abstract setting.

Mandatory for all students who have not followed MAA302 or equivalent course

Numerical Methods for ODEs MAA312

N. Spillane

ECTS Credits: 2

At least 3 Mandatory courses to choose between MAA306, MAA312, PHY306 and PHY307 for the double major Math/Physics

Recommended previous courses:MAA106, MAA208

In MAA312 "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.

Seminar: Mathematical Models MAA313

N. Spillane, L Gérin

ECTS Credits: 2

Mandatory for the double major Math/CS

The course Seminar: mathematical models (MAA313) covers simulation and statistics, while introducing students to PDEs and numerical optimization. During this course, students are asked to present scientific papers on different problems of mathematical modeling. Each presentation requires not only a deep understanding of the considered paper, but also a practical implementation of the numerical method proposed in the article. Students are free to focus on some more specific part or even to explore different ideas that might be of their own. This therefore requires a lot of autonomy, clarity, imagination and personal investment.

COMPUTER SCIENCE

2 Mandatory courses to choose between CSE304, CSE305 and CSE306 for the double major Math/CS

Complexity CSE304

O. Bournez

Prerequisites: CSE103, CSE203, CSE207

ECTS Credits: 4

Theoretical Computer Science has shown that computational problems can be classified according to how difficult they are to solve. We now know that some problems are intrinsically impossible to solve in a reasonable amount of time, or with a reasonable amount of resources. This course describes the rigorous model of computation required to compare and classify computational problems and their difficulty, giving an introduction to the theory of computational complexity and the standard complexity classes.

Concurrent and Distributed Computing CSE305

E. Goubault

Prerequisite: CSE103, CSE201, CSE202

ECTS Credits: 4

Today's programs and calculations operate not on one computer at a time, but rather on groups of processors or machines working together in concert. But ensuring efficiency and cooperation among the threads of a program is a deeply subtle, and fascinating, problem. This course aims to provide the techniques required to master efficient distributed programming, avoiding the many pitfalls that arise when computations share their resources.

Computer Graphics CSE306

N. Bonneel

Prerequisite: CSE103, CSE201

ECTS Credits: 4

This course explores fundamental concepts in 2D and 3D computer graphics, including digital images, 2- and 3-dimensional geometry, curves and surfaces, perspective, ray tracing, filtering and antialiasing, the graphics pipeline, and human visual perception.

ECONOMICS

At least 6 Mandatory courses to choose between MAA308 to MAA311 and ECO303 to ECO309 for the double major Math/Economics

Health and Development Economics ECO303

P. Rossi

ECTS Credits: 2

Prerequisite: ECO201

This course is an introduction to development economics with a specific focus on the relationship between health and development. To what extent do differences in the disease environment explain differences in economic performance? Which policies are effective at improving health in developing countries? We will study these questions from an empirical perspective and review recent evidence to shed light on important policy debates. We will touch upon the two main views on fundamental causes of economic growth: endowments and institutions.

Reading list:

- Acemoglu, Daron and Simon Johnson. (2007). "Disease and Development: The Effect of Life Expectancy on Economic Growth", Journal of Political Economy, Vol 115(6), p. 925-985.
- Hoyt Bleakley (2010). "Malaria Eradication in the Americas: A Retrospective Analysis of Childhood Exposure." American Economic Journal: Applied Economics, Vol. 2, p.1-45.
- Das Jishnu and Jeffrey Hammer (2014) "Quality of Primary Care in Low-Income Countries: Facts and Economics," Annual Review of Economics, Vol. 6 p. 525-553.
- Björkman Martina and Jakob Svensson (2009) "Power to the People: Evidence from a Randomized Field Experiment on Community-Based Monitoring in Uganda" The Quarterly Journal of Economics, Vol. 124(2) p.735-769.

Industrial Organization ECO304

R. de Nijs

Prerequisite: ECO201

ECTS Credits: 2

This course provides students the ability to analyzethe behavior and performance of firms in markets, with a particular focus on strategic interactions. Topics include monopoly power, behavior of firms in oligopoly markets, static and dynamic measurement of market performance, pricing and product choice decisions, advertising, research and development, and theory of the firm.

Textbook:

- *Introduction to Industrial Organization* by Luis M.B. Cabral
- *The Theory of Industrial Organization* by Jean Tirole

Social and Environmental Responsibility of Business ECO305

P. Crifo

ECTS Credits: 2

Prerequisite: ECO201, ECO202

This course introduces the economics of corporate social responsibility (CSR), and the determinants for businesses, acting on a voluntary basis, to incorporate social, environmental, and ethical concerns into their economic activities and interactions with their stakeholders. It consists in three parts. The first part presents the basic stylized facts about CSR and the role of governments and investors in promoting responsible behaviors. The second part presents the three main models which explain CSR decisions. The third part covers the data and impact analysis of CSR.

Textbook:

- *Corporate Environmentalism and Public Policy* by Thomas P. Lyon & John W. Maxwell (Cambridge University Press)
- *The Market for virtue: the potential and limits for* CSR by David Vogel (Brookings institution press)

International Trade ECO306

G. Corcos

ECTS Credits: 2

Prerequisite: ECO201, ECO202

This course introduces students to the economics of international trade. It consists of three parts. The first part presents facts about trade flows and trading firms and introduces the widely-used gravity equation. The second part covers three standard trade theories which explain trade patterns. The last part presents trade policy, with some focus on recent trade disputes.

Textbook:

- *International Economics*, Krugman, Obstfeld & Melitz (Pearson)
- *International Economics*, Feenstra & Taylor (Worth Palgrave MacMillan) Introduction to Research Frontiers A, B (ECO307, ECO308)

ECONOMICS

At least 6 Mandatory courses to choose between MAA308 to MAA311 and 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 reproducibilty. Approximately half of the sessions will consist in hands-on tutorials.

PHYSICS

Thermodynamics and Statistical Physics PHY305

L. Palencia-Sanchez

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

Prerequisite: PHY102, 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

At least 3 Mandatory courses to choose between MAA306, MAA312, PHY306 and PHY307 for the double major Math/Physics

Prerequisite: PHY101, PHY102, PHY105, **Recommended previous courses**: 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

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 a 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 decay
- scattering experiments: nucleus, nucleons, quarks
- the nonrelativistic quark-model and the magnetic moment of the nucleons
- neutrino oscillations.

ECTS Credits: 4

At least 3 Mandatory courses to choose between MAA306, MAA312, PHY306 and PHY307 for the double major Math/Physics

BIOLOGY

Cancer Biology BIO301

A. Gautreau

ECTS Credits: 3
Required for the Biology minor

The cancer biology course will include a series of lectures covering the molecular and cellular mechanisms of cancer development and current anti-cancer strategies. In parallel, students will actively participate in a new ambitious research and teaching program developed at Ecole Polytechnique thanks to the sponsoring of the pharmaceutical company Servier and the biotechology company Cellectis. This experimental project aims at reconstituting the tumoral process of cancer development using only the mutation repertoire found in a single breast cancer patient.

CHEMISTRY

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 description 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.

MANAGEMENT OF INNOVATION AND ENTREPRENEURSHIP

Fundamentals of Organizations MIE301

C. Chamaret

ECTS Credits: 1
Eligible as a supplementary course

This course covers the concepts and theories related to the management of organizations (culture, power, innovation…). The course includes a discussion of the main theories, which are useful to understand business problems and empirical situations. Upon completion of this course, students will demonstrate their ability to apprehend business situation and to understand typical human and organizational problems in various industries.

Course materials include written case studies, videos and simulations.

PERSONAL DEVELOPMENT

PDV303

B. Destremau

ECTS Credits: 1
Eligible as a supplementary course

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.