YEAR 3
COURSE OFFERING
Fall Semester

MATHEMATICS

Measure and Integration (MAA 301)

Prerequisite: MAA 202
MAA 301 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.

Professor(s):
Y. Martel
ECTS Credits: 5

MANDATORY

Topology and Differential Calculus (MAA 302)

Prerequisite: MAA 202
MAA 302 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.

Professor(s):
K. Carrapatoso
ECTS Credits: 5

MANDATORY

MATHEMATICS

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 (MAA 303)

Professor(s):
D. Izquierdo
ECTS Credits: 3

Prerequisite: MAA 104
MAA 303 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 (MAA 304)

Professor(s):
E. Moulines
ECTS Credits: 3

Prerequisite: MAA 203, MAA 204
MAA 304 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 (MAA 305)

Professor(s):
T. Mastrolia
ECTS Credits: 3

Prerequisites: MAA 203, MAA 204
This class examines Markov chains, Poisson processes, renewal processes and pure Markov chains. Starting with the theoretical aspects of process analysis, our lectures will then cover further applications and discuss modeling for issues appearing across various fields.

COMPUTER SCIENCE

Functional Programming (CSE 301)

Prerequisites: CSE 201 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).

Professor(s):
X. Rival
ECTS Credits: 5

1 Mandatory course to choose between CSE 301 and CSE 302 for the double major Math/CS

Compilers (CSE 302)

Prerequisite: CSE 201, CSE 207
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.

Professor(s):
K. Chaudhuri
ECTS Credits: 5

1 Mandatory course to choose between CSE 301 and CSE 302 for the double major Math/CS

Computer Science Project (CSE 303)

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.

Mandatory for the double major Math/CS, 1 Mandatory course to choose between CSE 303 and MAA 303 for the minor Computational Mathematics in the double major Math/Economics

Professor(s):

ECTS Credits: 3

ECONOMICS

Advanced Microeconomics (ECO 301)

Professor(s):
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)

ECONOMICS

Advanced Macroeconomics (ECO 302)

Professor(s):
E. Challe
ECTS Credits: 5

Mandatory for the double major Math/ Economics

This course builds on the Intermediate macroeconomics course (ECO 202) 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 (PHY 301)

Professor(s):
M. Ferrero
ECTS Credits: 5

Mandatory for the double major Math/ Physics

As its name suggests, this course is a sequel to PHY 205 "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.

PHYSICS

Introduction to Condensed Matter Physics (PHY 302)

Professor(s):
K. Behnia
ECTS Credits: 5

1 Mandatory course to choose between PHY 302 and PHY 304 for the double major Math/Physics

Condensed matter physics deals with the microscopic description of themacroscopic physical properties of matter when the interactions between its constituents are very strong. It has an overlap with materials science, chemistry, biophysics and nanotechnology, and relates closely to atomic and molecular physics. Progress in materials elaboration has always been a driving force for technological progress: semiconductors, magnetic memory devices ("hard disks"), composite materials, or nanostructures are only few examples of solid state systems that directly connect fundamental concepts to applied physics.

This course provides an elementary introduction to condensed matter physics. Starting from the laws of quantum mechanics governing the constituents of matter, the course explores how the electronic properties of materials at the macroscopic scale emerge from the microscopic organization on an atomic or molecular scale. It will cover theoretical, experimental and technological aspects. The necessary theoretical concepts of statistical physics will be introduced heuristically during the course, and will be put on a sound foundation in the 6th semester course "Thermodynamics and Statistical Physics".

The following subjects are expected to be treated:

- Crystal structures and symmetries. Structural characterization of solids.
- Quantum mechanics of electrons in crystalline solids, band theory.
- Metals, insulators and semiconductors.
- Transport properties (electric, thermal and thermoelectric)
- Collective phenomena (electronic orders including superconductivity)
- Spectroscopies: x-ray and neutron diffraction, tunneling
- Microscopy, photoemission.

PHYSICS

Advanced Lab III (PHY 303)

Professor(s):
Y. Laplace
ECTS Credits: 3

Mandatory for the double major Math/ Physics

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 PHY 303, 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). It is envisaged to encourage project work, and to provide the possibility to extend more elaborate experiments over two sessions.

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.

PHYSICS

Solid Mechanics (PHY 304)

Prerequisite: PHY 101, PHY 102, PHY 105, PHY 201, PHY 206. 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 permits the introduction of the fundamental concepts of the mechanics of deformable solids without recourse to the heavy mathematical formalism that is inherent to the description of their three-dimensional counterparts. It will thus allow us to solve problems and comprehend phenomena (such as the buckling of elastic beams) involving geometric or behavioral 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)
- Linearized elasticity of slender bodies and its applications
- Stability of conservative systems (first discrete systems, later, via the calculus of variations, continuous systems) and, time permitting,
- Dynamics: wave propagation in elastic beams, forced and free vibrations of elastic rods.

Professor(s):
M. Jabbour
ECTS Credits: 5

1 Mandatory course to choose between PHY 302 and PHY 304 for the double major Math/Physics

BIOLOGY

Biology Practicals (BIO 301)

Professor(s):

ECTS Credits: 3

Required for the Biology minor

Prerequisite: BIO 202

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 BIO 201 and BIO 202. 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 (CHE 301)

Professor(s):

ECTS Credits: 3

Required for the Chemistry minor

Prerequisite: CHE 202

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 (HSS 301)

HSS 301 offers students the opportunity to engage in study and discussion of some of the most significant texts of Western literature. Its purpose is to provide students an understanding of these works and their relation to the values of the time and the region in which they were produced. Some of the historical and critical issues commonly addressed in this course are the representation of reality in literature, changing views of human moral problems, and the building of Western culture including historical and national differences.

Professor(s):
I. de Vendeuvre
ECTS Credits: 2

Eligible as a supplementary course

PERSONAL DEVELOPMENT

Diversity Report (PDV301)

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.

Professor(s):
M. Bresson
ECTS Credits: 1

Eligible as a supplementary course

Active Volunteering (PDV302)

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.

Professor(s):
M. Bresson
ECTS Credits: 1

Eligible as a supplementary course

YEAR 3
COURSE OFFERING
Spring Semester

MATHEMATICS

Algebra and Geometry (MAA 306)

Prerequisite: MAA 206
The course "Algebra and geometry" splits into two parts. In the first part, we propose a geometric point of view on the differential calculus studied in the first semester. This includes an introduction to manifolds and a qualitative study of differential equations on manifolds. In the second part, we focus on specific groups of linear transformations arising from geometry and theoretical physics. We give in particular a very detailed description of their structures and links between them.

Professor(s):
D. Renard
ECTS Credits: 4

At least 3 Mandatory courses to choose between MAA 306, MAA 312, PHY 306 and PHY 307 for the double major Math/Physics

Convex Optimization and Optimal Control (MAA 307)

Prerequisite: MAA 202
Convex optimization and optimal control (MAA 307) covers: basic functional analysis tools, projection on Hilbert spaces, duality; convex sets and their topological properties, convex functions, Polarity, convex duality, Hahn-Banach and min-max theorems; convexity and differentiability; convex optimization (Kuhn-Tucker), linear programming; calculus of variations, Pontryagin maximum principle, mixed inequality constraints, state constraints; dynamic programming : from discrete to continuous time, linear quadratic regulator; discrete time stochastic control, introduction to differential games.

Professor(s):
S. Amstutz
ECTS Credits: 4

Mandatory for the double major Math/Economics

Image Analysis: Registration (MAA 308)

Prerequisite: MAA 206, MAA 208
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.

Professor(s):
S. Allassonnière
ECTS Credits: 2

Mandatory for the double majors Math/Physics and Math/CS (except if replaced by MAA 310)
At least 6 Mandatory courses to choose between MAA 308 to MAA 311 and ECO 303 to ECO 309 for the double major Math/Economics

MATHEMATICS

Image Analysis: Segmentation (MAA 309)

Professor(s):
S. Allassonnière
ECTS Credits: 2

Prerequisite: MAA 308
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.

Mandatory for the double majors Math/Physics and Math/CS (except if replaced by MAA 311)
At least 6 Mandatory courses to choose between MAA 308 to MAA 311 and ECO 303 to ECO 309 for the double major Math/Economics

Measure and Integration – Condensed (MAA 310)

Professor(s):
C. Valcu
ECTS Credits: 2

Prerequisite: MAA 202
MAA 310 is the condensed version of the course MAA 301, devoted to the modern theory of integration.

Mandatory for all students who have not followed MAA 301 or equivalent course

Topology and Differential Calculus – Condensed (MAA 311)

Professor(s):
I. Pasquinelli
ECTS Credits: 2

Prerequisite: MAA 202
MAA 311 is the condensed version of the course MAA 302, devoted mostly to the theory of metric and topological spaces in an abstract setting.

Mandatory for all students who have not followed MAA 302 or equivalent course

MATHEMATICS

Numerical Methods for ODEs (MAA 312)

Prerequisite: MAA 106, MAA 208
In MAA 312 "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.

Professor(s):
N. Spillane
ECTS Credits: 2

At least 3 Mandatory courses to choose between MAA 306, MAA 312, PHY 306 and PHY 307 for the double major Math/ Physics

Seminar: Mathematical Models (MAA 313)

The course Seminar: mathematical models (MAA 313) 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.

Professor(s):
N. Spillane
L Gérin
ECTS Credits: 2

Mandatory for the double major Math/CS

COMPUTER SCIENCE

2 Mandatory courses to choose between CSE 304, CSE 305 and CSE 306 for the double major Math/CS

Complexity (CSE 304)

Professor(s):
O. Bournez
ECTS Credits: 4

Prerequisites: CSE 103, CSE 203, CSE 207
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 (CSE 305)

Professor(s):
E. Goubault
ECTS Credits: 4

Prerequisite: CSE 103, CSE 201, CSE 202
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 (CSE 306)

Professor(s):

ECTS Credits: 4

Prerequisite: CSE 103, CSE 201
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

Game Theory (ECO 303)

This course introduces students to game theory and its applications to economics. Topics covered include strategic and extensive form games, dominant strategies, Nash equilibrium, subgame-perfect equilibrium, and Bayesian equilibrium. The theory is applied to repeated games, voting, auctions, and bargaining with examples from economics and political science.

Textbook:

- *An Introduction to Game Theory* by Martin J. Osborne
- *Game Theory by Maschler*, Solan and Zamir.

Professor(s):
X. Venel
ECTS Credits: 2

At least 6 Mandatory courses to choose between MAA 308 to MAA 311 and ECO 303 to ECO 309 for the double major Math/Economics

Industrial Organization (ECO 304)

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

Professor(s):
R. de Nijs
ECTS Credits: 2

At least 6 Mandatory courses to choose between MAA 308 to MAA 311 and ECO 303 to ECO 309 for the double major Math/Economics

ECONOMICS

Social and Environmental Responsibility of Business (ECO 305)

Professor(s):
P. Crifo
ECTS Credits: 2

At least 6 Mandatory courses to choose between MAA 308 to MAA 311 and ECO 303 to ECO 309 for the double major Math/Economics

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 (ECO 306)

Professor(s):
G. Corcos
ECTS Credits: 2

At least 6 Mandatory courses to choose between MAA 308 to MAA 311 and ECO 303 to ECO 309 for the double major Math/Economics

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)

ECONOMICS

Introduction to Research Frontiers A, B (ECO 307, ECO 308)

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.

Professor(s):
G. Corcos
ECTS Credits: 2+2

At least 6 Mandatory courses to choose between MAA 308 to MAA 311 and ECO 303 to ECO 309 for the double major Math/Economics

Computational Economics (ECO309)

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.

Professor(s):
P. Winant
ECTS Credits: 2

At least 6 Mandatory courses to choose between MAA 308 to MAA 311 and ECO 303 to ECO 309 for the double major Math/Economics

PHYSICS

Thermodynamics and Statistical Physics (PHY 305)

Professor(s):
L. Palencia-Sanchez
ECTS Credits: 4

Mandatory for the double major Math/ Physics

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 (PHY 306)

Prerequisite: PHY102, PHY 105, 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 (PHY 101), Mathematical Methods for Physicists I and II (PHY 102 and PHY 105), Classical Mechanics (PHY 201) and Waves and Heat Transfer in Geophysics (PHY 206).

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.

Professor(s):
S. Michelin
ECTS Credits: 4

At least 3 Mandatory courses to choose between MAA 306, MAA 312, PHY 306 and PHY 307 for the double major Math/Physics

PHYSICS

Introduction to Subatomic Physics (PHY 307)

Professor(s):

ECTS Credits: 4

Mandatory for the double major Math/ Physics

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 PHY 205 and PHY 301 (introductory and advanced quantum physics) as well as PHY 204 (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.

BIOLOGY

Cancer Biology (BIO 301)

Prerequisite: BIO 202
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.

Professor(s):

ECTS Credits: 3

Required for the Biology minor

CHEMISTRY

Mastering the Synthesis and Transformation of Molecules (CHE 302)

Prerequisite: CHE 202
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. CHE 302 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.

Professor(s):

ECTS Credits: 3

Required for the Chemistry minor

MANAGEMENT OF INNOVATION AND ENTREPRENEURSHIP

Fundamentals of Organizations (MIE 301)

Professor(s):
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

TBC (PDV303)

TBC

Professor(s):
M. Bresson
ECTS Credits: 1

Eligible as a supplementary course