CURRICULUM

Classes Préparatoires aux Grandes Ecoles
Two year intensive program in preparation for the nationwide competitive examinations to top French Engineer Schools

Mathematics, Physics and Engineering (1st academic year)
Advanced Mathematics and Physics (2nd academic year)
Lycée XX, **September XX - July XX**

First year – Mathematics, Physics and Engineering Science
September XX - July XX

MATHEMATICS

General Algebra

- Set theory and combinatories
- Number theory
- Group theory
- Arithmetic

Linear Algebra

- Vectors, vector spaces
  Free and generative families, bases, direct sum of subspaces
- Linear transformations and matrixes
  Image, kernel, trace, particular operators
- Determinants
  Determinant of n vectors, of a square matrix, of a linear operator
- Stable subspaces
- Polynomial functions of a matrix
- Reduction of a matrix
  Eigenvalues, eigenvectors, eigenspaces, triangular and diagonal reductions

- Linear operator reduction

Analysis

- Series
  Positive real series, real and complex series, convergence criteria
- Functions
  Local analysis of a function, continuity
  Derivation, C^1-functions, C^n-functions, Taylor formulas
  Primitives, Riemann integral of continuous-per-interval functions on closed, bounded intervals
  Integration on any interval
  Convolution product
- Comparison between numerical series and integrals
  Product of two absolutely convergent series
- Polynoms and rational fractions
- Generalization to finite dimension vector series and functions of a real variable

General Topology

- Distance and metric spaces
- Series and functions general features in metric spaces
- Norm and normed spaces

Geometry

- Affine geometry in finite dimension spaces
- Parametrical curves
- Local analysis of an oriented C^n-curve

PHYSICS

Newtonian Mechanics

- Kinematics of a punctual particle
  - Space and time, type of movements
  - Change of referential: laws of composition of speed and acceleration
- Dynamics of a punctual particle
  - Galilean referential, terrestrial referential
  - Terrestrial gravity, celestial mechanics, tides
  - Lorentz force
  - Movement of a charged particle in time-independent electric and magnetic fields
  - Hall Effect, local Ohm law, Laplace law
  - Oscillators
- Kinematics of an assembly of punctual particles
  - Mass, inertia centre, impulsion
  - Koenig's theorem
- Dynamics of an assembly of punctual particles
  - Movement in a central force field, Kepler laws
  - Elastic collision between two particles

Electrokinetics

- General laws in the approximation of quasi-stationary regimes
  - Current and tension, laws
  - Power received by a dipole
  - Generator, receptor
- Linear circuits
  - Model dipoles: resistance, inductance, capacitor
  - Association of several dipoles
  - Generator of current, generator of tension
  - Superposition theorem, Norton's theorem, Thevenin's theorem
  - Operational amplifier in linear regime
- RLC Circuit
  - Linear circuit in forced sinusoidal regime
  - Impedance
  - Average power in forced sinusoidal regime
  - Power transfer
  - Transfer functions: Bode diagrams, asymptotic diagrams
- Examples of non linear circuits
  - Operational amplifier in saturated regime
  - Simple diode, Zener diode

Thermodynamics

- Perfect gas
  - Molecular speed distribution, isotropy, homogeneity, quadratic average speed
  - Kinetic definition of temperature and pressure; perfect gas law
- Real gas
  - Van der Waals law
  - Thermoelastic coefficients, Calorimetric coefficients, Clapeyron law
  - Viriel development
- Diffusion of particles
  - Fick law, equation of diffusion
- Fluid statics
  - Archimedes force
  - Models of atmosphere
- Energetic balance
  - First principle, Second principle
  - Enthalpy, Entropy
  - Thermodynamic temperature and pressure
  - Third principle
- Thermal engines
- Thermodynamic viewpoint of paramagnetism and ferromagnetism
- Equilibrium radiation
  - Thermal balance and Einstein absorption and emission laws
  - Black corpse; Planck, Stefan and Wien laws

Geometrical optics

- Descartes laws
- Thin lens and spherical mirror conjugation formulas, enlargement formulas
- Composed optical systems

Laboratory work

Electrical Engineering

- Implementation of usual measuring devices
- Generation and amplification of signals
- Study of several electronic systems
  - Diode, Zener diode
  - Quasi-sinusoidal oscillator
  - Operational amplifier (linear mode, saturated mode and hysteresis cycle)

Mechanics

- Study of mechanical oscillators
  - Pendulum, spring, two coupled springs

Thermodynamics

- Calorimetric measures

CHEMISTRY

The periodical classification – Evolution of physical properties

- Chemical elements and spectral emission
- Quantum mechanics results
  - Schrödinger equation, quantum numbers (n, m, l, s) and orbitals (s, p, d, f)
  - Single electron atoms
  - Several electron atoms (Slater rules)
  - Pauli principle and Hund rules
- Principles underlying the periodical classification
- Trends for the main properties
  - Atom size, electronegativity, first ionization energy, electron affinity

The chemical bond

- Lewis theory
- VSEPR method
- Localized and delocalized bonds

Chemical balanced reactions

- Acid/base reactions
  - Strong acids and bases, weak acids and bases, pH determination
  - Buffered solutions
  - Titration of acid and basic solutions
- Complex forming reactions
- Dissolution reactions
- Redox reactions
  - Definition, redox potential, notion of battery
  - Thermodynamic aspects and Nernst formula
  - Redox titration
  - Diagrams: E/pH, E/pL

Kinetics

- Chemical reaction's kinetics
  - Reaction order, partial order
  - Van't Hoff principle and complex reactions study
- Activation energy
  - Arrhenius law
  - Influence of temperature and concentration
- Reaction path
  - Collision theory and transition states
  - Approximation of the quasi-stationary state and reaction intermediate products

Laboratory work

Acid/base titration

Determination of reaction constants

- Oxydoreduction potential
- Solubility product
- Dissociation constant
- Kinetics (determination of a reaction order, influence of temperature)

COMPUTER SCIENCE

Programming methods

- Basic principles
  - Proof of correctness
  - Complexity measures
- Iteration and recursivity
  - Conditional and unconditional control loops
  - Simple and cross recursivity
  - Ordering and termination

Data structures and algorithms

- Lists
- Pushdown stacks

Logic

- Syntax
  - Logical connectors
  - Abstract syntax
- Semantic and evaluation
  - Truth tables
  - Tautology
- Boolean functions
  - Disjunctive and conjunctive normal functions
  - De Morgan's laws
- Elementary circuits
  - Logical gates and digital processing
  - Adders

Programming in ML (with Ocaml)

Second year – Advanced Mathematics and Physics
September XX - July XX

MATHEMATICS

Linear and Bilinear Algebra

- Duality in finite dimension spaces
- Advanced reduction of linear operators
- Dunford decomposition, Jordan reduction
- Symmetric bilinear forms, quadratic forms and Gauss reduction
- Finite dimension matrix analysis

Euclidean and Hermitian spaces

- Real and complex prehilbertian spaces
  Dot product, semi-linear product, orthogonality
- Euclidean and Hermitian spaces
  Orthonormal bases, orthogonal projection, adjugate operator
- Operator and matrix analysis
  Auto-adjugate operator, orthogonal operator, Cartan decomposition and reduction

Analysis

- Series of functions
  Simple, absolute, uniform, normal convergence
  Continuity, derivation and C^n criteria
  Integral on an interval of a series of functions
  Approximation of a function of the real variable
  Study of the exponential function of matrixes
- Power series
  Convergence radius
  Study on the real axis and on the complex plan
- Fourier series
  Fourier coefficients, Parseval equality, quadratic mean convergence
  Punctual and uniform convergence, Dirichlet theorem
- Integral series and parametrical integrals
  Monotonous and dominated convergence theorems
  Continuity, derivation criteria

Geometry

- Curves in Euclidian spaces
- Parameterized arcs
- Implicit curves
- Conics and quadrics

Differential equations

- Linear differential equations
  - Systems of first order linear equations
  - General systems of first order equations
  - Cauchy-Lipschitz theorem
  - Systems of linear second order equations
- Non linear differential equations

Functions of several real variables and differential calculus

- Continuously differentiable functions
- Partial derived functions of order k>1
- Local inversion theorem, implicit functions theorem
- Curves and areas
- Integral calculus
  - Multiple integrals, vector fields of plane and space

PHYSICS

Mechanics of solid

- Kinematics
  - Kinematics of solids
  - Speed field, instantaneous translation vector and instantaneous rotation vector
  - Kinematics of the contact between two solids
- Strain modeling
- Dynamic analysis examples
  - Inertia matrix
  - Solid in rotation around a fixed axe
  - Top
  - Solid collision

Mechanical waves

- Coupling between two harmonic oscillators
  - Two oscillators: eigenmodes, free regime, forced sinusoidal regime
  - Infinite chain of oscillators: approximation of continuous media
- Non dissipative one-dimensional propagation
  - Transverse vibrations of a rope: wave equation of D'Alembert
  - Superposition of plane waves, either progressive or harmonic or stationary
- Dissipative one-dimensional linear propagation phenomenon
  - Dispersion relationship, dispersion, absorption

Wave optics

- Scalar model of light
  - Scalar vibration propagation along a beam, optical path
  - Plane wave, spherical wave
- Interferences
  - Plane wave interference
  - Young's system
  - Michelson interferometer
- Diffraction
  - Huygens-Fresnel principle
  - Plane wave infinite diffraction
  - Network diffraction
  - Resolution limits
- Polarization of light

Electromagnetism

- Electrostatics
  - Distribution of charges: invariance by rotation, translation; symmetries
  - Coulomb law
  - Basic properties of electric field
  - Potential energy of a punctual charge in an exterior electrostatic field
  - Flux of electric field, Gauss theorem
  - Electric dipole
  - Electric conductors in electrostatic equilibrium
- Magnetostatics
  - Distribution of currents: invariance by rotation, translation; symmetries
  - Biot-Savart law
  - Basic properties of magnetostatic field
  - Flux of magnetic field, Ampere theorem
  - Magnetic dipole
- Local equations
  - Current density
  - Local equation of charge conservation
  - Maxwell equations in vacuum
  - Existence of (A, V) potentials
  - Lorentz gauge
- Electromagnetic waves in vacuum
  - Equations of electromagnetic field propagation
  - Plane progressive wave structure, polarization states
  - Oscillating dipole radiation
- Electromagnetic waves in linear, isotropic, homogenous dielectric media
  - Polarization vector, magnetization vector
  - Polarization and magnetization currents
  - Maxwell equations in material media
  - Propagation, transmission and reflection of electromagnetic waves
- Electromagnetic induction in a fixed circuit
  - Laplace forces, Faraday law, Eigen inductance, mutual inductance
- Electromagnetic induction in a circuit moving in a stationary magnetic field
  - Laplace forces, Faraday law
  - Electromotive force
- Applications
  - Electromagnetic coupling: electrodynamic loudspeaker

Thermal diffusion

- Fourier law and thermal diffusion equation
- Thermal resistance
- Thermal diffusion plane wave and forced thermal regimes
- Conducto-convective flux

Laboratory work

Optics

- Approximation of geometrical optics
  - Reflection law
  - Refraction law
- Michelson interferometer
- Prism analysis
- Light polarization (production and analysis of polarized light)

CHEMISTRY

Structure and organization of condensed materials

- Cohesion of crystals
  - Types of bonds
  - Reticular energy
- Geometric arrangement

Thermodynamics

- State changes of pure products
- Liquid/vapour equilibrium
  - Clapeyron formula, Raoult and Henry laws for liquid mixtures, chemical momentum law
  - Different types of mixtures and distillation
- Free energy and free enthalpy, chemical potential and Gibbs-Duhem relation
- Reaction advancement, reaction product
- Thermodynamic characteristics of a chemical reaction
  - Reaction enthalpy, reaction entropy, thermal capacities, formation enthalpy
  - Kirchoff laws, Gibbs-Helmholz relation, Van't Hoff isobar law, Hess law
- Equilibrium displacement

Oxides formation and reduction: Ellingham diagrams

- Fundamentals: Ellingham approximation
- Formation and reduction of oxides
  - Thermodynamics
  - Kinetics
- Industrial applications (metallurgy)

COMPUTER SCIENCE

Programming methods

- Divide and conquer
  Searching and sorting

Data structures and algorithms

- Trees
  Evaluation of arithmetic expressions

Finite automata

- Determinism and non-determinism
  Graphic representation
- Regular languages
- Regular expressions
- Boolean algebra of regular languages

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