

Classes Préparatoires aux Grandes Ecoles : Curriculum  
Three years intensive program in preparation for the nationwide competitive  
examinations to the top French Engineering and Science Schools

Advanced Physics, Chemistry and Engineering Class (1<sup>st</sup> academic year)  
Advance Physics and Chemistry Class (2<sup>nd</sup> academic year)  
Lycée Pierre de Fermat, Toulouse, September 1997 – July 1999

## **MATHEMATICS**

### **GENERAL ALGEBRA**

**Number theory**

**Abstract algebra : Group Theory**

### **LINEAR APPLICATION'S IMAGE AND NUCLEUS**

### **LINEAR ALGEBRA AND GEOMETRY**

#### **Linear Algebra and Affine Geometry**

VECTOR SPACES, LINEAR TRANSFORMATION

Direct sum of vector subspaces

Image, kernel, trace of a linear transformation

DETERMINANTS

Determinant of  $n$  vectors

Determinant of a linear operator

Determinant of a squared matrix

Matrix analysis

STABLE SUBSPACES

FINITE DIMENSION DUALITY

SYMETRIC BILINEAR FORMS, QUADRATIC FORMS AND REDUCTION

POLYNOMIAL FUNCTIONS OF A MATRIX

EIGENVALUES, EIGENVECTORS, EIGENSPACES

FINITE DIMENSION MATRIX ANALYSIS

LINEAR OPERATORS REDUCTION

#### **Euclidean Spaces, Euclidean Geometry**

REAL OR COMPLEX PREHILBERTIAN SPACES

Dot product

Orthogonality

EUCLIDEAN SPACES

Orthonormal basis

Orthogonal projections

The adjugate matrix

Semi-linear product

#### **Geometry**

Curves in euclidean spaces

Parametrized arc

Implicit curves, conics, quadrics

# ANALYSIS AND DIFFERENTIAL GEOMETRY

## General Topology

### Series and Functions

NORMS, DISTANCES AND SERIES

VECTORS SPACES IN FINITE DIMENSION

Series of elements of a vector space in finite dimension

Local analysis of a function, continuity

Continuity of linear transformations

REAL OR COMPLEX NUMERICAL SERIES

Positive real series

Real or complex numerical series

SERIES OF FUNCTIONS

Simple convergence

Uniform convergence

Normal convergence

Approximation of functions of a real variable

### Functions of a real variable : Derivation and Integration

DERIVATION OF VECTOR FUNCTIONS

Derivative functions,  $C^1$ -functions

$C^k$ -functions

INTEGRATION OF VECTORS FUNCTIONS ON A CLOSED AND BOUNDED INTERVAL

Integral of a continuous-per-interval function

Integral on an interval of series of continuous function

Lebesgue integrals

DERIVATION AND INTEGRATION

Primitive and integral of a continuous function

$C^1$ -functions

Taylor formulas

Series of  $C^k$ -functions

Parametrical integrals

INTEGRATION ON ANY INTERVAL

Real positive functions that can be integrated

Complex functions that can be integrated

Convergence in mean and in quadratic mean

Theorems of monotone convergence and of dominated convergence

Parametrical integrals

CURVES IN PLAN AND IN SPACE

Parametrical curves

Local analysis of an oriented  $C^k$ -curve

### Series, Power Series, Fourier Series

REAL OR COMPLEX NUMERICAL SERIES

Comparison between series and integrals

Product of two absolutely convergent series

POWER SERIES

Convergence radius

Power series of a real variable

FOURIER SERIES

Fourier coefficients  
Convergence in quadratic mean, Dirichlet's theorem  
Punctual convergence

### **Differential Equations**

LINEAR DIFFERENTIAL EQUATIONS

Systems of linear equations with constant coefficient

Dirichlet's theorem

Systems of linear second-order equations

NONLINEAR DIFFERENTIAL EQUATIONS

### **Functions of several real variables**

DIFFERENTIAL CALCULUS

Continuously differentiable functions

Numerical continuously differentiable functions

Partial derived functions of order  $k \geq 2$

Curves and areas

INTEGRAL CALCULUS

Multiple integrals

Vector fields of plane and space

# PHYSICS

## ACADEMIC COURSES

### **NEWTONIAN MECHANICS**

#### KINEMATICS OF PUNCTUAL PARTICLE

Space and time, types of movement

Change of referential: laws for composition of speed and acceleration

#### DYNAMICS OF PUNCTUAL PARTICLE

Galilean referential, Newton's laws

Impulsion theorem

Kinetic momentum theorem

Kinetic energy theorem

Conservative force fields

Non-galilean referentials, inertia forces

#### APPLICATIONS

Geocentric referential, terrestrial referential

Terrestrial gravity, tides

Lorentz's force

Movement of a charged particle in uniform permanent electric and magnetic fields

Hall effect, local Ohm's law, Laplace's law

Harmonic oscillator : free regime, forced regime, resonance

#### KINEMATICS OF AN ASSEMBLY OF PUNCTUAL PARTICLES

Mass, inertia centre, impulsion, kinetic momentum, kinetic energy

Koenig's theorem

#### DYNAMICS OF AN ASSEMBLY OF PUNCTUAL PARTICLES

General theorems

Energy, mechanical energy, potential energy, theorem of kinetic energy

#### APPLICATIONS

Elastic collision between two particles

Kepler's laws

Solid rotating around a fixed axis

### **MECHANICS OF SOLIDS**

#### KINEMATICS

Kinematics of solids

Speed field, instantaneous rotation vector

Kinematics of the contact between two solids

#### STRAIN MODELING

#### DYNAMIC ANALYSIS EXAMPLE

### **FLUID MECHANICS**

#### STRAIN MATRIX

#### VISCOSITY

#### REYNOLDS NUMBER

#### FLUID STATICS

Hydrostatic pressure

Kinetic pressure, Molecular pressure

Fundamental equations of Fluid Statics

Isopressure surfaces

Archimedes' theorem  
FLUID KINEMATICS  
Velocity field : Lagrangean and Eulerian descriptions  
Acceleration field  
Deformation matrix, Rotation matrix, Stretch matrix  
OPENED SYSTEMS  
Material derivative  
Volume flux  
Mass conservation  
Navier-Stokes equation  
Vorticity equation  
STEADY MOTION OF AN INVISCID AND INCOMPRESSIBLE FLUID  
Bernoulli's theorem  
Applications : Venturi effect, Pitot tube, Magnus effect  
Rotational flows  
Irrotational flows  
Potential flows and streamfunction  
STEADY MOTION OF A VISCID AND INCOMPRESSIBLE FLUID (Notions)  
Reynolds similitude  
Drag force  
Limit layer  
Viscosity Measurements

## **ELECTROKINETICS**

GENERAL LAWS IN THE APPROXIMATION OF QUASI-6STATIONARY REGIMES  
Current, 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  
Operational amplification  
Superposition theorem, Norton's theorem, Thevenin's theorem  
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

## **THERMODYNAMICS**

MONOATOMICAL PERFECT GAS  
Molecular speed distribution ; isotropy, homogeneity, quadratic average speed  
Kinetic definition of temperature and pressure  
DIFFUSION OF PARTICLES  
Fick's law  
Equations of diffusion  
ENERGETIC BILANS  
First Principle, Second Principle

Enthalpy, Entropy  
Thermodynamic temperature and pressure  
Third Principle

#### THERMAL ENGINES

##### DESCRIPTION OF THE BIPHASED EQUILIBRIUM OF A COMPOUND

(p,T) diagrams, triple point, critic point  
Enthalpy and Entropy of a phase transformation  
Liquid-vapor equilibrium : (p,V) and (T,S) diagrams

#### THERMODYNAMIC POTENTIALS

Thermodynamic closed system evolution and equilibrium  
Monothermal evolution  
Monopressure and monothermal evolution  
Characteristic functions U, H, F, G  
Clapeyron law and derivation  
Mayer's law

#### THERMODYNAMIC VIEWPOINT OF PARAMAGNETISM AND FERROMAGNETISM

Paramagnetism  
Magnetic momentum of atoms and molecules  
Paramagnetic susceptibility  
Thermodynamic relations  
Ferromagnetism  
Curie-Weiss theory  
Microscopic behaviour, Bloch walls  
Coercibility, magnetic hysteresis  
Thermodynamic relations

## **ELECTROMAGNETISM**

### ELECTROSTATICS

Distribution of charges: invariance by rotation, translation; Symmetries of the problem  
Basic properties of magnetostatic field  
Biot-Savart's law  
Flux of magnetic field, Ampère's theorem

### LOCAL EQUATIONS

Current density  
Local equation of charge conservation  
Maxwell's equations in vacuum  
Existence of (A,V) potentials  
Lorentz gauge  
Poisson equations

### ELECTROMAGNETIC INDUCTION IN A FIXED CIRCUIT

Faraday's law, eigen inductance, mutual inductance

### ELECTROMAGNETIC INDUCTION IN A CIRCUIT MOVING IN A STATIONARY

### MAGNETIC FIELD

Faraday's law  
Lenz's law  
Electromotive force

### FOUCAULT CURRENTS

### APPLICATIONS

Electromagnetic coupling: electrodynamic loudspeaker

## **PHYSICS OF WAVES**

### **COUPLING BETWEEN TWO HARMONIC OSCILLATORS**

Two oscillators, eigenmodes, free regime, sinusoidal regime  
Infinite chain of oscillators: approximation of continuous media

### **NON DISSIPATIVE UNIDIMENSIONAL PROPAGATION**

Transverse vibrations of a rope : wave equation of D'Alembert  
Superposition of plane waves, either progressive, harmonic, or stationary  
Melde's rope

### **ACOUSTIC WAVES IN FLUIDS**

Equation of acoustic waves in the acoustic approximation  
Wave equation of D'Alembert  
Plane Progressive Harmonic waves  
Acoustic energy density  
Acoustic impedance  
Reflexion, transmission of an acoustic wave

### **ELECTROMAGNETIC WAVES IN VACUUM**

Equations of magnetic field propagation  
Plane progressive wave structures, polarization states  
Oscillating dipole radiation

### **ELECTROMAGNETIC WAVES IN CONDUCTOR AND PLASMA MEDIA**

Low frequency, high frequency behaviours  
Phase velocity, group velocity

### **DISSIPATIVE UNIDIMENSIONAL LINEAR PROPAGATION'S PHENOMENON**

Dispersion laws, dispersion, absorption  
Phase and group velocity

### **ELECTROMAGNETIC WAVES IN LINEAR ISOTROPIC HOMOGENEOUS DIELECTRIC**

#### **MEDIA**

Polarization vector, magnetization vector  
Polarization charges  
Polarization and magnetization currents  
Maxwell's equations in material media  
Dielectric and magnetic permittivity of linear isotropic homogeneous media  
Reflexion and refraction of a plane progressive harmonic wave in specific conditions : reflexion and transmission coefficients for amplitude and energy

## **WAVE OPTICS**

### **SCALAR MODEL OF LIGHT**

Scalar vibration propagation along a beam, optical way  
Waves areas, plane wave, spherical wave

### **INTERFERENCE**

Non-localized interferences with two coherent waves  
Applications : Young's system, Fresnel's mirrors  
Michelson's interferometric system

### **DIFFRACTION**

Huygens-Fresnel's principle  
Plane wave infinite diffraction  
Diffraction with rectangular, circular, thin apertures  
Young's system  
Rayleigh's criteria, separating power  
Babinet's theorem

## **THERMAL DIFFUSION**

FOURIER'S LAW  
THERMAL DIFFUSION EQUATION  
HEAT EQUATION  
FORCED CONTINUOUS REGIME  
    Thermal conductance  
    Forced sinusoidal regime  
    Thermal diffusion plane wave

## **LABORATORY WORK**

### **OPTICS**

APPROXIMATION OF GEOMETRICAL OPTICS  
IMPLEMENTATION OF USUAL MEASURING DEVICES  
REFLECTION'S, REFRACTION'S LAWS  
MICHELSON'S INTERFEROMETER  
    Reticulum Spectroscopy (diffraction, use of a goniometer)  
    Lights Polarization (production and analysis of polarized light)

### **ELECTRICAL ENGINEERING**

IMPLEMENTATION OF USUAL MEASURING DEVICES  
GENERATION AND AMPLIFICATION OF SIGNALS  
STUDY OF SEVERAL ELECTRONIC SYSTEMS: DIODE? QUASI-SINUSOIDAL OSCILLATOR  
STUDY OF FERROMAGNETISM: HYSTERESIS CYCLE, APPLICATION TO TRANSFORMERS

### **MECHANICS**

STUDY OF MECHANICAL OSCILLATOR

### **THERMODYNAMICS**

CALORIMETRIC MEASURES



# CHEMISTRY

## ACADEMIC COURSES

### MOLECULAR ARCHITECTURE

#### THE QUANTUM ATOM MODEL AND THE PERIODIC CLASSIFICATION

Hydrogen Emission Spectrum : analysis and interpretation

Bohr's model

Schrödinger equation : results for an hydrogenoid atom

Quantum numbers  $n, l, m_l$

Atomic orbitals  $s, p, d$

Polyelectronic atoms : shielding constants and Slater's rules

Energy and radius of Slater orbitals

Electronic spin : spin quantum number  $s$  and  $m_s$

Electronical configuration of atoms in ground state

Pauli's principle, Klechkovski's rule and Hund's rule

Periodic classification of the elements, connections with the quantum atomic model

Periodicity of atomic properties : ionisation energy, electron affinity, Mulliken's electronegativity, metallic, ionic and covalent radii

#### THE ELECTRONIC STRUCTURE OF A MOLECULE

Localized covalent bond : Lewis notation

Octet rule and 18 electron rule

Delocalized covalent bond : mesomeric effect and resonance

Geometry prediction : VSEPR theory

Electronic energy levels

Construction of molecular orbitals by linear combination of atomic orbitals

Crystal field theory

#### STRUCTURE AND ORGANIZATION OF CONDENSED MATTER

Interpretation of crystal cohesion

metallic, covalent and ionic bonds

intermolecular bonds (Van der Waals and hydrogen bond)

Crystal structure : networks, nodes, unit cells

Crystal compact packing with identical spheres : hexagonal and cubic packing

Ionic packing : examples of NaCl, ZnS, CaF<sub>2</sub>, CsCl

Connections between structural packing and ionic radii

Covalent model : description of diamond, graphite and silicium structures

Energy bands : conductor, semi-conductor and insulator behaviours

Real crystal : non-stoichiometry of FeO

#### METALLIC MATERIALS

Metals preparation techniques

Ellingham diagrams : making and interpretation, polymetallurgy example

Potential-pH diagrams : making and interpretation, hydrometallurgy example

Potential-intensity diagrams : example of the electrolytic preparation of Zn

Corroding phenomena

Usage of Zn to prevent the Fe corrosion

## **KINETICS**

KINETIC OF A REACTION : DEFINITIONS  
RATE OF DISAPPEARANCE, RATE OF APPEARANCE  
LAWS OF KINETICS AND REACTION ORDERS  
INFLUENCE OF TEMPERATURE AND CONCENTRATIONS  
ACTIVATION ENERGY  
MECHANISM OF A REACTION  
    Elementary reactions  
    Transition state  
    Intermediate products  
APPROXIMATION OF THE *QUASI*-STATIONARY STATE  
APPROXIMATION OF THE DETERMINING STEP

## **THERMODYNAMICS**

FIRST PRINCIPLE : APPLICATIONS  
    Closed chemical system, advancement of a reaction  
    Standard state of pure compounds  
    Physico-chemical reaction in a closed system  
        Standard internal energy  $\Delta_r U^0$  of a reaction  
        Standard enthalpy  $\Delta_r H^0$  of a reaction  
        Electron gain enthalpy, enthalpy of ionization  
        Bond enthalpy  
        Enthalpy of fusion, vaporization, sublimation  
CHEMICAL EQUILIBRIUM IN AQUEOUS MEDIA  
    Acido-basic reactions  
    Oxydo-reduction reactions  
    Complexation equilibrium  
    Precipitation reactions  
    Guldberg and Waage law  
    Electrode potential, Nernst equation  
    Dosages : acido-basic, redox, complexation, precipitation  
THERMODYNAMICAL POTENTIALS  
    Helmoltz Free Energy F  
    Gibbs Free Energy G  
    Elementary variations dS, dF, dG of thermodynamical potentials during a physico-chemical transformation  
    Gibbs-Helmoltz equation  
CHEMICAL POTENTIAL  
    Definition  
    Free enthalpy expressed with chemical potentials  
    Gibbs-Duhem equation  
    Dependance of the potential with temperature and pressure  
    Chemical potential of a perfect gas in ideal mixtures  
CHEMICAL EQUILIBRIUM  
    Standard entropy  $\Delta_r S^0$  of a reaction  
    Standard free enthalpy  $\Delta_r G^0$  of a reaction  
    Chemical affinity, evolution of a system  
    Thermodynamical constant  $K^0$   
    Van't Hoff law  
    Equilibrium displacement law  
PHASE EQUILIBRIUM OF BIPHASED MIXTURES

- Liquid-vapor equilibrium
  - Isopressure and isothermal behaviours
  - Complete miscibility or non-miscibility in liquid state
- Solid-liquid equilibrium
  - Isopressure behaviour
  - Complete miscibility or non-miscibility in solid state and complete miscibility in liquid state

## **ORGANIC CHEMISTRY : STRUCTURE, REACTIVITY AND SYNTHESIS**

### STEREOCHEMISTRY OF ORGANIC COMPOUNDS

- Newman and Cram projections
- Stereoisomers and chirality
- Enantiomers and diastereoisomery.
- Conformational analysis : ethane, butane, cyclohexane, monosubstituted and disubstituted cyclohexanes

### SIMPLE CARBON - HALIDE BOND

- Halogenoalkanes
- Nucleophilic Substitutions (SN)
  - SN1 and SN2 mechanisms and kinetics
  - Stereochemistry
- Elimination reactions (E)
  - E1 and E2 mechanisms and kinetics
  - Saytzev's rule
- E vs. SN competition : influence of solvent and reactants

### SIMPLE CARBON – OXYGEN BOND

- Williamson Ether Synthesis
- Reactions ROH  $\rightarrow$  RX (X = Cl, Br, I)
  - With HX reagent
  - With PCl<sub>3</sub> , PBr<sub>3</sub> , SOCl<sub>2</sub> reagents
- Intermolecular and Intramolecular Dehydrations in acid media

### CARBON-CARBON DOUBLE BONDS

- Electrophile Addition, Radical Addition
  - Regio- and stereoselectivity
  - Mechanisms
- Hydration, Hydrohalogenation and Halogenation

### ORGANOMAGNESIUM (Grignard Reagents)

- Organomagnesium synthesis : experimental conditions
- Nucleophilic and basic properties
- Nucleophilic Substitutions
  - with halogenoalkyles (Wurtz reaction), with epoxides
- Nucleophilic Additions
  - with carbonyl compounds, with CO<sub>2</sub> and  $\text{-C}\equiv\text{N}$

### THERMOPLASTIC ORGANIC MATERIALS

- Structure and reactivity of monomers : styrene and methyl methacrylate
- Anionic and radical homogeneous polymerisation
  - Polymerisation mechanism
  - Kinetics
  - Conformation of polymer chains (regioselectivity, stereoselectivity)
- Connection between structure and macroscopic properties of polymers

### IR AND RMN SPECTROSCOPY

- A help to determine structures
- IR spectroscopy : excitation of normal vibrational modes

RMN Spectroscopy :  
Proton nuclei energy levels, spin  
Coupling constants, resonance  
Free Induction Decay, cross peaks

#### ALKENES

conjugate systems in Hückel' s theory  
applications : description of ethylene and butadien molecular orbitals  
heterogeneous catalytic hydrogenation  
epoxidation by a peroxyacid : hydrolysis in acid or basic media, mechanisms  
*syn*-dihydroxylation by osmium tetroxide  
synthesis of primary alcohols by hydroboration  
potassium permanganate and ozonolysis oxidizing reactions  
Diels-Adler reaction : mechanism, molecular orbitals analysis

#### AROMATIC HYDROCARBONS

aromaticity  
geometric and electronic structure of benzene  
electrophilic aromatic substitution :  
mechanism, alkylation, acylation,  
nitration, sulfonylation , halogenation  
orientation of the electrophilic substitution on the monosubstituted benzenes

#### AMINES

Nucleophilic reactivity : alkylation, acylation  
Diazotisation of primary aromatic amines  
Diazo coupling reaction  
Sandmeyer reactions

#### CARBONYL COMPOUNDS

Synthesis by alcohols oxidations  
Nucleophilic additions  
Exploitations of Hückel data  
Acetalization in acid media  
LiAlH<sub>4</sub> and NaBH<sub>4</sub> additions  
Organomagnesium additions  
Keto-enol tautomerism  
Carbonyl  $\alpha$ -Reaction  
Enolate formation  
Carbanions  $\alpha$  to an electroattractive group formation  
Enolate ion  
Enolate reactions  
Aldolization (ketolization) mechanism  
Crotonation mechanism in acid and basic media  
Carbon alkylation  
Conjugate addition on  $\alpha$ -enones  
Organolithium, Lithium organocuprate (R<sub>2</sub> CuLi) and  
organomagnesium reactivity on  $\alpha$ -enones  
Wittig reaction

#### CARBOXYLIC ACIDS AND DERIVATIVES

Ester synthesis  
With acids and primary alcohols  
By activation of the acid functional group : acyl chlorides, acid  
anhydrides  
Ester, amides and nitriles hydrolysis in basic media  
Malonic synthesis

malonic diesters alkylation  
hydrolysis in basic media  
decarboxilation in acid media

## **LABORATORY WORK**

IMPLEMENTATION OF USUAL DEVICES

ACID-BASE DOSAGES

DETERMINATION OF THERMODYNAMICAL CONSTANTS

Oxydoreduction potential

Solubility product

Dissociation constants

Kinetics : reaction rate constant

ORGANIC CHEMISTRY

Synthesis : organomagnesium, ketones, alcohols

Filtration and decantation techniques

Functional group characterization

Cristallization and measurement of the melting point (Köfler hotstage)

Chromatography, spectroscopy techniques