Semester 3: Choose three 4 ECTS specializing courses, see the general FunPhys curriculum

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Teaching location for the following 4-credit courses : South pole of the Sciences Faculty: Luminy.

Complex_Syst_L_Machine_S3

Complex Systems and Introduction to Machine Learning

Contact: Alain Barrat or Christophe Eloy or Mathieu Génois

I-Introduction to complex systems and complex networks.

- What are complex systems (examples in various fields), how can they be represented, use of network representations.
- Elements of statistical characterization of networks (paths, degrees, centrality, community detections, degree distribution). Small-world, scale-free properties.
- Models of networks (random graphs, preferential attachment, copy model).
- Robustness and resilience of networks.
- Diffusion and spreading processes: from random walks to epidemiology.
- Models of social phenomena on networks.
- Introduction to computational social science, online social networks.

II-Learning from data: machine learning and deep learning

- Introduction to machine learning (learning problem, types of learning, overview...)
- Linear models (linear regression with one or multiple variables, logistic regression)
- Non-linear models (Support Vector Machines, naive Bayes, decision tree)
- Clustering (k-means, Gaussian mixture models)
- Neural networks (non-linearities, convolutional NN networks, recurrent NN...)
- Reinforcement learning (Markov Decision Processes, Dynamic Programming, Model-Free Prediction, Model-Free Control)
- Deep reinforcement learning (Policy gradient, exploration/exploitation, current models…)

AQFT-S3

Advanced quantum field theory

Contact: T. Krajewski

Interdisciplinary course, to be accessible to students in various fields (condensed matter, elementary particles, gravitation and cosmology) with interest in renormalization.

- Length scales in physics

- Critical phenomena, Landau-Ginzburg theory
- Wilson's renormalisation group approach
- Path integrals and Feynman rules
- Fixed points and asymptotic behavior
- General ideas on effective field theories

References : Le Bellac, Itzykson & Drouffe, Goldenfeld, Cardy, Zinn-Justin, ...

Soft Matter-S3

Soft Matter

Contact: Kheya Sengupta and Felix Rico

Principles of Soft Condensed Matter Physics

Abstract: This course intends to treat "Soft Matter" as a subfield of Condensed Matter physics, underlining the unifying principles. Soft Matter is defined as matter in which the interactions between the constituent particles, which may be molecules, macromolecules or larger entities, is weak and as a consequence, one defining property of soft matter is the ease with which small external forces can deform them. This means that they not only distort and flow easily, but also that thermal fluctuations play an important, often dominant, role in defining their properties. The structural diversity of soft materials means that they encompass a multitude of symmetry groups, some of which are not found elsewhere, and often exhibit interesting defect dominated phases. The prevalence of entropy dominated states and transitions, the relevance to every-day materials ranging from coffee and whipped cream to soap and paint, and the connection to active and living matter makes soft matter endlessly fascinating.

Content :

1. Revisit concepts of free energy, entropy and temperature; Introduction to forces, energies and length/time-scales in soft matter; Notions of entropic forces, thermal fluctuations; Examples of Soft Matter: Liquid Crystals (Nematic and Smectic phases), Colloids, Polymers, Surfactants, Membranes.
2. Revisit phase space and ensembles (classical stat mech); correlations and ordered systems; Introduction to order parameter.
3. Symmetry and scattering; Disordered and ordered phases (examples from Liquid Crystals and ordered phases of surfactants and polymers)
4. Elasticity and deformation in anisotropic media (focus on Liquid Crystalline phases)
5. Defects and defect phases (with examples from Soft Matter)
6. Phase transitions and notion of Landau Theory (with examples from Soft Matter)
7. Fluctuations and dissipation

8. Rheology of complex fluids (focus on polymers)
9. Basics of hydrodynamics, life at low Reynold's numbers
10. Forces and potentials at surfaces and interfaces (focus on colloids and membranes)
11. From soft to living systems
12. New developments in active matter

Pre-requisite: Classical statistical mechanics, elements of thermodynamics, familiarity with basic mathematics.

Out of Equilibrium Quantum Statistical Physics-S3

Out of Equilibrium Quantum Statistical Physics

Contact: Pr. Thierry Martin

As a starting point, one proceeds with an introduction of non- relativistic quantum field theory with the goal to describe a system of interacting fermions (Coulomb interaction, electron- phonon interaction, or impurity averaged collision with a potential for disorder). We start with the zero-temperature formalism, which exploits the adiabatic switching hypothesis of the interaction potential in order to compute average values of operators in the Heisenberg picture. On establishes a dictionary between the Heisenberg picture and the Interaction picture were the Wick theorem can be used. Single particle Green's functions are introduced for fermions and bosons, and one shows how perturbation theory can be used to express these quantities in terms of Feynman diagrams. The analytic properties of such Green function allow to introduce the concept of quasiparticles. The self energy of the Dyson series is introduced at this end of this first part.
Next, the non-equilibrium field theoretical framework of quantum statistical mechanics of Keldysh and Schwinger is introduced. Green's functions thus become two by two matrices as each time argument can be placed on the top or bottom part of the Keldysh contour. This allows to treat open systems and in particular to compute quantum transport quantities such as current and the noise (the current current correlation function in time, subsequently Fourier transformed).
We apply this formalism to several situations : 1) the calculation of the current through a tunnel barrier (a quantum point contact) to all orders in the tunneling amplitude. 2) the calculation of transport through a generalized nano-object such as a single molecule ; 3) the calculation of transport in superconducting systems using the Nambu formalism. In these systems if the starting Hamiltonian is quadratic in the fermions degrees of freedom, the Dyson series can be summed to all orders.
We will also provide an introduction to one-dimensional fermionic systems where the Tomonaga Luttinger formalism allow to treat interaction in a non-perturbative manner : this is called the bosonization technique, as fermion operators are expressed in terms of an exponential of bosnic

fields. The price to pay in the calculation of thermodynamical quantities is that the tunnel Hamiltonian is non-quadratic in the bosonic fields and it has to be dealt with using perturbation theory. An application to the edge state picture of the fractional quantum Hall effect (where quasiparticle excitations propagate on the edges of a two-dimensional electron gas will allow to compute the current and noise, and thus to compute its ratio with provides a direct determination of the non-integer charge of these excitations for the Laughlin sequence of the fractional quantum Hall effect.

References:

- Abrikosov, Gorkov and Dyalishinsky, "quantum field theory methods fo statistical physics",
- Rammer "quantum field theory of non-equilibrium states",
- Altland and Simons "Condensed matter field theory",
- Kamenev "Field theory of non- equilibrium systems",
- T. Martin, "Noise in mesoscopic physics" in «Nanophysics: Coherence and Transport » École d'été de Physique des Houches Session LXXXI H. Bouchiat, S. Gueron, G. Montambaux, J. Dalibard eds

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GaugeTH-SM-S3

Gauge Theories & Standard Model

Contact: A. Bharucha & S. Lazzarini

Prerequisite: QFT

1st part: Gauge Theories

Motivations:

- Notion of symmetry: within the framework of geometry or differential algebra.
- There is a strong link between geometry and physics.
- Symmetries confer a structure to spaces, give conserved quantities (Noether)
- In Quantum Mechanics: gauge transformation of the 4-potential vs unitary transformation
- Gauge principle in field theory: covariant derivative, coupling matter to Maxwell gauge potential (→ Yang-Mills theories.)
- Analytical Mechanics and symplectic geometry (geometric quantization)
- General Relativity : Riemann geometry, diffeomorphisms

Covered issues:
- Why the notion of fiber bundles appears in Physics? The very important role of Lie groups
- Which geometric interpretation to give to:

- the Yang-Mills potential? / to the Christoffel symbols? Notion of connection.

- the Yang-Mills field? / to the Riemann tensor? Notion of curvature.

- How to view the notion of connection? get an image of a gauge choice (local description)
- What about representations of Lie groups? Associated fiber bundles.
- What geometrical meaning for the matter fields? Notion of smooth sections.
- What is a gauge group? (gauge transformations? gauge fixing?)
- How to formulate a gauge theory in terms of geometrical concepts?
- How to translate an infinitesimal symmetry in algebraic terms? Notion of differential algebra
- Differential geometry & differential algebra: an elegant unifying language for all theories? (Yang-Mills, gravitation, ...)

2nd part: The Standard Model of Particle Physics: Emphasis on symmetries and applications to the standard model

Successes of the standard model

- Consistent (unitary and renormalizable) theory
- Weak neutral currents and gauge bosons
- High energy chromodynamics
- P and CP violation
- Cancellation of chiral anomalies
- Higgs boson

Challenges to the Standard model

- Derivation of confinement and hadronic physics
- Hierarchy of masses (electron mass = 0.5 MeV; top mass = 173 GeV)
- Status of massive neutrinos
- Number of free parameters ≥ 18
- Fine tuning of the Higgs mass

Topics

• One loop β function, asymptotic freedom
• Construction of the standard model (including massive neutrinos)
• Physical consequences (CP violation, low and high energy behavior in QCD, ...)
• Physics beyond the standard model

Astroparticles and Primordial Cosmology_S3

Astroparticles and Primordial Cosmology

Contacts: J.-P. Ernenwein, W. Gillard and C. Schimd

Astroparticles (20 h)

0. Introduction: Historical aspects: from early steps to the current domain of Astroparticles

1. Sources and transport of particles in the Universe
• Sources and their vicinity: production and acceleration mecanisms
• Examples of sources: Supernova Remnants, Binary systems, Active Galactic Nuclei, Gamma-ray bursters.
• Transport: General aspects, case of cosmic-ray interaction with the CMB: "GZK cut-off", case of propagation of gamma-rays.

2. Cosmic rays at Earth
• Primary cosmic rays: Composition and Flux. Experimental aspects: satellites, balloons.
• Secondary cosmic rays: Atmospheric showers, secondary particles at sea level and underground. Experimental aspects: detection (examples: KASCADE, AUGER).

3. Gamma-ray astronomy
• Methods: Satellites: example of FERMI; Ground based detectors: Imaging Atmospheric Cherenkov Telescopes (example of H.E.S.S.), arrays of detectors (example of HAWC),
• Multi-wavelength studies: combining observations from radio to gamma rays.

4. Other messengers
• Search for astrophysical neutrinos: neutrino telescopes: ICECUBE, ANTARES,
• Gravitational waves: LIGO, VIRGO,
• Multi-messenger aspects.

5. Dark Matter (DM)
• Phenomenological context: why the DM ? What is DM ?
• Detection techniques and current limits: direct and indirect detection.

Primordial Cosmology (20 h)

1. Thermodynamics of primordial universe:
• Friedmann models (recap).
• The early universe: equilibrium thermodynamics, entropy, phase transitions and thermal history.
• Big-bang nucleosynthesis: Numerical modelling and comparison to recent observations,
• Thermodynamics in expanding universe: Boltzmann equation, freeze-out and origin of species (CDM, HDM, WIMPS), out-of-equilibrium decay, recombination. Neutrino cosmology. Baryogenesis.
Applications (learning-by-doing): Lithium abundance, abundance of WIMPZILLA's and UHECR, Lee-Weinberg bound.

2. Quantum fluctuations during inflation:
• Klein-Gordon equation in expanding universe, linear perturbations and quantization of massless and massive inflaton, gauge invariance.
• Metric fluctuations, gauge invariance, quantum-to-classical transition, curvature and matter perturbations, gravitational waves, scalar and tensor power spectra, consistency relations.
• Primordial non-gaussianities (fNL, gNL). Reheating, pre-heating.

Applications (learning-by-doing): numerical solution of KG equation for some inflationary model (power-law, lambda phi^4 , hybrid, natural), study of the dynamical system.

3. Cosmic Microwave Background:
• Recombination and decoupling.
• Monopole, dipole and residual fluctuations. Spherical statistics.
• Temperature fluctuations: kinetic description, Sachs-Wolfe plateau, acoustic peaks, secondary anisotropies. Sources of noise and map-making: dust absorption, synchrotron radiation and Bremsstrahlung. Polarization: E- and B-modes, gravitational waves.
Applications (learning-by-doing): use of Boltzmann codes (CAMB, CLASS) to simulate CMB spectra and maps.

4. From post-recombination Universe to large-scale structure:
• From CMB to dark ages, ionization sources of H and He. Lyman systems and LyA-forest, IGM fluctuations, Gunn-Peterson effects. 21-cm cosmology.
• Density and velocity fields: Jeans modelling, Zel'dovich approximation.
• Statistics of fluctuations on large scales: counts, correlation functions, power spectrum.
• Spherical collapse, mass function, bias; halo model.
Applications (learning-by-doing): numerical solution of Jeans equation in neutrino cosmology, estimation of massive clusters' counts in cosmologies with pNG (fNL).

5. Statistical analysis of cosmological models:
• Combination of probes to extract cosmological parameters. Degeneracies.
• Frequentist and Bayesian approaches: grid method, gradient method, MCMC.
• Forecasts: Fisher analysis and Monte Carlo simulation. Modelling of systematics.
Applications (learning-by-doing): fitting the Hubble diagram from supernovae (Union 2) and CMB TT power spectrum (WMAP or Planck), Fisher matrix of cluster counts for fNL.

References:

– P. Peter, J.-P. Uzan, "Primordial Cosmology", Oxford University Press (2013)
– D. Lyth, A. Liddle, "The Primordial Density Perturbation: Cosmology, Inflation and the Origin of Structure", Cambridge University Press (2009)
– S. Dodelson, "Modern Cosmology", Elsevier (2003)
– M Spurio, “Particles and Astrophysics, a Multi-Messenger Approach”, Springer (2015), ISBN 978-3-319-08050-5
– T.K. Gaisser, “Cosmic Rays and Particle Physics”, Cambridge University Press (1990)

Experimental Test of Standard Model and Beyond-S3

Experimental Test of Standard Model and Beyond

subtitle: *Beyond Standard Model and Experimental Test of Particle Physics*

Contact: Pr. Marlon Barbero

In a first part, we will see what are the sources of particles relevant to our discussion (astrophysical objects, accelerators). We will cover the interaction of particles of various types in matter, and the important figures of merit related to these interactions (radiation length, critical energy, etc...). We will see various detection techniques used either at colliders or to detect astroparticles (Cerenkov detectors, scintillators, gaseous detectors, semiconductor detectors, ...) and finish with examples of practical layouts of complex modern detectors.
In a second part, after a reminder on the Standard Model of particles, some important elements of modern particle physics experiments will be addressed: triggering, data collection, reconstruction and analysis. Flavor physics will also be introduced.
The third part will be devoted to neutrino physics, starting from the physics of standard neutrino, introducing then the concept of neutrino oscillations, and finishing with the open questions in neutrino physics (nature of the neutrino, mass hierarchy, ...).
In the fourth and final part, the ElectroWeak Symmetry Breaking mechanism will be introduced, leading to the Standard Model Higgs boson. We will describe the search for the Higgs boson at current colliders, and the state of the art in terms of Higgs boson properties. This part will be concluded with solutions proposed to solve the hierarchy problems, introducing extra-dimensions, super-symmetry and making the connection to cosmology (dark matter, WIMP, baryogenesis...).

References:

1- W.R. Leo, Techniques for Nuclear and Particle Physics Experiments
2- C. Grupen, Handbook of Particle Detection and Imaging
3- Full review of PDG, section “passage of particle through matter” + other chapters covered
4- Specific literature for sub-topic: Rossi et al, “Pixel Detectors: From fundamental to application”
5- Carlo Giunti, "Fubndamentals of neutrino physics and astrophysics"
6- Kai Zuber, "Neutrino Physics"

Advanced Quantum Mechanics-S3

Advanced Quantum Mechanics

Contact: Pr. Alberto Verga or Pr. Alejandro Perez

I- Path Integrals: The path integral representation of quantum mechanics (History, relation with the Schrödinger representation, advantages relation to the classical theory), the phase space path integral, the configuration space path integral, duality with statistical mechanics (Brownian motion, Wick rotation), stationary phase approximation, Gaussian integrals (bosonic and fermionic), The heat kernel expansion, Examples (free particle, the harmonic oscillator, the particle in a uniform magnetic field, the particle in a circle, the particle in a box), the Aharonov-Bohm effect. Tunneling and instantons.

II- Quantum information: entanglement and entropy; open systems, master equation, decoherence; chaos, random matrices, dynamical localization.

References:

B. Schumacher and M. Westmoreland, Quantum Process, Systems and Information, Cambridge 2010

Haake, Quantum Chaos, Springer 2010.

Physics of Living Systems II -s3

Physics of Living Systems II

Contact: ROUAULT Herve

Course proposal Physics of living matter (now: Matthias Merkel, Hervé Rouault, J-F. Rupprecht)

Whether it is the development of an organism from egg cell to adult, tumor growth and metastasis, wound healing, or the functioning of a complex nervous system, many biological processes rely on the self-organized, coordinated action of a large number of cells. This course is designed to provide a general background in biology and demonstrate how concepts from theoretical physics can help understand how multicellular systems robustly organize to fulfill their respective function.

I) Development and patterning
● Fundamentals of multicellular development
● Classical patterning theories
● Cell polarity

II) Understanding living systems as active soft matter
● Non-equilibrium physics applied to living systems
● Biological tissues as soft active matter

III) Inference and neural networks
● Single neuron physiology: the Hodgkin-Huxley model
● Neuron networks: notions of discrete and continuous attractors.
● Noisy neuronal dynamics: the Fokker-Planck approach
● Learning dynamics: the perceptron model, recurrent neural networks.

Radiation Matter Interaction, Radiative Transfer-S3

Radiation Matter Interaction, Radiative Transfer

Contact: Pr. Olivier Peyrusse

1) Emission and Absorption of radiation between discrete levels, coefficients for emission and absorption, induced effects
2) A brief introduction to line broadening
3) Spectral emission of a plasma – free-free, free-bound emission and absorption
4) Semi-classical evaluation of the cross section for photoionization and Bremsstrahlung
5) Theoretical evaluation of transition probabilities between discrete levels
6) Statistical equilibrium models for the atomic or ionic populations :
  (a) Microscopic processes
  (b) Local Thermodynamical Equilibrium laws (Statistical Mecanics derivation)
  (c) Non Local Thermodynamical Equilibrium (the most general context) : Collisional-Radiative Equilibrium
7) Formal Radiation Transfer Theory
  (a) Main radiative quantities, moments of the radiative intensity
  (b) Derivation of the radiative transfer equation (RTE)
  (c) Simplification of the angular problem ; moments of the RTE ; Eddington closure ; main approximations (P1, Diffusion, radiative conduction)
8) Detailed Balance and microreversibility
9) Radiation-Matter energy coupling

References:

- D. Mihalas, Foundations of Radiation Hydrodynamics, Dover (1999) ;
- J.I. Castor, Radiation hydrodynamics, Dover (2007) ;

- J. Bauche, C. Bauche-Arnoult, O. Peyrusse, Atomic Properties in Hot Plasmas, Springer (2015).

Teaching location for the following 4-credit courses: North pole of the Sciences Faculty: St-Jerome or Chateau-Gombert.

Magnetohydrodynamics in Plasmas -S3

Magnetohydrodynamics in Plasmas

Contact: Matteo Faganello

FR:
1. MHD INSTABILITES IDEALES ET RESISTIVE

- Rappels sur les équations MHD: ondes, illustration des théorèmes d'Alfvén
- Forme conservative des équations MHD
- Principe d’énergie en MHD idéale Instabilité de torsion des lignes de champ et principe d'énergie
- Instabilité de déchirement

2. Application aux tokamaks:

- Ilots magnétiques, aspects non linéaires
- Dégradation du confinement et disruptions dans les tokamaks
- Instabilité d'interchange, application aux tokamaks

3. Application à la magnétosphère

- Instabilité de Kelvin-Helmholtz magnétique
- Reconnexion dans les plasmas astrophysiques
- Turbulence hydrodynamique et Alfvénique, application au vent solaire

4. Dynamique stellaire :

- Dynamo solaire (tachocline)
- Thermoconvection: quelques illustrations en fusion, géophysique externe, et en solaire (zone de convection)

English description:

1. IDEAL AND RESITIVE MHD INSTABILITIES

- Review on MHD equations: waves and Alfvén theorem
- Conservative form of MHD equations Energy principle in ideal MHD
- Kink instability and energy principle
- Tearing instability

2. Tokamak applications:

- Magnetic islands, non-linear features
- Confinment degradation and disruptions in tokamaks
- Interchange instability, tokamak applications

3. Magnetospheric applications:

- Magnetized Kelvin-Helmholtz instability
- Magnetic reconnection in astrophysical plasmas Hydrodynamic and alfvénic turbulence, solar wind applications

4. Star dynamics

- Solar dynamo (tachocline)
- Thermoconvection: some illustrations in fusion, geophysics and in the sun (convection zone)

Plasma Kinetics, Turbulence and Transport-S3

Plasma Kinetics, Turbulence and Transport

Contact: N. Dubuit

Programme:

I) Turbulence et transport
• Vitesses de dérive particulaires et fluides
• instabilité d'ondes de dérive avec et sans champ magnétique
• instabilité générique type « interchange »
• transport quasi-linéaire
• mécanismes de saturation non-linéaire et contrôle de la turbulence
• principe d'invariance et lois d'échelle
• modèles réduits de transport à gradient critique

II) Chauffage et génération de courant
• Le tokamak comme transformateur : du fonctionnement transitoire au régime continu.
• Les différentes sources de courant : courant de configuration et courant forcé.
• Calculs tracés de rayon + Fokker-Planck pour l'onde électronique cyclotronique (EC) et l'onde hybride (LH).
• Chauffage par onde EC.
• Résultats expérimentaux et diagnostics.

Strong Heat Flux and Irradiation Effects on Materials-S3

Strong Heat Flux and Irradiation Effects on Materials

Contact: Ph. Maugis

Programme:

I) Rappel en physico-chimie et mécanique des Matériaux :
• notions de base ; structure électronique ; thermodynamique ; métallurgie - magnétisme

II) Haut flux thermique :
• Introduction à la problématique des Matériaux pour Hautes Températures
• Superalliages (base nickel, fer ou cobalt)
• Aciers hautes températures
• Alliages de titane, de zirconium et métaux réfractaires
• Céramiques monolithiques
• Composites à matrice céramiques (CMC)
• Revêtements protecteurs haute température
• Matériaux futurs

III) Haut flux neutronique :
• Comportement de matériaux irradiés, Evolutions géométriques
• Durcissement induit par l'irradiation. Fragilisation des aciers. Phénomènes de canalisation de la déformation. Localisation de la déformation après irradiation
• Restauration des défauts d'irradiation : dommage réversible et irréversible. Cinétiques de restauration
• Comportement sous irradiation de matériaux spécifiques pour la fusion magnétique
• Aciers ferrito-martensitiques
• Couverture tritigène
• Cas des céramiques
• Alliages liquides.

Power Sources: HF, Laser-S3

Power Sources: HF, Laser

Contact: L. GALLAIS-DURING

Program:

I) High Power Microwaves: Generation and Transmission (16h)
• Microwave Tubes
• Modes and Mode Conversion in Rectangular and Circular Waveguides
• Waveguide Mode Converters
• Quasi-Optical Mode Converters

II) Laser
• Laser Fundamentals (laser Amplifiers, Resonator Optics, Laser Operation) – 6h
• TD Lasers – 2h
• Mode Locked Lasers – 2h
• Semiconductor Lasers – 2h
• High Power Lasers – 4h (Guest lecture)
• TP1 Nd :YAG Laser– 4h (Ecole Centrale Marseille)
• TP2 High Power laser processing – 4h (Institut Fresnel)

Laser Created Plasmas-S3

Laser Created Plasmas

Contact: O. Peyrusse

1) Introduction to the various kinds of lasers as tools to produce and study different kinds of plasmas

2) Basics of Laser-Matter Interaction :
• Maxwell equations, wave-equation in matter, response of the medium (dielectric function)
• Drude-Lorentz model
• Transient electronic properties
• The different interaction regimes : weakly perturbative (non-linear optics) ; perturbative (radiation damage, ablation, cold plasma production) ; strongly perturbative (hot plasma production, relativistic regime)

3) Laser-plasma hydrodynamics :
• The one-fluid two-temperature model coupled with laser energy deposition.
• Specific topics (Ionization state, Equation-of-State, electron transport)

4) Scientific and Industrial applications :
• Low flux plasma processes (laser carving, drilling, Laser-induced Forward Transfer, material structuration, laser cleaning)
• Pump-probe diagnostic processes
• High flux plasma processes : X-ray generation, Laser particle acceleration

References:

P. Gibbon, Short Pulse Laser Interactions with Matter: An Introduction (Imperial College Press 2005) ;

W.L. Kruer, The Physics of Laser Plasma Interactions (Addison-Wesley, 1988)

Particle Transport Modeling_S3

Particle Transport Modeling

Contact: Joël Rosato

Objectif : acquérir des compétences dans la modélisation et la résolution de problèmes de transport en physique
On alterne des cours magistraux et des travaux dirigés. Ces travaux dirigés permettent aux étudiants d'appliquer les connaissances qu'ils acquièrent en cours. L'enseignant peut accompagner les étudiants de manière individuelle, notamment en cas de questions sur des points techniques non détaillés pendant les séances. Les étudiants doivent travailler en présentiel mais il leur est recommandé de travailler aussi de manière autonome hors des séances en classe (à la maison ; à la bibliothèque universitaire ; etc.).

1) Rappels de formalisme
2) Modèles de relaxation vers l'équilibre
3) Etude de l'équation de Vlasov
4) Marches aléatoires
5) La méthode Monte Carlo appliquée aux problèmes de transport
6) Formalisme quantique

Goal: to acquire skills in modeling and solving transportation problems in physics
We shall alternate lectures and tutorials. These tutorials allow students to apply the knowledge they are learning in class. The teacher can accompany the students individually, especially in case of issues on technical points not detailed during the sessions. Students must work face-to-face, but it is recommended that they also work independently from classroom sessions (at home, at the university library, etc.).

1) Recalling of the Formalism
2) Relaxation models towards equilibrium
3) Study of the Vlasov equation
4) Random walks
5) The Monte Carlo method applied to transport problems
6) Quantum Formalism

References:

R. Balescu, Statistical Dynamics - Matter out of Equilibrium (Imperial College Press, 1997)
D. C. Montgomery and D. A. Tidman, Plasma Kinetic Theory (McGraw-Hill, 1964)

T.-Y. Wu, Kinetic Equations of Gases and Plasmas (Addison-Wesley, 1966)
L. D. Landau and E. M. Lifshitz, Statistical Physics (Butterworth-Heinemann, 1980)
W. Paul and J. Baschnagel, Stochastic Processes from Physics to Finance (Springer, 1999)
G. C. Pomraning, The Equations of Radiation Hydrodynamics (Pergamon, 1973)
J. Spanier and E. M. Gelbard, Monte Carlo Principles and Neutron Transport Problems (Dover, 2008)
E. M. Lifshitz and L. P. Pitaevskii, Physical Kinetics (Pergamon, 1981)
G. C. Pomraning, Linear Kinetic Theory and Particle Transport in Stochastic Mixtures (World Scientific, 1991)
S. Chandrasekhar, Radiative Transfer (Oxford, 1950)

Planetary Systems-S2

Planetary Systems

Contact: Mousis Olivier

- Solar System and exoplanets
- Planetary formation and evolution, planetary atmospheres
- Characterization techniques and limitations
- astrobiology
- project

Instrumentation for Astronomy from Ground and Space-S3

Instrumentation for Astronomy from Ground and Space

Contact: Pr. Philippe Amram

- principles of instrumentation
- observations from ground
- observations from space

- elementary systems and limitations

Structure and properties of condensed matter-S3

Structure and properties of condensed matter

Contacts: P. Mueller & O. Thomas

1. Large scale facilities to investigate the structure of matter : physical principles. Synchrotron radiation, neutron sources, transmission electron microscopy.
2. A short reminder on quantons (photons, neutrons, électrons)-matter interaction : Absorption, Scattering (inelastic and elastic).
3. Structure of condensed matter : Pair distribution function / short range order : glasses / long range order : quasi-crystals and crystals / Intermediate states : liquid crystals.
4. Long range periodic order : Bravais lattices. Diffraction by lattices. Reciprocal space. Structure factor and extinctions. Surface diffraction and diffraction from nanocrystals.
5. Point groups. Influence of symmetry on properties (Curie-Neumann principle). Tensorial properties: piezoelectricity, birefringence, elasticity etc
6. Size effects in condensed matter and properties of nano-objects: Critical lengths, surface effects, confinement effects, grain effects.