# lphys2215

*2021*

# Statistical field theory

| 5.00 credits | 30.0 h | Q2 |
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⚠ **This biannual learning unit is not being organized in 2021-2022 !**

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| Teacher(s) | Walmsley Hagendorf Christian ; |
| Language : | English |
| Place of the course | Louvain-la-Neuve |
| Prerequisites | Having followed LPHYS2131, LPHYS2113 and LPHYS2114 is an asset. |
| Main themes | This teaching unit provides an introduction to field-theoretic methods in statistical mechanics. In particular, it deals with path integrals and functional integrals, perturbative expansions and Feynman diagrams, renormalisation theory and Wilson's renormalisation group. The theoretical concepts are illustrated via their applications to statistical mechanics and condensed matter physics. |
| Learning outcomes | **At the end of this learning unit, the student is able to :**<br><br>    **a.    Contribution of the teaching unit to the learning outcomes of the programme (PHYS2M and PHYS2M1)**<br>    1.1, 1.2, 2.1, 3.1, 3.2, 3.3, 3.4, 4.1, 5.4<br>    **b.    Specific learning outcomes of the teaching unit**<br><br>1        At the end of this course, the student will be able to :<br>'    apply path-integral methods to solve problems in statistical mechanics and quantum mechanics ;<br>'    derive Feynman rules and the perturbation theory of a quantum field theory from quantisation via functional integration ;<br>'    use methods of perturbative renormalisation in order to compute critical exponents ;<br>'    apply the ideas of Wilson's renormalisation group to systems of statistical mechanics. |
| Evaluation methods | The evaluation is based on an oral exam. The students are asked to present their personal work on a physical or mathematical problem that is related to the teaching unit's topics. The evaluation tests the student's knowledge and his/her understanding of the notions seen in the theoretical course, his/her ability to apply them to new problems and his/her oral presentation skills.<br>The evaluation methods may be adapted and modified according to the evolution of the Covid-19 pandemic. |
| Teaching methods | The learning activities consist of lectures.<br>The lectures introduce fundamental concepts of the theory of nonlinear systems and their motivation through concrete examples from various scientific disciplines. |
| Content | The main goal of statistical field theory is to describe a system of statistical mechanics at the vicinity of a critical point by methods of (Euclidian) quantum field theory. The purpose of this teaching unit is to provide the student with an introduction to this field-theoretical approach and to treat the theory of renormalisation in statistical mechanics. The teaching unit's approach to these problems is based on quantisation via functional integration.<br>The teaching unit attempts to cover the following topics:<br><br>1. **Path integrals and functional integrals:** the path integral for a quantum particle in one dimension — derivation, generalisation higher dimensions, observables and correlation functions, finite-temperature systems — Euclidean theory, Euclidean quantum mechanics and statistical physics, boson and fermion systems.<br><br>2. **The quantisation of the free field via functional integration:** free fields and the scaling limit of the Gaussian model, correlation functions and propagators, Wick's theorem.<br><br>3. **Critical phenomena — a reminder:** phase transitions and universality, critical exponents, mean-field theory and Landau theory, critical dimension, critical phenomena and Euclidian field theory, magnetic systems.<br><br>1. **The phi**4 **model — perturbation theory:** functional integral for the phi4 theory, perturbation series and Feynman rules, combinatorics of Feynman diagrams, connected and irreducible graphs, correlation functions and connected diagrams, effective action. |

2. **The** phi4 **model : renormalisation:** ultraviolet divergences and their regularisation, renormalisation in d = 4 dimensions, substraction scales, scaling dimensions, beta function, renormalisation in d < 4 dimensions: '-expansion, renormalisation group flow.

3. **Wilson's renormalisation group:** basic principles, renormalisation group flow in the space of Hamiltonians, examples from statistical mechanics (Gaussian model, Ising model, decimation procedure of Migdal-Kadanoff), fixed points and critical manifolds, linearisation and critical exponents.

| Inline resources | The MoodleUCL website of this teaching unit contains a detailed plan of the covered topics and a bibliography. |
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| Bibliography | • J. Cardy, *Scaling and renormalisation in statistical physics.* Camebridge lecture notes in statistical physics (1996).<br>• F. David, *Théorie statistique des champs.* EDP Sciences (2019).<br>• G. Parisi, *Statistical field theory.* Addison-Wesley (1988).<br>• J. Zinn-Justin, *Intégrale de chemin en mécanique quantique : introduction.* EDP Sciences (2003).<br>• J. Zinn-Justin, *Quantum field theory and critical phenomena.* Oxford Science Publications (1996). |
| Faculty or entity in charge | PHYS |

| Programmes containing this learning unit (UE) | | | | |
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| Program title | Acronym | Credits | Prerequisite | Learning outcomes |
| Master [120] in Physics | PHYS2M | 5 | | 🔍 |
| Master [60] in Physics | PHYS2M1 | 5 | | 🔍 |