Basic/Essential Course Information	
Course title	Statistical Mechanics
Degree Course title	Physics
ECTS	6
Compulsory attendance	No
Course teaching language	ENGLISH

Teacher	Giuseppe Gonnella	gonnella@ba.infn.it

ECTS Details	Disciplinary area/broad field:	SSD	ECTS
	Characterizing	FIS/02	6

Time management and teaching activity type	Period	Year	lesson type
	I st semester	I	Lessons (40h) Exercises (15h)

Time management	Total hours	in-class/in-lab study hours	out-of-class study hours
	150	55	95

Course calendar	Starting date	Ending date
	Last week of September	Second week of December

Syllabus	
Prerequisites	Calculus, general and modern physics, at first level physics courses. Thermodynamics at level of undergraduate textbooks.
Expected learning outcomes (according to Dublin Descriptors)	**Knowledge and understanding** Consolidation of knowledge of statistical physics for classical and quantum systems and understanding of the microscopic origin of the laws of thermodynamics. **Applying knowledge and understanding.** Understanding of the foundations of the statistical description for many particle systems and theoretical elements useful for deriving thermodynamic equilibrium properties in classical and quantum contexts. Capability to apply the concepts learned to a wide variety of physical systems. Solve simple problems concerning thermal equilibrium statistical properties. **Making judgements.** Knowledge and skills acquired in this course will develop the ability to critically interpret and evaluate the most recent and significant scientific literature in the field of statistical mechanics, having as reference point the concepts learned during the course and also discussing possible

	alternative research strategies. **Transferable Communication skills.** Development of the ability to work in groups of 2-3 units, to whom it is proposed the solution of even complex problems of statistical mechanics. Communication skills are also developed through the presentation of seminars, proposed to students on a voluntary basis, on subjects complementary to those of the course. **Lifelong learning skills.** Follow the current progress and further prospects within the areas of statistical mechanics. Skills in the consultation of bibliographic material, databases and material on the web.
Course contents summary	Foundation and principles of statistical physics. Classical statistical mechanics. Quantum statistical mechanics. Interacting systems, Phase transition and critical phenomena.
detailed syllabus	**Foundations and principles of statistical physics.** Reversibility and irreversibility in physics. Loschmidt and Zermelo paradoxes. Macroscopic and microscopic points of view. Analogy with probability theory. Binomial distribution, large-number law and central limit theorem. Geometrical point of view. Kullback-Leibler entropy. Explanation of paradoxes. Ergodic hypothesis. Fundamental postulate of statistical mechanics. Equivalent expressions for the Boltzmann entropy. Additivity property. Intensive thermodynamic quantities. Derivation of thermodynamics. Classical ideal gas. Mixing entropy and Gibbs paradox. Microcanonical distribution. The ergodic problem. Rigorous results for ergodicity of extensive variables. **Classical statistical mechanics.** Canonical distribution. Derivation of thermodynamics and consistency with microcanonical distribution. Energy fluctuations and fluctuation-dissipation relation. Generalized Ensembles. The P-T ensemble and the hard-sphere gas in One Dimension. Gran-canonical distribution. Energy and particle number fluctuations. Gibbs variational principle. Energy equipartion and Virial theorems. Statistics of paramagnetism: Langevin and Brillouin models. Curie law. Negative temperatures. Virial for a system of classical particles. Pair distribution function. Cluster expansion for a classical fluid. Virial expansion of the state equation and first and second Virial coefficients. Problems. **Quantum statistical mechanics.** General features of quantum systems with a large number of particles.

	Density matrix and statistical operator. Pure and mixed states. Liouville-von Neumann equations and stationary solutions. Microcanonical, canonical and gran-canonical distributions. Ideal gases in gran-canonical formalism. Thermodynamics of non-interacting fermions. State equation expansion at low and high temperature. Magnetic behavior of non-interacting fermions. Pauli paramagnetism and Landau diamagnetism. Non-interacting boson thermodynamics. Bose-Einstein condensation. Thermodynamics of boson gases. Problems. **Interacting systems, Phase transition and critical phenomena.** Introduction. General observations on the problem of condensation. Van Hove, Lee e Yang results. Liquid-gas coexistence and critical point. Van der Waals equation. Critical exponents and singular behavior. Binary mixtures and lattice gas. Ising model. Simmetries, spontaneous symmetry breaking and order parameters. Peierls argument for phase transition in the Ising model in D=2. Duality and exact determination of the critical point. Mean field theory for Ising model. Variational formulation. Landau theory for phase transitions. Ginzburg criterium. Correlation functions. Scaling hypothesis for thermodynamic functions. Universal behavior at criticality. Scaling laws and Kadanoff theory.
books	L. Peliti, "Statistical Mechanics", Princeton University Press. R.K. Pathria, "Statistical Mechanics", Butterworth&Heinemann. D. Dalvit, J. Frastai, I. Lawrie, "Problems on Statistical Mechanics", Institute of Physics Publishing 1999. K. Huang, "Statistical Mechanics". M. Falcioni, A. Vulpiani, "Meccanica Statistica Elementare: I Fondamenti", Springer 2014.
notes	Available for the whole program.
Teaching methods	Lectures and exercise on the blackboard in classroom.
Assessment % of final mark	Oral exam (90%) and written proof (10%)
Evaluation criteria	Capability to discuss models, concepts and mathematical principles introduced in the course. Adequate comprehension, global and detailed knowledge of arguments and mathematical developments described throughout the course.