COURSE OF STUDY Physics

ACADEMIC YEAR *2023-2024*

ACADEMIC SUBJECT *ISTITUZIONI DI FISICA TEORICA II (Modulo B: Fisica Statistica)*

General information	
Year of the course	*3rd year*
Academic calendar (starting and ending date)	*1st semester (From 18-09-2023 to 22-12-2023)*
Credits (CFU/ETCS):	5
SSD	*Fis/02*
Language	*Italiano*
Mode of attendance	*No (attendance suggested)*

Professor/ Lecturer	
Name and Surname	*Antonio Suma*
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Telephone	
Department and address	*Dipartimento Interateneo di Fisica, room 10 at ground floor*
Virtual room	
Office Hours (and modalities: e.g., by appointment, on line, etc.)	*Timetable to be arranged at student's request. In-person or online mode*

Work schedule			
Hours			
Total	Lectures	Hands-on (laboratory, workshops, working groups, seminars, field trips)	Out-of-class study hours/ Self-study hours
150	*32*	*15*	*103*
CFU/ETCS			
5	*4*	*1*	

Learning Objectives	*Knowledge of the physical and mathematical foundations of elementary statistical physics*
Course prerequisites	*Basics of thermodynamics and elementary quantum mechanics*

Teaching strategies	*Classroom lectures/exercises*
Expected learning outcomes in terms of	
Knowledge and understanding on:	○ Knowledge of the theoretical foundations of thermodynamics ○ Knowledge of the theoretical foundations of statistical physics
Applying knowledge and understanding on:	○ development of physical-mathematical tools appropriate for the study of thermodynamic systems at equilibrium from macroscopic and microscopic perspectives
Soft skills	• *Making informed judgments and choices* ○ Develop connections and relationships between theories and physical descriptions on different scales ○ Develop critical sense in applying the most correct methodologies to solving physical problems • *Communicating knowledge and understanding* ○ Comprehensive, logical and formally correct exposition of a physical topic

	• *Capacities to continue learning* o Skill in consulting bibliographic materials, databases and materials on the Web.
Syllabus	
Content knowledge	*General principles of thermodynamics (Ch. 1-9 from Callen)* *1. Problems and postulates.* Composition of thermodynamic system. Internal energy. Thermodynamic equilibrium. Walls and constraints. Quantitative definition of heat. The basic problem of thermodynamics. Entropy postulates. *2. Equilibrium conditions*. Intensive parameters. Equation of state. Intensive entropic parameters. Temperature and thermal equilibrium. Mechanical equilibrium. Equilibrium with matter flow. Chemical equilibrium. *3. Formal relations and examples of physical systems*. Euler equation. Gibbs-Duhem relation. Monatomic ideal gas. Ideal gas mixture. Van Der Waals ideal fluid. Electromagnetic radiation. Rubber band. Heat capacity. *4. Reversible processes and maximum work theorem.* Possible and impossible processes. Quasi-static and reversible processes. Relaxation times and irreversibility. Heat flow between coupled systems. Maximum work theorem. *5. Alternative formulations of the fundamental relation.* Energy minimum principle. Legendre's transform. Thermodynamic potentials. Generalized Massieu functions. *6. Extremum principle in the Legendre transformed representations.* The energy minimum principles for potentials. Helmoltz potential. The enthalpy. Gibbs potential. *7. Maxwell's relations.* A thermodynamic mnemonic diagram. *8. Stability of thermodynamic systems.* Intrinsic stability. Stability conditions for thermodynamic potentials. Le Chatelier's principle. *9. Phase transitions*. Simple mechanical model. Phase transition of water. Latent heat. Phase transition in the van der Waals model. General properties for first-order phase transitions. *Kinetic theory of gases (Ch. 3 and Sect. 2.7 from Kardar).* Problem formulation and general definitions. Liouville's theorem. BBGKY hierarchy. Boltzmann transport equation. H theorem and irreversibility. Maxwell-Boltzmann equilibrium and distribution. Information, entropy and estimates. *Statistical Physics (Chapters 1-6 and 8-9 from Guénault)* *1. Basic ideas.* Macrostates and microstates. Construction of distributions. Example model. Statistical entropy and microstates. *2. Distinguishable particles*. Equilibrium distribution. Meaning of α and β. Statistical definition of temperature. Boltzmann distribution and partition function. Calculation of thermodynamic functions. Two-state particles solid. Localized harmonic oscillators. *3. Indistinguishable particles: gases.* Density of states. Identical particles. Counting microstates for fermions, bosons and dilute gases. Derivation of the distributions of Fermi-Dirac, Bose-Einstein and Maxwell-Boltzmann. *4. Maxwell-Boltzmann gas properties.* Partition function. Distribution of velocities. Derivation of thermodynamic functions. *5. Fermi-Dirac gas property.* Fermi energy. Thermodynamic functions. *6. Bose-Einstein gas properties.* Bose temperature. Bose-Einstein condensation.
Texts and readings	*1. H. Callen, "Thermodynamics and an Introduction to Thermostatics," John Wiley & Sons.* *2. M. Kardar, "Statistical Physics of Particles" Cambridge University Press.* *3. T. Guènault, "Statistical Physics" Springer.* *4. K. Huang, "Meccanica Statistica" Zanichelli.* *5. M. Alonso and E. Finn, "Fundamental University Physics: Quantum and*

	Statistical Physics," Addison-Wesley Publishing.
Notes, additional materials	*Only some chapters and sections.*
Repository	

Assessment	
Assessment methods	*Written exam with theoretical questions and exercises done in class.*

Assessment criteria	• *Knowledge and understanding*
	  ○ Know the theoretical foundations of elementary statistical physics
	• *Applying knowledge and understanding*
	  ○ Use the knowledge gained to solve problems in the field of statistical physics
	• *Autonomy of judgment*
	  ○ Develop physical-mathematical tools to independently model physical problems related to simple statistical systems
	• *Communicating knowledge and understanding*
	  ○ Express in a proper way physical and mathematical concepts characterizing elementary statistical physics
	• *Communication skills*
	  ○ Acquire an appropriate rigorous language to communicate science
	• *Capacities to continue learning*
	  ○ Develop mathematical and physical tools to model physical problems

Final exam and grading criteria	*The exam is considered passed when the grade is greater than or equal to 18. The award of the highest grade with honors (30 cum laude) is expected. Honors are awarded when the student has demonstrated full mastery of the subject. Accuracy in solving statistical physics problems and precision in exposing theoretical concepts are evaluated.*
Further information	
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