SYLLABUS

Level of study	Master's Course (II SUM)

Course title in Ukraine	Статистична фізика		
Course title in English	Statistical Physics		
Course code		ECTS credits	5
Lecturer(s)	Prof. dr hab. Ryszard J. Radwański sfradwan@up.krakow.pl, rjradwanski@gmail.com Dr Renata Bujakiewicz-Korońska, rbk@up.krakow.pl		

Course objectives (learning outcomes)	This course aims to get students acquainted with knowledge of laws, issues and concepts of statistical physics as consistent mathematical theory for description of great-number particle systems and of phenomological thermodynamical laws.

Knowledge	Knowledge of algebra, mathematical analysis and basic thermodynamics.
Skills	Ability to differentiate, integrate, solve ordinary and partial differential equations.
Courses completed	

Learning effects:

	Learning effects of the course	Relation of the learning effects to the specialization
Knowledge	**W01** A student knows **Classical Thermodynamics and** description of **Classical gases** **W02** A student knows **Fundamentals of Statistical Physics** **W03** A student knows **Canonical ensemble and its applications** **W04** A student knows description of **Quantum Gases** and **Specific heat of solids** **W05** A student knows description of **BlackBody Radiation** and **Phase Transitions**	K_W01 – K_W05

Skills	Learning effects of the course	Relation of the learning effects to the specialization
	U01 A student applies three thermodynamics laws in description of physical systems and is able to describe Ideal Gas, its energy and equation of state; can use the Maxwell Distribution, van der Waals interactions **UO2** A student is able to formulate concept of Microcanonical Ensemble , Canonical Ensemble, Chemical Potential, Grand Canonical Ensemble in description of real physical systems. **U03** A student is able to calculate Boltzmann distribution for Canonical Ensemble (systems with discrete energy spectrum, Schootky anomaly and over quasi atomic states in 3d/4f ions) **U04** A student is able to describe electron gas in metal, its characteristics and properties (Density of States, Fermi-Dirac Distribution and Fermi Gas); can use in practice the formalism of the Debye Model of Vibrations in a Solid, Bose-Einstein Distribution and Bose-Einstein Condensation, **U05** A student is able to describe bosons (phonons) in a real solid (Bose-Einstein Distribution) using concept of oscillators with derivation of energy spectrum of the quantum oscillator; can use in practice the formalism of the Einstein and Debye Model of Vibrations in a Solid for description of the specific heat of solids. **U06** A student can study properties of the blackbody radiation as resulting from gas of photons. **UO7** A student can describe theory of the phase transitions (phase diagram and evaporation of water; magnetic transition, ..)	K_U01 – K_U05

Social skills	Learning effects of the course	Relation of the learning effects to the specialization
	K01. A student has the creativity and the ability to conceptual thinking. **K02** A student is able to present and justify the personal point of view. **K03** A student is able to use the aquired knowledge and skills for the communication with the scientific community. **K04** A student is aimed to expand personal knowledge and skills. **K05** A student has the legal erudition.	K_K01 – K_K05

Course organization:

Form of classes	Lecture (W)	Group-exercises					
		A (large group)	K (small group)	L (Lab)	S (Seminar)	P (Project)	E (Exam)
Contact hours	30		30				1
Semester	1						
Language	English						

Teaching methods:

The course consists of open for discussion and questions lectures and classes.
In-class exercises are designed to probe knowledge with emphasis on how well students have understood the underlying topics of the course. The lecture will be completed with a large number of practical examples of use of different statistical distribution functions to real physical systems.

Assessment methods:

	E – learning	Didactic games	Classes in schools	Field classes	Laboratory tasks	Individual project	Group project	Discussion participation	Student's presentation	Written assignment (essay)		Written exam	Other
W01								x	x		x		
W02								x	x		x		
W03								x	x		x		
W04								x	x		x		
U01						x	x	x	x		x		
U02						x	x	x	x		x		
U03						x	x	x	x		x		
U04						x	x	x	x		x		
K01							x	x	x		x		
K02							x	x	x		x		
K03							x	x	x		x		
K04							x	x	x		x	x	
K05							x	x			x	x	

Assessment criteria:

Grades	The grading scale will be as follows: 90 – 100 % - **A** including **A**- **excellent** (eq. in Ukraine:відмінно (very good)) 82–89 % : **B** including **B** – **very good** (eq. in Ukraine: добре (good)) 74–81 %: **C** including **C** - **good** (eq. in Ukraine: добре (good)) 64–73 %: **D** including **D** – **satisfactory** (eq. in Ukraine: задовільно (satisfactory)) 60–63 %: **E** including **E** – **acceptable** (eq. in Ukraine: задовільно (satisfactory))

	< 59 %: **F failded** (eq. in Ukraine: незадовільно (unsatisfactory))
Criteria	**A.** A student knows all terms and concepts mentioned in W1-W5, U1- U5 and K1-K5. A student can work without any assistances, his/her knowledge's are creative and easily applied to decision of specific problem. **B**. A student knows all terms and concepts mentioned in W1-W5, U1- U5 and K1-K5, yet needs a little help when decision of specific problem. **C.** A student knows all terms and concepts mentioned in W1-W5, U1- U5 and K1-K5, however needs a help when decision of specific problem. **D.** A student knows the most of terms and concepts mentioned in W1-W5, U1- U5 and K1-K5 and has difficulty in decision of specific problem. **E.** A student knows only several terms and concepts mentioned in W1-W5, U1- U5 and K1-K5 and can solve only a simple problem. **F**. A student does not know most of terms and concepts mentioned in W1-W5, he/she did not reach the satisfactory level of knowledge this course.

Course content (topics list):

Topics	**1. Classical Thermodynamics:** Temperature and the Zeroth Law; The First Law; Heat and temperature - history; Heat balance; Calculations of different examples; 2. The Second Law - the entropy increases; Carnot Cycles; Entropy; calculations of the entropy change during the solidization and evaporation of water; Maxwell Relations; The Third Law. **3. Classical Gases:** Equation of state for the ideal gas; kinetic theory; pressure from statistical mechanics; Maxwell Distribution of velocities; 4. History of the kinetic theory; real gases and interactions; van der Waals Equation of State; Classical Partition Functions; Equipartition; **5. Fundamentals of Statistical Physics:** Subject of Stat. Phys.; Concepts of the statistical physics - Stat.Phys as consistent mathematical theory for description of great-number particle systems and of phenomological thermodynamical laws; Calculations of the particle density of different physical systems and the degeneration temperature; Appearance of quantum effects; 6. Microcanonical ensemble and calculated examples with the use of combinatorical methods; Microstates and macrostate; Entropy and the Second Law; absolute temperature; negative temperature in lasers; Mathematical methods of statistical physics - Stirling's formula, Lagrange multipliers; Characteristics of the equilibrium state; Energy Fluctuations. **7. Canonical ensemble and its applications:** Boltzmann distribution and partition function Z; Schottky anomaly; calculated examples on occupancy over discrete energy states at different temperatures; Discussion of physical systems with discrete states - open 4f (lanthanides) and 3d transition-metal many-electron ions; Maxwell Distribution - revisited (exponent). 8. Quasi-atomic states of trivalent rare-earth ions; two Hund's rules; effect of spin-orbit coupling and crystal field; calculations of temperature dependence of Z, the occupancy, energy, free energy, entropy; Two-State Spin System. **9. Quantum Gases:** Electron gas in copper metal; Calculations of its characteristics - density, wave vector, Fermi energy, Density of States. 10. Fermi-Dirac Distribution; White Dwarfs; Pauli Paramagnetism; Fermions and bosons. Bose-Einstein Distribution and Bose-Einstein Condensation. 11. Specific heat of solids; Classical and Quantum oscillator; Calculated from QM allowed energy states; phonons, Einstein and Debye Model of Vibrations in a Solid; Gas of photons; Blackbody Radiation; Planck distribution; Wien and Stefan-Boltzmann radiation law. **12. Phase Transitions:** Water and its characteristics, phase diagram, anomalous properties of water; van der Waals equation Revisited; Phase Equilibrium; Maxwell Construction;

	13. Grand Canonical Ensemble, Chemical Potential; Clausius-Clapeyron Equation; Critical Point; Ising Model; Mean Field Theory; Critical Exponents; Landau Theory for second-order phase transition (magnetic transition). **14. Summary** - Statistical physics provides very consistent theoretical explanations for observed thermodynamical properties; Spontaneous breaking of symmetry as realization of the Third thermodynamic law in Nature.

Literature:

Compulsory reading	D. Tong: Lectures on Statistical Physics (Berkeley, pdf in the Internet) K. Huang : Introduction to Statistical Physics
Recommended reading	A. I. Anselm: Podstawy fizyki statystycznej I termodynamiki, po rosyjsku: Osnowy statisticzeskiej fizike L. D. Landau, J. M. Lifshitz: Statistical Physics

Estimation of the total working time of students:

Contact hours	Lectures	30
	Classes in small group	30
	Other (consultation, meetings)	10
Students' work hours (without the lecturer)	Reading books and preparation for the lectures	10
	Preparation to the seminar	10
	Preparation of an individual presentation	10
	Preparation to the exam	25
Total works' hours		100
ECTS credits		5