Course Specification

(Postgraduate Programs)

Course Title:	**Advanced Statistical Mechanics**
Course Code:	**PHY 6251**
Program:	**Master of Science in Physics**
Department:	**Physics**
College:	**Science**
Institution:	**Imam Mohammad Ibn Saud Islamic University**
Version:	**3**
Last Revision Date:	***26/09/2024***

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A. General information about the course:

1. Course Identification:

1. Credit hours: 4				
2. Course type				
A.	☐ University	☐ College	☒ Department	☐ Track
B.	☒ Required		☐ Elective	
3. Level/year at which this course is offered: Level 3/Year 2				
4. Course General Description:				
This course will provide the fundamental concepts in statistical physics and apply this knowledge to solve problems in elementary particles, nuclear, atomic and molecular physics, as well as solids.				
5. Pre-requirements for this course (if any): None				
6. Pre-requirements for this course (if any): None				
7. Course Main Objective(s):				

At the end of this course, students will be able to:

- **Demonstrate knowledge of fundamental concepts in statistical physics and apply this knowledge to solve problems in elementary particles, nuclear, atomic and molecular physics, as well as solids;**
- **Find in statistical mechanics a wholly new and counterintuitive way of thinking about the world;**
- **Develop physical intuition, mathematical reasoning, and problem solving skills;**
- **Deal with conceptually rich and technically difficult theoretical problems;**
- **Know how to use the theory to discuss statistical phenomena quantitatively;**
- **Have learned the techniques to solve, through discussion and reading, a wide range of specific theoretical problems, including their backgrounds and implications;**
- **Have experienced the adept application of physics and mathematics to solve real life problems;**
- **Prepare for the necessarily rigorous sequence in physics.**

2. Teaching Mode: (mark all that apply)

No	Mode of Instruction	Contact Hours	Percentage
1	Traditional classroom	75	100%
2	E-learning		
3	Hybrid • Traditional classroom • E-learning		
4	Distance learning		

3. Contact Hours: (based on the academic semester)

No	Activity	Contact Hours
1.	**Lectures**	**45**
2.	**Laboratory/Studio**	**0**
3.	**Field**	**0**
4.	**Tutorial**	**30**
5.	**Others (specify)……**	**0**
	Total	**75**

B. Course Learning Outcomes (CLOs), Teaching Strategies and Assessment Methods:

Code	Course Learning Outcomes	Code of PLOs aligned with the program	Teaching Strategies	Assessment Methods
1.0	**Knowledge and understanding**			
1.1	Outline the background and main features of the historical development of statistical mechanics.	**S1, S2**	• Lectures. • Tutorials. • Class discussions.	▪ Exams. ▪ Participation. ▪ Discussions.
1.2	Outline the basic concepts and principles of statistical mechanics.	**S2, S3**	• Lectures. • Tutorials. • Class discussions.	▪ Exams. ▪ Homework. ▪ Quizzes.
1.3	Describe and discuss physical phenomena.	**S4**	• Lectures. • Class discussions. • Tutorials.	▪ Participation. ▪ Exams. ▪ Discussions. ▪ Homework.

Code	Course Learning Outcomes	Code of PLOs aligned with the program	Teaching Strategies	Assessment Methods
2.0	**Skills**			
2.1	**Explain and summarize the basic knowledge gained from studying statistical mechanics course.**	**S1, S2**	• Lectures. • Class discussions. • Tutorials.	▪ Exams. ▪ Discussions. ▪ Participation.
2.2	**Develop the students ability to solve and analyze problems in physics related the topics covered by the course.**	**S2, S3**	• Problem classes and group tutorial. • Homework assignments as well as problems solutions.	▪ Exams. ▪ Discussions. ▪ Homework.
2.3	**Communicate in a clear and concise manner orally, and using IT for acquiring and analyzing information.**	**S4**	• Lectures. • Class discussions. • Tutorials. • Encourage students to use electronic mail and internal network for submitting homework and assignments. • Use digital library.	▪ Exams. ▪ Participation and activities of students in the course community and blackboard. ▪ Homework.
3.0	**Values, autonomy, and responsibility**			
3.1	**Show the collaboration and inter-professionalism in class discussions or team works, as well as solve problems independently.**	**V1, V2, V3**	• Small team tasks • Open discussion at classroom. • Office hours.	▪ Participation ▪ Homework. ▪ Mini-project(s).

C. Course Content:

No	List of Topics	Contact Hours
1.	**The Macroscopic View:** Thermodynamics, Thermodynamics variables, Thermodynamics limit, Thermodynamics transformations, Classical ideal gas, First law of thermodynamics, Magnetic systems.	6
2.	**Heat and Entropy:** The heat equations, Applications to ideal gas, Carnot cycle, Second law of thermodynamics, Absolute temperature, Temperature as integrating factor, Entropy, Entropy of ideal gas, The limits of thermodynamics.	8
3.	**Using Thermodynamics:** The energy equation, Some measurable coefficients, Entropy and loss, The temperature-entropy diagram, Condition for equilibrium, Helmholtz free energy, Gibbs potential, Maxwell relations, Chemical potential.	8
4.	**Phase Transpiration:** First–order phase transition, Condition for phase coexistence, Clapeyron equation, van der Waals equation of state, Viral expansion, Critical point, Maxwell construction, Scaling.	8
5.	**The Statistical Approach:** The atomic view, Phase space, Distribution function, Ergodic hypothesis, Statistical ensemble, Microcanonical ensemble, The most probable distribution, Lagrange multipliers.	8
6.	**Maxwell-Boltzmann Distribution:** Determining the parameters, Pressure of an ideal gas, Equipartition of energy, Distribution of speed, Fluctuations.	5
7.	**Transport Phenomena:** Collisionless and hydrodynamics regimes, Navier-Stokes equation.	5
8.	**Quantum Statistics:** Thermal wavelength, Identical particles, Occupation numbers, Spin, Fermi statistics, Bose statistics.	5
9.	**The Fermi and the Bose Gas:** Fermi energy, Ground state, Fermi temperature, Low-temperature properties, Particles and holes, Electrons in solids, Semiconductors. Photons, Bose enhancement, Phonons, Debye specific heat, electronic specific heat, Conservation of particle number.	8
10.	**Bose-Einstein Condensation:** Macroscopic occupation, The condensate, Liquid helium.	4
11.	**Canonical and Grand Canonical Ensembles:** Microcanonical ensemble, Classical canonical ensemble, The partition function, Energy fluctuations, Quantum ensemble, Quantum partition function, The particle reservoir, Grand partition function, Photon fluctuations.	4
12.	**The Order Parameter:** Broken symmetry, Ising spin model, Ginsburg-Landau theory.	2
13.	**Superfluidity:** Condensation wave function, Mean-field theory, Gross–Pitaevsky equation, quantum phase coherence, Superfluid flow, Meissner effect.	2
14.	**Stochastic Processes:** Randomness and probability, Binomial distribution, Poisson, Distribution, Gaussian distribution, Central limit theory.	2
15.	**Time-series Analysis:** Ensemble of paths, Markov process, Fokker-Planck equation, Langevin equation.	2
	Total	**75**

D. Students Assessment Activities:

No	Assessment Activities *	Assessment timing (in week no)	Percentage of Total Assessment Score
1.	Class Activities (class quizzes, homework, solving problems, etc.....)	weekly	20 %
2.	Midterm Exam 1	6th week	20 %
3.	Midterm Exam 2	12th week	20 %
4.	Final Exam	16th week	40 %

*Assessment Activities (i.e., Written test, oral test, oral presentation, group project, essay, etc.)

E. Learning Resources and Facilities:

1. References and Learning Resources:

Essential References	*-K. Huang, Introduction to Statistical Physics, Taylor & Francis, 2001.*
Supportive References	*-F. Mandl, Statistical Physics, 2nd edition, Wiley, 2000.* *-W.G.Y. Rosser, An Introduction to Statistical Physics, Wiley, 1982.*
Electronic Materials	https://units.imamu.edu.sa/colleges/en/science/Pages/default.aspx
Other Learning Materials	Multimedia associated with the textbook and the relevant websites.

2. Educational and Research Facilities and Equipment Required:

Items	Resources
facilities (Classrooms, laboratories, exhibition rooms, simulation rooms, etc.)	- Classrooms - XRD research Lab
Technology equipment (Projector, smart board, software)	- Classroom equipped with a whiteboard and a projector.
Other equipment (Depending on the nature of the specialty)	

F. Assessment of Course Quality:

Assessment Areas/Issues	Assessor	Assessment Methods
Effectiveness of teaching	- Students. - Second examiner	Indirect (The student will complete evaluation forms at the end of semester. Final exam is evaluated by the second examiner)
Effectiveness of students' assessment	- Instructors	Direct (exams, HW, project, ...)

Assessment Areas/Issues	Assessor	Assessment Methods
Quality of learning resources	- Faculty - Students	Indirect (surveys)
The extent to which CLOs have been achieved	- Instructors - Program Leaders	Direct (excel sheet)
Other		

Assessor (Students, Faculty, Program Leaders, Peer Reviewer, Others (specify)

Assessment Methods (Direct, Indirect)

G. Specification Approval Data:

COUNCIL /COMMITTEE	Quality Unit-Physics Department
REFERENCE NO.	Department council No. 6
DATE	26/09/2024