

## Syllabus template

<b>Semester: VII</b>	
<b>Programme : PHYSICS</b>	
<b>Course : Thermal Physics III: Statistical Mechanics &amp; Quantum Mechanics III</b>	
<b>Paper code: C4PH230711T</b>	<b>Credits: 2+2</b>
<b>Hours/week : 4</b>	
<b>Category: Core/MDC/SEC/VAC : CORE(Major)</b>	
<b>Theory / Practical / Composite : THEORY</b>	
<b>No of Modules : 2</b>	
<b>Course Overview: Thermal Physics III</b>	
<p>Thermal Physics III introduces advanced topics in quantum statistical mechanics, focusing on density matrix formalism, quantum statistics of indistinguishable particles, and interacting spin systems. The course bridges microscopic quantum mechanics with macroscopic thermodynamic behavior and lays the foundation for modern condensed matter physics. Emphasis is placed on formal development, physical interpretation, and applications to real physical systems such as electron gases, white dwarfs, and magnetic materials.</p>	
<b>Course Overview: Quantum Mechanics III</b>	
<p>This course introduces approximation methods and many-particle concepts in quantum mechanics for analyzing realistic physical systems. Topics include time-independent and time-dependent perturbation theory with applications to the Zeeman and Stark effects, the variational method and the helium atom, and the quantum theory of identical particles, spin, and statistics.</p>	
<b>Course Outcome: Thermal Physics III</b>	
<ol style="list-style-type: none"> <li>1. Formulate statistical mechanics using density matrices</li> <li>2. Derive quantum statistical distributions</li> <li>3. Analyze quantum gases in various regimes</li> <li>4. Understand degeneracy pressure and astrophysical applications</li> <li>5. Solve basic interacting spin models</li> <li>6. Develop readiness for research in condensed matter and statistical physics</li> </ol>	
<b>Course Outcome: Quantum Mechanics III</b>	
<ol style="list-style-type: none"> <li>1. Apply time-independent perturbation theory to non-degenerate and degenerate quantum systems and calculate first- and second-order corrections to energy levels and eigenstates.</li> <li>2. Analyze physical effects of external perturbations such as the Zeeman effect (without electron spin) and the Stark effect in hydrogen using appropriate quantum mechanical methods.</li> <li>3. Use the variational method to estimate ground-state energies of quantum systems and apply it to multi-electron atoms such as helium.</li> </ol>	

4. Employ time dependent perturbation theory to compute transition probabilities for systems under harmonic and general time-dependent perturbations.

5. Evaluate and compare quantum states of identical particles, distinguish symmetric and antisymmetric wavefunctions and justify the connection between spin and quantum statistics with application to the helium atom.

**Prerequisites:** *Basic knowledge about any prior course*

**SYLLABUS**

UNIT/ Module	CONTENT	HOURS of NUMBER OF CLASSES	CO Mapping	COGNITIVE LEVEL
I.	<p><b>Thermal Physics III</b>  <b>A) Density matrix:</b> Idea of quantum mechanical ensemble. Statistical and quantum mechanical approaches, Properties. Quantum Liouville's theorem, density matrices for microcanonical, canonical, grand canonical            Pure and Mixed states.            Density matrix for stationary ensembles. Application to a free particle in a box, an electron in a magnetic field.            Density matrix for a beam of spin <math>\frac{1}{2}</math> particles.</p>	10L	CO1	K2, K3, K4
	<p><b>B) Systems of indistinguishable particles:</b>            BE and FD distributions, Ideal Bose and Fermi gas, statistics of occupation number, equation of state, BE condensation, Thermodynamic behaviour of an ideal Bose gas, blackbody radiation, thermodynamic behaviour of ideal Fermi gas, the electron gas in metals, statistical equilibrium of white dwarf stars.</p>	8L	CO2 CO3	K2, K3, K4, K5
	<p><b>C) Interacting systems:</b> Ising model. Idea of exchange interaction and Heisenberg Hamiltonian. Exact solution of one-dimensional Ising system. Applications</p>	6L	CO4 CO5 CO6	K1, K2, K3, K4, K5, K6

<b>II.</b>	<u><b>Quantum Mechanics III</b></u>  <b>A)</b> Time independent perturbation theory: Non-degenerate case. First order perturbation. Second order perturbation. Perturbation of an oscillator. Degenerate case. Zeeman effect without electron spin. First order Stark effect in hydrogen. Introduction to the variational method.	<b>10L</b>	<b>CO1, CO2, CO3</b>	<b>K2, K3, K4, K5</b>
	<b>B)</b> Time dependent perturbation theory: First order perturbation. Harmonic perturbation. Transition probabilities.	<b>5L</b>	<b>CO4</b>	<b>K3</b>
	<b>C)</b> Identical particles and spin: Indistinguishability of identical particles. Symmetric and antisymmetric wavefunctions. Connection between spin and statistics. Spin matrices and eigenfunctions. The helium atom.	<b>6L</b>	<b>CO5</b>	<b>K4, K5</b>

**Text Books**

**Module A**

1. F. Reif, Fundamentals of Statistical and Thermal Physics.
2. K. Huang, Introduction to Statistical Mechanics
3. R. K. Pathria, Statistical Mechanics
4. David Chandler, Introduction to Modern Statistical Mechanics

**Module B**

1. R. Shankar, Principles of Quantum Mechanics (Springer)
2. Cohen Tannoudji, Diu and Laloe, Quantum Mechanics (Wiley VCH)
3. L. I. Schiff, Quantum Mechanics (McGraw-Hill)
4. S. Gasiorowicz, Quantum Physics (John Wiley)
5. J. J. Sakurai and Jim Napolitano, Modern Quantum Mechanics (Cambridge University Press)

**Suggested readings**

1. Kadanoff, Statistical Mechanics. World Scientific.
2. R. Kubo, Statistical Mechanics. (Collection of problems)
3. Kardar, M., Statistical Physics of Particles, Cambridge University Press, 2007

<b>Web Resources (OER)</b>	
1.	<i>Tong, D., Statistical Physics.</i> <i>Department of Applied Mathematics and Theoretical Physics, University of Cambridge.</i> <i>Available at: <a href="http://www.damtp.cam.ac.uk/user/tong/statphys.html">http://www.damtp.cam.ac.uk/user/tong/statphys.html</a></i>
2.	<i>MIT OpenCourseWare</i> <i>8.044 Statistical Physics I.</i> <i>Massachusetts Institute of Technology.</i> <i>Available at: <a href="https://ocw.mit.edu/courses/8-044-statistical-physics-i-spring-2013/">https://ocw.mit.edu/courses/8-044-statistical-physics-i-spring-2013/</a></i>
3.	<i>Fitzpatrick, R.</i> <i>Statistical Mechanics.</i> <i>University of Texas at Austin (Lecture Notes).</i> <i>Available at: <a href="https://farside.ph.utexas.edu/teaching/sm1/lectures/">https://farside.ph.utexas.edu/teaching/sm1/lectures/</a></i>
4.	<i>MIT OpenCourseWare</i> <i>8.06 Quantum Physics III.</i> <i>Massachusetts Institute of Technology.</i> <i>Available at: <a href="https://ocw.mit.edu/courses/8-06-quantum-physics-iii-spring-2018/">https://ocw.mit.edu/courses/8-06-quantum-physics-iii-spring-2018/</a></i>
<b>Evaluation Theory CIA: 30 (2 x 10 + 5/assgn.+ 5/attn.) Semester Exam:70</b>	
<b>Paper Structure for Theory Semester Exam Module : For each module of 35 Marks:</b> 15 Marks from 3 marks questions (5 out of 7) 20 Marks from 10 marks questions (2 out of 3)	

**Course outcomes (COs) for Thermal Physics III and Cognitive Level Mapping**

<b>COs</b>	<b>CO Description</b>	<b>Cognitive levels</b>
<b>CO1</b>	Formulate statistical mechanics using density matrices	K2,K3,K4
<b>CO2</b>	Derive quantum statistical distributions	K2,K3,K4,K5
<b>CO3</b>	Analyze quantum gases in various regimes	K4,K5
<b>CO4</b>	Understand degeneracy pressure and astrophysical applications	K1,K2,K3,K4
<b>CO5</b>	Solve basic interacting spin models	K4,K5

<b>CO6</b>	Develop readiness for research in condensed matter and statistical physics	K1,K2,K3,K4,K5,K6

**Course outcomes (COs) for Quantum Mechanics III and Cognitive Level Mapping**

<b>COs</b>	<b>CO Description</b>	<b>Cognitive levels</b>
<b>CO1</b>	Apply time-independent perturbation theory to non-degenerate and degenerate quantum systems and calculate first- and second-order corrections to energy levels and eigenstates.	<b>K2,K3,K4,K5</b>
<b>CO2</b>	Analyze physical effects of external perturbations such as the Zeeman effect (without electron spin) and the Stark effect in hydrogen using appropriate quantum mechanical methods.	<b>K3, K4, K5</b>
<b>CO3</b>	Use the variational method to estimate ground-state energies of quantum systems and apply it to multi-electron atoms such as helium.	<b>K3</b>
<b>CO4</b>	Employ time dependent perturbation theory to compute transition probabilities for systems under harmonic and general time-dependent perturbations.	<b>K3</b>
<b>CO5</b>	Evaluate and compare quantum states of identical particles, distinguish symmetric and antisymmetric wavefunctions and justify the connection between spin and quantum statistics with application to the helium atom.	<b>K4, K5</b>