## Master of Science in Physics
## M.Sc. (Physics) Semester II

| Course Code | **PS02CPHY51** | Title of the Course | **Quantum mechanics & Atomic and Molecular Physics** |
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| Total Credits of the Course | 4 | Hours per Week | 4 |

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| Course Objectives: | 1. The basic objective of this course on quantum mechanics is to train the students to grasp the Dirac notations and basic mathematics of quantum mechanics. It aims at training student grasp concepts of angular momentum which is key to solve quantum mechanics problems.<br>2. The topics of atomic and molecular physics aims to describe the structure and dynamics of atoms and simple molecules and to make the students grasp concepts of fine structure and hyperfine structure of hydrogen atom and approximations for many body and diatomic electronic structure.<br>3. Provide basic and advance knowledge about Laser spectroscopy which includes conventional and unconventional lasers as well as the theory of fundamental Raman effect and advanced nonlinear Raman phenomenon. |

| Course Content | | |
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| Unit | Description | Weightage* (%) |
| 1 | Representation of state vectors. Dynamical variables as matrix operators. Product of operators, Self-adjointness and Hermiticity, Diagonalization, Continuous basis, The Schrödinger representation. Degeneracy-Labeling by commuting observables. Change of basis, Unitary transformations. Unitary transformations induced by change of coordinates translations, Unitary transformation induced by rotation of coordinate system. The algebra of rotation generators and the transformations of dynamical variables, concept of parity. | 25% |
| 2 | *Angular momentum:* Quantum theory of angular momentum and its eigenvalue spectrum. Matrix representation of angular momentum operators, spin angular momentum, Pauli matrices and their properties, total wave function, non-relativistic Hamiltonian including spin. Addition of angular momenta, definition of Clebsch-Gordan coefficients, Phase convention, spin-wave function for a system of two spin-1/2 particles, Identical particles with spin, addition of spin and | 25% |

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| | orbital angular momenta. | |
| 3 | Atoms and Molecules Schrödinger equation for one-electron atoms – H-atom, the dipole selection rules. Fine structure of hydrogenic atoms, The Lamb shift and its determination, Hyperfine structure and isotopic shifts. Schrödinger equation for Two-electron atoms, the role of Pauli exclusion principle, Energy levels of Helium atom, Doubly excited states, Auto-ionization in Helium. Thomas-Fermi model for many-electron atoms. The Born-Oppenheimer approximation for molecule, electronic structure of diatomic molecules, LCAO approximation for $H_2^+$ ion. | 25% |
| 4. | Laser Spectroscopy Emission and absorption spectroscopy: UV-visible-IR absorption (introduction),Classical view of Einstein coefficients; two-level system, Three-level Laser system, Variation of Laser power around threshold.$NH_3$ maser, He-Ne Laser (energy level diagram), $CO_2$ Laser, Semiconductor Lasers, Rayleigh and Raman scattering, Stimulated Raman effect, Hyper-Raman effect: Classical treatment, Quantum mechanical treatment, Coherent anti-stokes Raman scattering (CARS), Spin-flip Raman Laser, Free-electron Laser. | 25% |

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| Teaching-Learning Methodology | Lectures using traditional blackboard teaching, Tutorials, class assignments as well as the ICT tools for effective delivery of the content. |

| Evaluation Pattern | | |
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| Sr. No. | Details of the Evaluation | Weightage |
| 1. | Internal Written / Practical Examination (As per CBCS R.6.8.3) | 15% |
| 2. | Internal Continuous Assessment in the form of Practical, Viva-voce, Quizzes, Seminars, Assignments, Attendance (As per CBCS R.6.8.3) | 15% |
| 3. | University Examination | 70% |

| Course Outcomes: Having completed this course, the learner will be able to | |
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| 1. | Students will be proficient in the basic mathematics involved in solving quantum mechanics problems like coordinate and unitary transformations etc. |

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| 2. | Student will be able to apply basic knowledge of angular momenta and spin to understand atomic systems. |
| 3. | Student shall have advanced knowledge of modern atomic and molecular physics in order to understand both experimental and theoretical working methods in atomic and molecular physics. |
| 4. | Students will be able to carry out experimental and theoretical studies on atoms and molecules, with emphasis on the structure and dynamics of atoms and molecules. |

Suggested References:

| Sr. No. | References |
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| 1 | A text book of Quantum Mechanics<br>P. M. Mathews and K. Venkatesan, TMH (2010) |
| 2 | Quantum Mechanics<br>Ghatak & Loknathan; McMillan India Publication (2004) |
| 3 | Quantum Mechanics<br>G. Aruldhas, Prentice-Hall India, Pvt., Ltd.(2016) |
| 4 | Physics of Atoms and Molecules<br>B. Bransden and C. J. Joachain, Pearson Education Publication, New Delhi (1990). |
| 5 | Fundamentals of molecular spectroscopy<br>C. N. Banvel, McGraw-Hill Inc.,US (1983) |
| 6 | LASERS Theory and Applications<br>K. Thyagarajan and A. K. Ghatak , Macmillan India Ltd., (2008). |
| 7 | Lasers and Non-linear Optics ($2^{nd}$ Ed.)<br>B. B. Laud, New Age International, (1996). |

On-line resources :

https://webhome.phy.duke.edu/

www.phy.duke.edu

http://www.saha.ac.in/web/e-library/library-open-e-resources

*link.springer.com*

www.physics.ucc.ie

www.freebookcentre.net

*aapt.scitation.org*