S. No	New Course code	Name of Course	L-T-P-C	Proposed Level (UG/PG)
1	PH 601	Theory of Laboratory Techniques	2-1-0-6	
2	PH 602	Research Project in Physics	2-1-0-6	
3	PH 603	Advanced Mathematical Physics	3-0-0-6	
4	PH 604	Research Seminar	0-0-4-4	
5	PH 605	Silicon Photovoltaics	3-0-0-6	
6	PH 701	Photonics: Fundamentals and Technology	2-1-0-6	
7	PH 703	Advanced Atomic and Molecular Physics	2-1-0-6	
8	PH 704	Molecular Spectroscopy	2-1-0-6	
9	PH 705	Remote Sensing	2-1-0-6	
10	PH 708	Superconductivity and Magnetism	2-1-0-6	
11	PH 709	Quantum Computation	2-1-0-6	
12	PH 802	Quantum Information Theory	2-1-0-6	
13	PH 803	Quantum Optics	4-0-0-8	
14	PH 804	Tunable Coherent Optical Devices	2-1-0-6	
15	PH 805	Molecular Dynamics Imaging: Methodologies and Applications	3-0-0-6	
16	PH 807	Third Generation Photovoltaics: Materials, Integration and Devices	3-0-0-6	

1	**Title of the course** (L-T-P-C)	**Theory of Laboratory** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	NIL
3	**Course content**	Vacuum Techniques: Production and measurement of vacuum, different types of vacuum systems and gauges, their working and limitations, techniques for production of ultra- high vacuum, applications of kinetic theory: theoretical background. Crystallography: Basic principles of powder X ray diffraction technique, single crystal X ray diffraction method and backscattered X ray Laue diffraction technique to investigate the single crystals. • Electronics: Measurement techniques in electronics, use of different measuring devices, their scopes, and limitations. Design, fabrication and testing of some circuits, Lock-in amplifier. Detectors: Study of different types of detectors. Photographic detectors, optical detectors, X ray detector.
4	**Texts/References**	**1.** Introduction to Solid State Physics - C Kittel, 7th ed., John Wiley (2005). Electronic Principles, A. Melvino and D. Bates, McGraw Hill Education 7th Edition (2017).

1	**Title of the course** (L-T-P-C)	**Research Project in Physics** **(4-0-0-8)**
2	**Pre-requisite courses(s)**	None
3	**Course content**	The student can do a project with any faculty in the Department of Physics. The topic of the project could be chosen through discussion between the student and the faculty.
4	**Texts/References**	None

1	**Title of the course** (L-T-P-C)	**Advanced Mathematical Physics** **(3-0-0-6)**
2	**Pre-requisite courses(s)**	None
3	**Course content**	Vector & Tensor Analysis; Matrix Analysis. **Complex Variables** – Complex integrals & applications: Geometrical representations of $w = f(z)$: Conformal Transformations; Schwarz– Christoffel Transformation; Solutions to Dirichlet and Newmann problems; Applications to fluid flow, electrostatics, and heat flow. **Differential equations** – Ordinary differential equations and Partial differential equations, including Sturm-Liouville Theory, Separation of Variables, Laplace and Poisson Equations, Wave Equation, Heat-flow, Green's functions. **Group Theory** –Subgroups and Classes, Group representations, Characters, Physical applications, Infinite groups, Irreducible representations of SU (2), SU (3) and O (3). **Special Functions** – Neumann and Hankel functions, Bessel, Hermite, Laguerre, Legendre, Hypergeometric and Confluent hypergeometric functions, Chebyshev polynomials. **Integral transforms -** Fourier transforms and Laplace transforms. **Integral Equations** – Neumann Series; Hilbert-Schmidt Theory; Probability and Statistics.
4	**Texts/References**	**1**. George B. Arfken and Hans J. Weber, Mathematical methods for physicists, Academic Press Inc., 6th Edition, 2005. **2**. I.A. Gradshteyn, I.M. Ryzhik, Sixth Edition, Academic Press, 2000. **3**. M. Abramowitz and I. A. Stegan, Handbook of Mathematical Functions, Dover Publications, INC., New York, 1965. **4.** E. Kreyszig, Advanced Engineering Mathematics, Wiley India, 8th Edition, 2008.

1	**Title of the course** (L-T-P-C)	**Research Seminar** **(2-0-0-4)**
2	**Pre-requisite courses(s)**	--
3	**Course content**	NA
4	**Texts/References**	NA

1	**Title of the course** (L-T-P-C)	**Silicon Photovoltaics** **3-0-0-6**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Status, Trends, and Challenges: Photovoltaics effect, Myths and history of Photovoltaics, PV Costs, Markets and forecasts, PV research and manufacturing, Global trends in performance and applications, Silicon progress and challenges, thin film progress and challenges, Future of emerging PV technologies Introduction to semiconductor physics: Band structure, Optical absorption, and doping; Semiconductor types: crystalline, multicrystalline, amorphous, thin-film; Transport phenomena: the p-n junction, Charge carrier dynamics in semiconductors; Current-voltage characteristics of solar cells, Loses- optical and recombination, Asymmetrical devices: Metal-semiconductor contacts and semiconductor surface. Solar cell operation: Solar spectrum; solar cell fundamentals; Theoretical limits of photovoltaic conversion, Thermodynamics, and photovoltaic conversion; Effect of temperature and parasitic resistance. Solar modules: Module and circuit design, Identical and non-identical cells, Thermal consideration, Hot-spot heating, Environmental protections. Crystalline semiconductor solar cells: Description of the crystalline silicon photovoltaic technology from bulk crystal growth. Extension to III-V compounds solar cells. New Directions in Si PV Technology: Heterojunction technology; Passivated Emitter and Rear Cell (PERC); Tunnel Oxide Passivated Contact (TOPCon)
4	**Texts/References**	**1.** Honsberg, C., and S. Bowden. Photovoltaics: Devices, Systems and Applications CD-ROM. (A free online resource), 1999. **2.** Wenham, S., M. Green, et al., eds. Applied Photovoltaics. 2nd ed. Routledge, 2006. ISBN: 9781844074013. **3.** Solanki, C. S., Solar Photovoltaics- Fundamentals, Technologies and Applications, PHI Learning, 2009. ISBN:9788120351110 **4.** Shah, A., Solar Cells and Modules, Springer, 2020. ISBN:9783030464875 **5.** Satpathy, R. K., Pamuru, V., Solar PV Power, Design, Manufacturing and Applications from Sand to Systems, Elsevier, 2020. ISBN:9780128176276

1	**Title of the course** (L-T-P-C)	**Photonics: Fundamentals and Technology** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	Electrodynamics, Fundamentals of Optics
3	**Course content**	Laser Technology: Optical radiation processes, conditions for the amplification of radiation, three level and four level lasers, resonators and cavity designs, practical laser systems till date, with their applications. Nonlinear Optics and Devices: Origin of nonlinearity, nonlinear optical interactions, intensity dependent refractive index, linear and nonlinear absorptions, nonlinear optical materials, sources based on nonlinear optical interactions and their applications. Attoscience, Ultrafast Optics and Spectroscopy: High-harmonic generation, Attosecond pulse generation and technology, detectors and diagnostics, Spectroscopy techniques and applications. Fiber Optics: Ray model, Wave model, fiber parameters, Signal Distortion, Dispersion, nonlinear effects in fiber, Integrated Optics & Devices, fiber-based systems. Photonic crystal fibers.
4	**Texts/References**	**1.** Saleh and Teich, "Fundamentals of Photonics," 2nd edition, Wiley-Interscience, 2012. **2.** F. Graham Smith, "Optics and Photonics: An Introduction," 2nd edition, John Wiley & sons, 2007. **3.** Orazio Svelto, "Principles of lasers", 5th edition, Springer Science & Business Media, 2010. **4.** Robert W. Boyd, "Nonlinear Optics," 3rd edition, Academic Press, 2008. **5.** John A Buck, "Fundamentals of Optical Fibers," 2nd edition, Wiley-Interscience, 2004.

1	**Title of the course** (L-T-P-C)	**Advanced Atomic and Molecular Physics** **(4-0-0-8)**
2	**Pre-requisite courses(s)**	Introductory Quantum Mechanics.
3	**Course content**	Recapitulation of quantum mechanics. One-electron atoms: Schrodinger equation, energy levels, interaction with electromagnetic fields, transition rates, density of states, dipoleapproximation, Zeeman, and Stark effects. Multi-electron atoms: Helium atom, central field approximation, Thomas-Fermi model of the atom, Hartree-Fock method, L-S and J-J coupling, interaction with external fields. Molecular structure: Born-Oppenheimer approximation, electronic structure of molecules, Hydrogen molecule ion, Approximate molecularorbital (MO) theory, homo and hetero-nuclear diatomic molecules, electronic term symbols, valence bond (VB) theory of diatomic molecules,comparison of VB and MO theories. Molecular spectra: Rotational, Vibrational and Electronic spectra. Introduction to molecular dissociation.
4	**Texts/References**	**1.** Physics of Atoms and Molecules, B. H. Bransden and C. J. Joachain,Pearson Education, Ltd. (2003). **2.** Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles, R. Eisberg and R. Resnick, John Wiley & Sons, Inc. (1985). **3.** Atoms, Molecules and Photons, W. Demtroder, Springer-Verlag Berlin(2010). **4.** Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash, McGraw Hill Education (2013). **5.** Molecular Quantum Mechanics, P. Atkins and R. Friedman, Oxford University press (2011). **6.** Quantum Chemistry, I. N. Levine, Pearson (2016).

1	**Title of the course** (L-T-P-C)	**Remote Sensing** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	None
3	**Course content**	Introduction, Electromagnetic radiation, Interaction of electromagnetic radiation with atmosphere, Effects of Atmosphere- Scattering, Absorption, Atmospheric window, Energy interaction with surface features, Spectral reflectance of earth objects and land covers, Resolution concepts, Satellites, orbits, and missions. Remote sensing system: Physical basis of signatures: Reflective optical region (multispectral and hyperspectral), thermal IR region and microwave region. Sensors: Historical development, Resolutions, Opto-mechanical electro-optical sensors, across track and along track scanners, multi spectral scanners, characteristics of different types of platforms, medium and high-resolution missions, Data products and characteristics. Data analysis: Sources of errors, scene, sensor and atmospheric causes, Corrections: geometric and radiometric, visual, and digital interpretation, elements of interpretation, interpretation keys, digital analysis and classification, Image formation, visualization: image enhancement, filters, Image classification: unsupervised and supervised, thematic mapping, accuracy assessment. Applications of Remote Sensing.
4	**Texts/References**	**1.** Introduction to Remote Sensing, J. B Campbell, Taylor & Francis. **2.** Physical Principles of Remote Sensing, W.G. Rees, Cambridge University Press. **3.** Fundamentals of Remote Sensing, George Joseph & C Jeganathan, Universitiy Press, India **4.** Introductory digital image processing: a remote sensing perspective, John R. Jensen, Prentice Hall. **5.** Remote sensing and image interpretation, T. M. Lillesand, R. W. Kiefer, and J. W. Chipman, Wiley.

1	**Title of the course** (L-T-P-C)	**Superconductivity and Magnetism** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	None
3	**Course content**	**Superconductivity:** Overview, types of superconductors, electrodynamics and thermodynamics of superconductors, elements of Ginzburg-Landau theory and BCS theory; Fluxoid quantization; Josephson tunnelling; applications of superconductivity; SQUID, recent discoveries on superconductors. **Magnetism:** Classification of magnetic materials, localized and itinerant magnetism, various types of exchange interactions- direct, super, RKKY and DM, magneto-crystalline anisotropy energy, shape anisotropy, domains, domain walls and magnetization process, magnetism in thin films and fine particles; basics of spin dependent scattering/spin- polarized transport; magneto-transport effects, basics of magnetic recording, Hall effect, spintronics and spintronic devices.
4	**Texts/References**	Superconductivity, Superfluids and Condensates- J F Annet, Oxford Master Series (2004), Superconductivity- C Poole, H Farach and R Creswick, R Prozorov, Elsevier (2014), Introduction to Superconductivity, M. Tinkham Ed. McGraw-Hill Inc. (1996). Magnetism in Condensed Matter - Stephen Blundell, Oxford Master Series (2001), Magnetism and Magnetic Materials – J. M. D. Coey, Cambridge University Press (2012) Physics of Ferromagnetism - S. Chikazumi, Oxford University Press (1997), Introduction to Spintronics - S. Bandyopadhya and M. Cahay, CRC press (2020), Introduction to Solid State Physics - C Kittel, 7 th ed, John Wiley (2005)

1	**Title of the course** (L-T-P-C)	**Quantum Computation** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	Exposure to PH101 – Quantum Mechanics and Applications MA102 - Linear Algebra
3	**Course content**	Introduction to Classical Computation: The Turing Machine –The Church-Turing thesis, Universal Turing Machine, Probabilistic Turing machine; Circuit model of computation – Binary arithmetics, Elementary logic gates, Universal classical computation; Computational complexity – Complexity classes, Chernoff bound; Energy and information – Maxwell's demon, Landauer's principle, Extracting work from information; Reversible computation – Toffoli and Fredkin gates, billiard ball computer. Framework of Quantum Mechanics: The Dirac notation and Hilbert Space, Dual Vectors, Operators, Spectral Theorem, Functions of operators, Tensor Products, Schmidt Decomposition theorem; The state of quantum system, time-evolution of a closed system; composite systems, measurement, mixed states, and general quantum operations. Quantum Computation: The quantum circuit model, Quantum Gates – 1-qubit gates, Controlled-U gates; Universal Sets of Quantum Gates, Implementing measurements with quantum circuits. Quantum communications: Super dense coding, Quantum Teleportation. Quantum Algorithms: Probabilistic versus quantum algorithms, Phase Kick-Back, Deutsch algorithm, Deutsch-Jozsa Algorithm, Simon's Algorithm, Grover's quantum search Algorithm. Quantum computational Complexity Theory and lower bounds: computational complexity, Black-Box Model, General Black-box lower Bounds, Polynomial Methods, Block Sensitivity. Quantum Error Corrections: Classical error corrections – The error model, encoding, error recovery, Fault tolerance, Quantum error correction, Three- and nine-qubit quantum codes, Fault tolerant quantum computation. Quantum Computation with physics systems
4	**Texts/References**	**1**. Quantum Computation and Quantum Information, M. A. Nielsen & I. L. Chuang, 10th Edition, Cambridge University Press, NY, USA (2011). **2**. An introduction to Quantum Computing, P. Kaye, R. Laflamme and M. Mosca, Oxford University Press, (2010). **3**. Preskill's lecture notes on Quantum Information and Quantum Computation, http://www.theory.caltech.edu/people/preskill/ph229/ **4**. Principles of Quantum Computation and Information (Vol.-1), G. Benenti, G. Casati, and G. Strini, World Scientific, 2004. **5**. Classical and Quantum Computation, A. Yu. Kitaev, A. H. Shen, and M. N. Vyalyi, Americal Mathematical Society, 2002 **6**. Quantum Coputation and Quantum Communication-Theory and Experiments, M. Pavicic, Springer, 2006. **7**. Quantum Computer Science, N. D. Mermin, Cambridge, 2007. **8**. Lectures on Quantum Information, Edited by D. Bruss and G. Leuchs, Wiley-VCH Verlag, 2007

1	**Title of the course** (L-T-P-C)	**Quantum Information Theory** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	Introduction to Quantum Information and Computation
3	**Course content**	Advanced entanglement theory (GM, GGM, newly proposed measures etc). Quantum Correlation Beyond Entanglement (Quantum Discord, Geometric discord, Work-Deficit etc). Resource theory in QI (Entanglement, Quantum Coherence, Reference Frame, Asymmetry etc). Continuous variable quantum information. General evolution and Decoherence theory. Open quantum systems; Master equations, Markovian and Non-Markovian, Various measure of non markovianity. Quantum Thermodynamics. Advanced topics in quantum channels. Quantum information and condensed matter systems. Beyond quantum mechanics No signaling theories.
4	**Texts/References**	**1.** Quantum Theory: Concepts and Methods, A. Peres, Springer, 1995 **2.** Quantum Computation and Quantum Information, M. A. Nielsen & I. L. Chuang, 10th Edition, Cambridge University Press, NY, USA (2011). **3.** Quantum Information Theory, M. M. Wilde, Cambridge University Press, 2nd edition, 2017. **4.** Lectures on Quantum Information, Edited by D. Bruss and G. Leuchs, Wiley-VCH Verlag, 2007.

1	**Title of the course** (L-T-P-C)	**Quantum Optics** **(4-0-0-8)**
2	**Pre-requisite courses(s)**	Linear Algebra (finite-dimensional vector spaces, matrices, eigenvectors and eigenvalues, linear maps, etc.), Introductory & Advanced Quantum Mechanics.
3	**Course content**	**Elementary Quantum Systems & Operator Algebra:** The Oscillator in the Heisenberg Picture and its Energy-Eigenvalue problem; Physical interpretation of number, creation, and annihilation operations – Bosons and Fermions; Transformation function from N to q representation for Oscillator; The Coherent States; Spin Operators. Some General Operator Theorems; Ordered Boson Operators and its algebraic properties; Characteristic functions – Wigner Distribution function; Wick's Theorem for Boson operators. Definition of Entropy. **Quantization of Electromagnetic Field:** Potential theory for the classical EM field; Canonical communication relation; Pure states and statistical mixtures; Time development of quantum optical systems; Interaction of quantized field with atom; Quantum degrees of first and second- order coherence. **Single/Multimode/Continuous mode quantum optics:** Single- mode field operators; Number states; Coherent States; Chaotic light; The squeezed vacuum; Squeezed coherent states; Beam splitter input-output relations; Multimode states; Continuous-mode field operators; photon bunching and antibunching; Photon pair states; Homodyne detection. **Interaction between light and a two-level atom**: The Jaynes-Cummings model interaction and the corresponding Hamiltonian - its solution and the expression for the population inversion; the experimental developments; the classical and quantum signatures-collapses and revivals.
4	**Texts/References**	**1.** Quantum Statistical Properties of Radiation, William H. Louisell, Wiley Classics Library Edition (1990). **2.** The Quantum Theory of Light, Rodney Loudon, Oxford University Press, New York (2000). **3.** Quantum Optics, O Scully, and S Zubairy, Cambridge University Press (1997). **4.** Quantum Optics, DF Walls and Grad J Milburn, Springer (2010). **5.** Quantum Optics: An Introduction, M. Fox, Oxford University Press (2007). **6.** Fundamentals of Quantum Optics, John R Klauder and E C G Sudarshan, Dover Publications Inc. (2006). **7.** Introductory Quantum Optics, C. Gerry and P. Knight, Cambridge University Press (2004). **8.** Optical Coherence and Quantum Optics, Leonard Mandel, Cambridge University Press (1995). **9.** Quantum Optics, Girish S. Agarwal, Cambridge University Press (2012).

1	**Title of the course** (L-T-P-C)	**Tunable Coherent Optical Devices** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	Electrodynamics, Fundamentals of Optics
3	**Course content**	Tunable laser: Materials, Active medium (Solid- state, Fiber, semiconductor), Pump source, Spectral range, Timescale, Development of systems. Quantum Cascade laser: Development and characteristics. Micro structured semiconductors and periodically poled crystals: Fabrication and properties. Tunable systems based on nonlinear optical materials: Wide spectral coverage (Ultraviolet to Terahertz), all time scale. Applications: Trace gas sensing, exhaled breath monitoring, laser-tissue interaction.
4	**Texts/References**	**1.** Michael Bass, Handbook of Optics: Volume IV - Optical Properties of Materials, Nonlinear Optics, Quantum Optics, Third Edition (OSA, vol IV, 2010). **2.** Majid Ebrahim-Zadeh and Irina T. Sorokina, eds., Mid-Infrared Coherent Sources and Applications (Springer, 2008). **3.** Richard L. Sutherland, "Handbook of Nonlinear Optics," CRC Press, 2003 **4.** Robert W. Boyd, "Nonlinear Optics," 3rd edition, Academic Press, 2008. **5.** Orazio Svelto, "Principles of lasers", 5th edition, Springer Science & Business Media, 2010.

1	**Title of the course** (L-T-P-C)	**Molecular Dynamics Imaging: Methodologies and Applications** **3-0-0-6**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Charged particle imaging: History, fragment ion imaging, electron imaging, angular information of products, coincidence measurements. Recoil-Ion Momentum Spectroscopy: Imaging Spectrometers for Ions, Target Preparation, Target Preparation, Imaging Spectrometers for Electrons, New developments. Velocity Map Imaging: Newton spheres - concept, creation and analysis, experimental requirements, characterization of the surface patterns of Newton spheres. Velocity map imaging of photo-dissociation. Reconstruction methods: Symmetric distributions, Abel and Hankel inversion methods, Back-projection method, Iterative inversion, Basis set expansion method, Forward convolution. Time resolved imaging: 3-D imaging scheme, experimental schemes, Detector time calibration, multi-particle detection. Applications: Kinematically complete imaging of molecular many-body fragmentation: coincident multi-particle detection and analysis, Photoelectron and photo-ion imaging with femtosecond pump-probe time clocking, Multiple Ionization, and fragmentation in strong Laser fields.
4	**Texts/References**	**1.** Imaging in Molecular Dynamics: Technology and Applications, Benjamin J. Whitaker, Cambridge University Press, 2003. **2.** Many-Particle Quantum Dynamics in Atomic and Molecular Fragmentation, J. Ullrich, and V. P. Shevelko, Springer, 2003. **3.** Quantum Control of Molecular Processes, M. Shapiro, and P. Brumer, Wiley, 2012. **4.** Ultrafast Phenomena in Molecular Sciences, R. de Nalda, and L. Bañares, 2014.

1	**Title of the course** (L-T-P-C)	**Third Generation Photovoltaics: Materials, Integration and Devices** **3-0-0-6**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Device Physics of Solar Cells: Principle of solar energy conversion, Shockley-Quisser limit- Single, Tandem, and multi-junction solar cells, Solar cell modeling-optical and electrical. Dye Sensitized Solar Cells: Introduction, Fabrication of Dye Sensitized Solar Cells' Design of novel dye, Design of solid electrolytes materials, Counter electrode engineering. Organic Solar Cells: Introduction, Physics of Bulk Hetero junction (BHJ) Solar Cells, Morphology, and charge separation in BHJ, Design of low band gap polymers, Novel architecture and limitations in BHJ. Perovskite Solar Cells: Fabrication of perovskite solar cells, Photophysics in perovskite solar cells, Stability in perovskite solar cells, Lead free perovskite solar cells. Photovoltaic system engineering, Thermo- Photovoltaic generation of electricity, Concentration and storage of electrical energy, Photovoltaics modules, system, and application, Building integrated photovoltaic systems.
4	**Texts/References**	**1.** Zdyb, A. Third Generation Solar Cells, Routledge, 2023. ISBN 9781032052557 **2.** Green, M. Third Generation Photovoltaics- Advanced Solar Energy Conversion. Springer, 2006. ISBN: 9783540265634. **3.** Ponseca, C. S., Emerging Photovoltaic Technologies- Photophysics and Devices, Jenny Stanford Publishing, 2019. ISBN:9781000021769 **4.** Jean, J., Brown, P. R., Emerging Photovoltaic Technologies, IOP Publishing, 2019. ISBN:9780750321525 **5.** Elseman, A. M., Solar Cells- Theory, Materials and Recent Advances, IntechOpen, 2021. ISBN:9781838810160