M.Sc. program in Physics

Semester-I

Sl. No	Course Name	Course codes	L-T-P-C	Credits
1	**Electrodynamics**	PH 314	2-1-0-6	6
2	**Classical Mechanics**	PH 323	2-1-0-6	6
3	**Quantum Mechanics - I**	PH 301	2-1-0-6	6
4	**Electronics**	PH 435	3-0-0-6	6
5	Computer Programming	CS 101	3-0-2-8	8
6	**Electronics Laboratory**	PH 436	0-0-3-3	3
	Total			**35**

Semester-II

Sl. No	Course Name	Course codes	L-T-P-C	Credits
1	**Statistical Physics**	PH 304	2-1-0-6	6
2	**Laser Physics and Technology**	PH 434	2-1-0-6	6
3	**Quantum Mechanics-II**	PH 405	2-1-0-6	6
4	**Mathematical Physics-1**	PH 322	2-1-0-6	6
5	**Advanced Atomic and Molecular Physics**	PH 425	2-1-0-6	6
6	**General Physics Lab**	PH 312	0-0-3-3	3
7	**Experimental Techniques**	PH 430	2-1-0-6	6
	Total			**39**

Semester-III

Sl. No	Course Name	Course codes	L-T-P-C	Credits
1	**Nuclear and Particle Physics**	PH 428	2-1-0-6	6
2	**Numerical Methods**	PH 502	2-0-2-6	6
3	**Mathematics Physics-II**	PH 501	2-1-0-6	6
4	**Institute Elective - I**	NA	2-1-0-6	6
5	**Physics Project - I**	PH 503	0-0-6-6	6
6	**Advanced Physics Lab**	PH411	0-0-3-3	3
	Total			**33**

Semester-IV

Sl. No	Course Name	Course codes	L-T-P-C	Credits
1	Institute Elective – II	NA	2-1-0-6	6
2	Physics Project - II	PH 504	0-0-18-18	18
				24

L: Lecture; T:Tutorial; P:Practical; C:Credits

Electives (Offered by the Department of Physics)

1. PH402: Astrophysics (2-1-0-6)
2. PH426: Special Theory of Relativity (2-1-0-6)
3. PH424: Photonics (2-1-0-6)
4. PH401: Laser Physics and Technology (2-1-0-3)
5. PH407: Nonlinear Optics (2-1-0-3)
6. PH422: Physics of Photovoltaics (2-1-0-3)
7. PH431: The Film Science and Technology (2-1-0-6)
8. PH 404: Introduction to Quantum Information & Quantum Computation (2-1-0-6)
9. PH701: Photonics: Fundamentals and Technology (2-1-0-6)
10. PH804: Tunable Coherent Optical Devices (2-1-0-6)
11. PH601: Theory of Laboratory techniques (2-1-0-6)
12. PH 605: Silicon Photovoltaics (3-0-0-6)
13. PH703: Advanced Atomic and Molecular Physics (2-1-0-6)
14. PH704: Spectroscopy (2-1-0-6)
15. PH705: Remote Sensing (2-1-0-6)
16. PH708: Superconductivity and Magnetism (2-1-0-6)
17. PH606: Advanced Mathematical Physics (2-1-0-6)
18. PH802: Quantum Information Theory (2-1-0-6)
19. PH803: Quantum Optics (2-1-0-6)
20. PH709: Quantum Computation (2-1-0-6)

The students can also choose Electives offered by other Science and Engineering departments.

Note:

1. The courses with text in green color are laboratory courses.
2. The course with text in red color is offered by the department of CSE, IIT Dharwad.

Program Credit Structure

Core Theory: 86

Core Labs: 9

Elective: 12

Projects: 24

Total: 131

1	**Title of the course** (L-T-P-C)	**Electrodynamics** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	Successful completion of PH102
3	**Course content**	Review of electrostatics and magnetostatics. Electrodynamics: Differential and integral forms of Maxwell's equations, Scalar and vector potentials, gauge transformations, Coulomb and Lorentz Gauge; Maxwell's equations in terms of potentials. Energy and momentum in electrodynamics. Electromagnetic waves: Electromagnetic waves in non-conducting media: Monochromatic plane waves in vacuum, propagation through linear media; Boundary conditions; Reflection and transmission at interfaces. Fresnel's laws; Electromagnetic waves in conductors: Modified wave equation, monochromatic plane waves in conducting media, Dispersion: Dispersion in non-conductors, free electrons in conductors and plasmas. Guided waves. Retarded potentials, Electric dipole radiation, magnetic dipole radiation. Radiation from a point charge: Lienard-Wiechart potentials, fields of a point charge in motion, power radiated by a point charge. Electrodynamics and Relativity: Review of special theory of relativity, Lorentz transformations, Minkowski four vectors, energy-momentum four vector, covariant formulation of mechanics; Transformation of electric and magnetic fields under Lorentz transformations, field tensor, invariants of electromagnetic field, Covariant formulation of electrodynamics, Lorentz force on a relativistic charged particle. Waveguides, Resonant Cavities and Optical Fibers, Basics of Antennas.
4	**Texts/References**	(1) D. J. Griffith: Introduction to Electrodynamics, 4th edition, Pearson, 2015. (2) J.D. Jackson: Classical Electrodynamics, Wiley student edition, 3rd edition, 2007. (3) Modern Electrodynamics, Andrew Zangwill, Cambridge University Press, 2012. (4) Foundations of Electromagnetic Theory, J. R. Reitz, F. J. Milford, and R. W. Christy, Addison-Wesley, 4th edition, 2008. (5) W K H Panofsky and M Philips: Classical Electricity and Magnetism Addison Wesley, 2nd edition, 1962. (6) W Greiner: Classical Electrodynamics, Springer, 1998. (7) Hayt, William H., Jr., and John A. Buck, "Engineering Electromagnetics", 7th ed. McGraw-Hill, 2006. (8) M.A. Heald and J.B. Marion, Classical Electromagnetic Radiation, Saunders, 1983.

1	**Title of the course** (L-T-P-C)	**Classical Mechanics** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	Nil
3	**Course content**	Review of Newtonian Mechanics - Newton's Laws of Motion and Conservation Laws. Principles of Canonical Mechanics - Constraints and generalized coordinates, Alembert's principle, Lagrange's equation, Hamilton's variational principle, canonical systems, symmetries and conservation laws, Noether's theorem, Liouville's Theorem. Central Force: Equations of motion Virial Theorem, Kepler's Laws, Scattering in a Central Force Field. Rigid Body: Euler angles, Coriolis Effect, Euler equations, moment of inertia tensor, motion of asymmetric top. Small Oscillations: Eigen value problem, frequencies of free vibrations and normal modes, forced vibration, dissipation. Special Theory of Relativity: Newtonian relativity, Michelson-Morley experiment, Special theory of relativity, Lorentz transformations and its consequences, addition of velocities, variation of mass with velocity, mass-energy relation, Minkowski four-dimensional continuum, four vectors. Hamiltonian Equation, Gauge transformation, canonical transformation, Infinitesimal transformation, Poisson brackets, Hamilton-Jacobi equations, Separation of variables Lagrangian and Hamiltonian formulation of continuous systems.
4	**Texts/References**	1. Classical Mechanics: H. Goldstein, C. P. Poole, and J. Safko, Pearson 2011. 2. Classical Mechanics: N. C. Rana and P. S. Joag, Tata McGraw Hill, 2017. 3. Introduction to Classical Mechanics: David Morin, Cambridge University Press, 2008. 4. Mechanics: L.D. Landau and E. M. Lifshitz, Butterworth- Heinemann, 3rd edition, 1982. 5. Mechanics: From Newton's Laws to Deterministic Chaos, F. Scheck, Springer, 5th edition, 2010. 6. Introduction to Classical Mechanics, R G Takwale and P S Puranik, Tata McGraw Hill, 2008.

1	**Title of the course** (L-T-P-C)	**Quantum Mechanics - I** **(3-1-0-8)**
2	**Pre-requisite courses(s)**	PH101 MA101
3	**Course content**	Review of Wave mechanics, Schrodinger equation, Uncertainty principle, wave packets, group velocity and phase velocity. Postulates of quantum mechanics, probability and probability current density, operators, eigenvalues and eigenfunctions. Bound states, delta-function potential, and harmonic oscillator. Formalism: Hilbert space, Observables, Eigenfunctions of Hermitian operator, Dirac's notation, matrix representations of vectors and operators, parity operation, matrix theory of harmonic oscillator. Theory of Angular Momentum: Spherical harmonics, eigenvalues of L^2 and L_z, addition of angular momentum, commutation relations, degeneracies. Hydrogen atom, quantum numbers, two particle systems.
4	**Texts/References**	1. Introduction to Quantum Mechanics, D. J. Griffiths and D. F. Schroeter, Cambridge University Press, 3rd edition, 2019. 2. Modern Quantum Mechanics, J. J. Sakurai, Cambridge University Press, 2017. 3. Principles of Quantum Mechanics, R. Shankar, Springer, 2014. 4. Quantum Physics, S. Gasiorowicz, John Wiley, 2000. 5. Quantum Mechanics, L. D. Landau and E.M. Lifshitz, Pergamon press, 1965

1	**Title of the course** (L-T-P-C)	**Electronics** **2-1-0-6**
2	**Pre-requisite courses(s)**	—
3	**Course content**	• Network theorems; application to simple circuits. • Semiconductor basics, diodes, p-n junction devices, transistors; biasing schemes; small signal amplifiers; feedback theory; oscillators; power supply. wave shaping circuits. • Bipolar junction transistor: configurations, small signal amplifier, oscillators. JFET and MOSFET: characteristics, small signal amplifier. • OP-AMP: Differential amplifiers; Op-Amp (741) circuits (amplifiers; scalar. adder; subtractors; comparator; logarithmic amplifiers; etc.) • Digital electronics : Logic gates, Boolean algebra, Karnaugh maps, flip flops, shift registers, adders, counters, ADC and DAC.
4	**Texts/References**	1. J. Millman, C. C. Halkias, C. D. Parikh, Integrated Electronics, 2nd edition, McGraw Hill Education (2017). 2. A. P. Malvino, Electronic Principles, 7th edition, McGraw Hill Education (2017). 3. R. L. Boylestad and L. Nashelsky, Electronic Devices and Circuit Theory, 11th edition, Prentice Hall (2013). 4. D. P. Leach, A. P. Malvino and G. Saha, Digital Principles and Applications, 8th edition, McGraw Hill Education (2014). 5. R. Gaekwad, Op-Amps and Linear Integrated Circuits, 4th edition, Prentice Hall of India (2015).

1	**Title of the course** (L-T-P-C)	**Electronics Laboratory** **0-0-3-3**
2	**Pre-requisite courses(s)**	--
3	**Course content**	The following is the proposed list of experiments/topics for this lab: **1.** Diode properties of transistor junctions **2.** Transistor as function generator **3.** Characteristics of field-effect transistor **4.** Half and full-wave rectifier **5.** RC-coupled amplifier **6.** Differential amplifier circuits **7.** Unregulated and regulated power supply **8.** Wein bridge oscillator using OP-Amp **9.** Op-Amp as adder/subtractor/integrator/differentiator **10.** MOSFET characteristics **11.** Universality of NOR/NAND gates **12.** Verification of De Morgan's theorem **13.** RC/ LR/ LCR circuit
4	**Texts/References**	1. J. Millman, C. C. Halkias, C. D. Parikh, Integrated Electronics, 2nd edition, McGraw Hill Education (2017). 2. A. P. Malvino, Electronic Principles 7th edition, McGraw Hill Education (2017). 3. R. L. Boylestad and L. Nashelsky, Electronic Devices and Circuit Theory 11th edition, Prentice Hall (2013). 4. D. P. Leach, A. P. Malvino and G. Saha, Digital Principles and Applications 8th edition, McGraw Hill Education (2014). 5. R. Gaekwad, Op-Amps and Linear Integrated Circuits, 4th edition, Prentice Hall of India (2015).

1	**Title of the course** (L-T-P-C)	**Statistical Physics** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	None
3	**Course content**	Thermodynamics: Thermal equilibrium, the laws of thermodynamics; temperature, energy, entropy, and other functions of state. Probability Theory: Probability densities, cumulants and correlations; central limit theorem; laws of large numbers. Kinetic Theory: Phase space densities; Liouville's theorem, the Boltzmann equation; transport phenomena. Classical Statistical Mechanics: Postulates; microcanonical, canonical and grand canonical ensembles; Gibb's paradox, non-interacting examples. Maxwell Boltzmann distribution, ideal gas. Quantum Statistical Mechanics: Indistinguishability, Bose-Einstein and Fermi- Dirac distributions and Applications Interacting Systems: Virial and cluster expansions; van der Waals theory; liquid- vapor condensation. Quantization effects in molecular gases; phonons, photons; density matrix formulation. Identical Particles: Degenerate quantum gases; Fermi liquids; Bose condensation; superfluidity.
4	**Texts/References**	1. Huang, Kerson. Statistical Mechanics. 2nd ed. Wiley, 1987. 2. Baierlein, Thermal Physics (Cambridge University Press, 1999). 3. Pathria, R. K. Statistical Mechanics. Pergamon Press, 1972. 4. Ma, Shang-keng. Statistical Mechanics. Translated by M. K. Fung. World Scientific Publishing Company, 1985. 5. J. K. Bhattacharjee, Statistical Physics: Equilibrium and Non-Equilibrium Aspects, Allied Publishes, 2000 6. F. Reif, Fundamentals of Statistical and Thermal Physics Statistical Physics :Amit and Verbin, Word Scientific, 1999

1	**Title of the course** (L-T-P-C)	**Condensed Matter Physics** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	Successful completion of the first two semesters
3	**Course content**	Crystal structure: Miller indices, Bravais and reciprocal lattice, Bragg and von Laue diffraction, structure factor; Lattice vibration and thermal properties: harmonic approximation, monatomic and diatomic lattices, Brillouin zone, density of states, acoustic and optical modes, phonons, crystal momentum, Debye model of specific heat, thermal expansion and conductivity; Free electron theory: Fermi gas, specific heat, Ohm's law, magneto- resistance, thermal conductivity; Band theory: Electrons in a periodic potential, Nearly free electron model, Bloch's theorem, Kronig Penny model, effective mass, concept of hole, classification of metal, insulator and semiconductor; Semiconductor: Intrinsic and extrinsic semiconductors, mobility and electrical conductivity, Fermi level, Hall effect; Magnetism: Diamagnetism, Hund's rules, Lande g-factor, quantum theory of paramagnetism, Pauli paramagnetism, exchange interaction, ferromagnetism, hysteresis; Superconductivity: Meissner effect, London equations, type-I and type-II superconductors, Outlines of BCS theory, flux quantization, Josephson tunneling, high temperature superconductors.
4	**Texts/References**	1. C. Kittel, Introduction to Solid State Physics, 8th Edition, Wiley 2. N. W. Ashcroft, N. D. Mermin, Solid State Physics, CENGAGE 3. A. J. Dekker, Solid State Physics, Mcmillan, 1986. 4. J. R. Christman, Fundamentals of Solid State Physics, Wiley, 1988.

1	**Title of the course** (L-T-P-C)	**Quantum Mechanics-II** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	PH101-Quantum Physics and Applications Quantum Mechanics - I
3	**Course content**	Time independent Perturbation Theory – Zeeman and Stark effects. Wentzel–Kramers–Brillouin approximation Variational method Time dependent perturbation theory, Scattering Theory, Born Approximation, Partial Wave analysis, Path Integral approach to Quantum Mechanics, Relativistic Quantum Mechanics Introduction to Quantum Field Theory, Quantization of free scalar field. Master equations, open and closed quantum system dynamics.
4	**Texts/References**	1. Modern Quantum Mechanics, J J Sakurai, Addison-Wesley, Reading, MA, 1994 2. Advanced Quantum Mechanics, J J Sakurai, Pearson, 1967. 3. Quantum Mechanics (Vol 1 and 2), C. Cohen-Tannoudji, B. Diu, and F. Laloe, Wiley VH; 2nd edition 2019. 4. R. Shankar, Principles of Quantum Mechanics, 2nd Ed. (Plenum Press, New York, 1994) 5. Quantum Mechanics and Path Integrals, R. P. Feynman and A. R. Hibbs, McGraw-Hill, New York, 1965. 6. An Introduction to Quantum Field Theory, M.E. Peskin, D. V. Schroeder, Westview Press, 1995. 7. The theory of open quantum systems, H. P. Breuer and F. Petruccione, Oxford University Press, 2002.

1	**Title of the course** (L-T-P-C)	**Mathematical Physics-1** **2-1-0-6**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Vectors in Physics, Coordinates, Cartesian, polar, Spherical Polar, Cylindrical, Transformation. Complex variables, Cauchy-Riemann conditions, Cauchy's integral theorem, Singularities and Laurent expansion, Calculus of Residues, Evaluation of Definite Integrals. Differential equations, Ordinary Differential Equations (ODE), Second order ODE, Series solution - Frobenius method, Inhomogeneous ODEs, Nonlinear ODEs Partial Differential Equation: First order PDE, Second order PDE, Separation of Variables, Laplace and Poisson equation, Uniqueness conditions. Operators, Self-Adjoint, Unitary, Hermitian Transformation of operators, Hermitian Eigenvalue problem, Hilbert-Schmidt theorem. Special Functions: Legendre Function - Spherical harmonics, Orthogonality, Generating functions, Bessel, Neumann, Hankel, Modified Bessel.
4	**Texts/References**	1. Sadri Hassani, Mathematical methods: for students of physics and related fields: 719 (Lecture Notes in Physics), 2nd edition, Springer (2009). 2. H. A. Hinchey, Introduction to Applicable Mathematics Part I, Wiley Eastern, (1980). 3. G. B. Arfken, H. J. Weber, F. E. Harris, Mathematical Methods for Physicists, 7th ed., Academic Press Prism Books, (2017). 4. P. Morse and H. Feshbach, Methods of Theoretical Physics, Vol.1, McGraw Hill, (1953). 5. V. Balakrishnan, Mathematical Physics, Ane Books (2017). 6. K. F. Riley, M. P. Hobson, H. J. Bence, Mathematical Methods for Physics and Engineering, 3rd edition, Cambridge University Press (2006).

1	**Title of the course** (L-T-P-C)	**Experimental Techniques** **3-0-0-6**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Vacuum technology: gases, gas flow, pressure and flow measurement, vacuum pumps, pumping mechanisms, ultrahigh vacuum, leak detection Optical systems: optical components, optical materials, optical sources Charge particle optics: electrostatic lenses, charged-particle sources, energy and mass analyzer Detectors: optical detectors, photoemission detectors, particle and ionizing radiation detectors, signal to noise ration detection, surface barrier detector, Particle detector: interactions of charged particles and photons with matter; gaseous ionization detectors, scintillation counter, solid state detectors Electronic noise, survey of analog and digital I/Cs, signal processing, data acquisition and control systems, data analysis evaluation Nano- and micro-fabrication: various lithography techniques such as photolithography, nanoimprint lithography, e-beam lithography, ion-ball milling SEM, TEM, X-ray diffraction, SQUID Magnetometry, Magneto transport, PL/CL time resolved spectroscopy, Rutherford Backscattering spectrometry (RBS), RBS-Channeling, UV-ViS-iR spectrometry.
4	**Texts/References**	1. The art of Measurement, by Bernhard Kramer (V. C. H. Publication) 2. Building Scientific Apparatus by J. H. Moore et. al. 3. Experiments in Modern Physics, Second Edition by Adrian C. Melissinos and Jim Napolitano 4. The art of Experimental Physics by Daryl W. Preston, 5. Vacuum Technology by A. Roth (North-Holl and publisher) 6. Charge particle Beams by Stanley Humphries (John Wiley and Sons) 7. Principles of Charged Particles Acceleration, by Stanley Humphries (John Wiley and Sons) 8. Radiation Detection and Measurements by G. Knoll (3rd Edition) 9. Techniques for Nuclear and Particles Physics Experiments by W. R. Leo (2nd edition, Springer)

1	**Title of the course** (L-T-P-C)	**Nuclear and Particle Physics** **2-1-0-6**
2	**Pre-requisite courses(s)**	---
3	**Course content**	Basic properties of nuclei and interactions, Nuclear binding energy, Nuclear moments, Nuclear models- independent particle model, shell model, Deuteron problem, Central and tensor forces, Radioactive decay-theory of alpha decay, Fermi theory of beta decay, gamma decay, Nuclear reactions- direct and compound reactions, Elementary particles- classification, symmetries and conserved quantum numbers, quark model, Particle Accelerators, Detectors (electrostatic accelerators, cyclotron, synchrotron; linear accelerators, fixed target, and colliding beam accelerators, circular colliders), Particle interactions and introduction to Feynman diagrams, Standard Model of Particle Physics.
4	**Texts/References**	1. S S M Wong, Introductory Nuclear Physics, 2nd Edition, Wiley-VCH Verlag GmbH & Co, 2004. 2. B L Cohen, Concepts of Nuclear Physics, Mc Graw Hill, 2017. 3. H A Enge, Introduction to Nuclear Physics Addison-Wesley 1966. 4. J S Lilley, Nuclear Physics: Principles and Applications, John Wiley and Sons 2001. 5. K Hyde, Basic ideas and concepts in nuclear physics, CRC Press 2004. 6. W E Burcham, Nuclear and Particle Physics, Addison Wesley 1994. 7. G Kane, Modern Elementary Particle Physics, Westview Press 1993. 8. D J Griffiths, Introduction to Elementary Particles, John Wiley and Sons 1987.

1	**Title of the course** (L-T-P-C)	**Atomic and Molecular Physics** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	PH101 Quantum Mechanics and Applications
3	**Course content**	Recapitulation of quantum mechanics; One-electron atoms: energy levels, interaction with electromagnetic fields, transition rates, density of states, dipole approximation, 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, molecular orbital (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.
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)	**General Physics Lab** **0-0-3-3**
2	**Pre-requisite courses(s)**	--
3	**Course content**	**Experiments:** 1. Faraday effect 2. Centrifugal force 3. Coupled Pendulum 4. Hall effect 5. Specific heat of solids 6. Pohl's pendulum 7. Millikan oil drop 8. Hysteresis loop 9. Franck-Hertz Experiment. Newton's ring
4	**Texts/References**	1. R. A. Dunlop, Experimental Physics, Oxford University Press, 1988. 2. A. C. Melissinos, Experiments in Modern Physics, Academic Press, 1996. 3. P. B. Zbar and A. P. Malvino, Basic electronics: A text-lab manual, Tata McGraw Hill, 1983.

1	**Title of the course** (L-T-P-C)	**Numerical Methods** **2-0-2-6**
2	**Pre-requisite courses(s)**	--
3	**Course content**	**Representation of numbers.** Round-off error. Condition and stability. Convergence. **System of Linear Equations:** Exact methods: Lower-Upper (LU) decomposition, Gauss-elimination methods without and with partial pivoting, Iterative methods: Gauss-Jacobi and Gauss- Seidal methods, Matrix norm Condition number and Ill-conditioning, Singular value decomposition, Matrices- Eigenvalues and eigenvectors. **Non-linear Equations and Roots of Polynomials:** Bisection method, Newton–Raphson's method, Direct Iterative method with convergence criterion. **Numerical Interpolation and Curve Fitting:** Lagrange, Hermite, cubic spline interpolation methods and discussion on associated errors, Curve fitting by least squares. **Numerical Calculus:** Integral Calculus:- General quadrature formula, Simpson's rules, Improper integrals, Gaussian quadrature formulae. Differential Calculus:- Numerical differentiation, Richardson Extrapolation, Monte Carlo Methods. **Ordinary Differential Equations:** Euler methods, Runge- Kutta methods and Numerov methods, second order differential equations, coupled differential equations, finite differences, eigen values via finite differences, Power method and eigenvalue problem. **Partial Differential Equations:** Numerical solutions, Finite difference representation, Elliptic equations.
4	**Texts/References**	1. P L DeVries, J E Hasbun "A First Course in Computational Physics", John Wiley, 2nd Edition, 2010. 2. Tao Pang, An Introduction to Computational Physics, Cambridge Univ. Press, 2nd Edition, 2006. 3. K E Atkinson, "An Introduction to Numerical Analysis", Wiley 2nd Edition, 2008. 4. S S Sastry, "Introductory Methods of Numerical Analysis", Prentice Hall, 5th Edition, 2012. 5. E W Cheney, D R Kincaid, "Numerical Mathematics and Computing", Cengage Learning, 7th Edition, 2012.

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1	**Title of the course** (L-T-P-C)	**Mathematics Physics-II** **2-1-0-6**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Tensor analysis, Curvilinear coordinates. Group Theory, Group Representation, Irreducible representation. Lorentz Group SU(2) O(3).... Differential equations- boundary value problems–Sturm-Lioville theory. Fourier Analysis, Fourier Transforms, Convolution, Discrete FT. Dirac Delta Function, Green's function in 1-d, 2-d and 3-d Special functions: Gamma, Beta, Sterling Series, Riemann Zeta function, Hermite, Laguerre, Chebyshev, Elliptical Integrals Asymptotic series, Method of Steepest descent, Integral equations.
4	**Texts/References**	1. G. F. Simmons, Differential Equations with Applications and Historical notes, 2nd edition, Mc Graw Hill, 1991. 2. H. A. Hinchey, Introduction to Applicable Mathematics Part I, Wiley Eastern, 1980. 3. G. B. Arfken, H. J. Weber, F. E. Harris, Mathematical Methods for Physicists, 7th ed., Academic Press Prism Books, 2017. 4. P. Morse and H. Feshbach, Methods of Theoretical Physics, Vol.1, McGraw Hill, 1953. 5. V. Balakrishnan, Mathematical Physics, Ane Books 2017. 6. K. F. Riley, M. P. Hobson, H. J. Bence, Mathematical Methods for Physics and Engineering, 3rd edition, Cambridge University Press (2006).

1	**Title of the course** (L-T-P-C)	**Advanced Physics Lab** **0-0-3-3**
2	**Pre-requisite courses(s)**	--
3	**Course content**	**Experiments:** 1. Fabry Perot Interferometer 2. Contact angle measurements and plasma cleaning 3. Electron Spin resonance 4. Four probe methods 5. Confocal Raman Spectrometer 6. X-Ray Diffraction 7. Zeeman Effect 8. Optical fiber characterization
4	**Texts/References**	1. Anthony E. Siegman, “Lasers”, University Science Books, 1986, ISBN: 9780935702118. 2. Richard L. Sutherland, “Handbook of Nonlinear Optics,” CRC Press, 2003, ISBN: 9780824742430.

1	**Title of the course** (L-T-P-C)	**Electronics** **2-1-0-6**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Network theorems; application to simple circuits. Semiconductor basics, diodes, p-n junction devices, transistors; biasing schemes; small signal amplifiers; feed-back theory; oscillators; power supply; wave shaping circuits. Bipolar junction transistor: configurations, small signal amplifier, oscillators; JFET and MOSFET: characteristics, small signal amplifier. OP-AMP: Differential amplifiers; Op-Amp (741) circuits (amplifiers; scalar; adder; subtractors; comparator; logarithmic amplifiers; etc.) Digital electronics : Logic gates, Boolean algebra, Karnaugh maps, flip flops, shift registers, adders, counters, ADC and DAC.
4	**Texts/References**	1. J. Millman, C. C. Halkias, C. D. Parikh, Integrated Electronics, 2nd edition, McGraw Hill Education (2017). 2. A. P. Malvino, Electronic Principles, 7th edition, McGraw Hill Education (2017). 3. R. L. Boylestad and L. Nashelsky, Electronic Devices and Circuit Theory, 11th edition, Prentice Hall (2013). 4. D. P. Leach, A. P. Malvino and G. Saha, Digital Principles and Applications, 8th edition, McGraw Hill Education (2014). 5. R. Gaekwad, Op-Amps and Linear Integrated Circuits, 4th edition, Prentice Hall of India (2015).

1	**Title of the course** (L-T-P-C)	**Astrophysics** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	Successfully finishing first 3 semesters
3	**Course content**	1. a. An inventory of the Universe, b. Celestial sphere, Coordinates c. Units, sizes, masses and distance scale 2. Electromagnetic spectrum a. Radio, Microwave, Infrared, Optical, X-ray and Gamma Ray b. Telescopes and Detectors 3. Stars A. General a. Sun, Planets, (Mother Earth) b. Mass, Radius, Luminosity, Temperature, Chemistry, Age and Types of stars c. Hertzsprung-Russell Diagram d. Birth and Evolution of stars c. Limits on Mass - Quantum mechanism at large scale: Brown Dwarf B. Structure of a star: a. Virial Theorem (qualitative) b. Nuclear Energy, Pressure, Interaction with radiation. c. Basic Equations of Stellar Structure d. Thermal Equilibrium, Radiation and Convection - Schwarzschild Criterion e. Helioseismology 4. Galactic and Extragalactic Astronomy a. The Milky Way and Andromeda b. Rotation Curve - Dark Matter c. Structures within 500 mega light years d. Clusters of Galaxies, Superclusters, Filaments and Voids 5. Special Topics: a. White Dwarf - Quantum Mechanics and Gravitation: Chandrasekhar limit b. Supernova, Neutron Stars, (Pulsar astronomy), c. Black Holes, Gravitational Wave Astronomy d. Gamma Ray Burst e. Quasars and Active Galactic Nuclei 6. Topics in Cosmology (This will be decided after discussing certain issues with Department members) a. Hubble Expansion - Cosmic Distance Scale - Age of the Universe b. Standard Model of Cosmology c. Cosmic Microwave Background d. Supernova Cosmology Project and Dark Energy e. Gravitational Lens 7. Major Astronomical facilities where India is involved: GMRT, SKA, Thirty Metre Telescope, LIGO, ASTROSAT 8. Open questions in Astrophysics and Cosmology
4	**Texts/References**	2. The New Cosmos: An introduction to Astronomy and Astrophysics, A.Unsold and B. Baschek, Springer, 5th edition, 2010. 3. An Introduction to Modern Astrophysics, B.W. Carroll and D.A. Ostlie, Cambridge University Press, 2nd edition, 2017. 4. Elements of Cosmology, J.V. Narlikar, University Press, 1996.

1	**Title of the course** (L-T-P-C)	**Special Theory of Relativity** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	PH101, PH102
3	**Course content**	Experimental Background: Galilean Transformation, Michelson-Morley Experiment, Postulates of Special Relativity, Relativistic Kinematics: Lorentz Transformations, Addition of Velocities, Aberration and Doppler Effects, Relativistic Dynamics: Relativistic Momentum, Mass, Force Law and their Transformation Properties, Relativity and Electromagnetism: Transformation of electric and magnetic fields, Field of uniformly moving charge and current-carrying wire, Forces between moving charges, Invariance of Maxwell's equations. Geometric Representation of Space-Time: Spacetime Diagram, Simultaneity, Contraction, Dilation, Time order and space separation of events. Introduction to General Relativity.
4	**Texts/References**	Introduction to Special Relativity, R. Resnick Wiley India, (2005). Special Relativity, A. French, C R C Press, (2017).

1	**Title of the course** (L-T-P-C)	**Laser Physics and Technology** **(2-1-0-3)**
2	**Pre-requisite courses(s)**	PH101
3	**Course content**	Optical radiation processes, conditions for the amplification of radiation, three level and four level lasers, optical beams, resonators and cavity designs, laser oscillation and dynamics, Q-switching, mode-locking, practical laser systems till date with their applications.
4	**Texts/References**	1. William. T Silfvast , "Laser fundamentals", 2nd edition, Cambridge University Press, 2004. 2. Orazio Svelto, "Principles of lasers", 5th edition, Springer Science & Business Media, 2010. 3. Anthony E. Siegman, "Lasers", University Science Books, 1986. 4. Majid Ebrahim-Zadeh and Irina T. Sorokina, eds., Mid-Infrared Coherent Sources and Applications (Springer, 2008).

1	**Title of the course** (L-T-P-C)	**Photonics** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	
3	**Course content**	Optical radiation processes, conditions for the amplification of radiation, three- level and four-level lasers, resonators and cavity designs, electro-optic and acousto-optic modulators, Q-switching, mode-locking, practical laser systems till date, with their applications. 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, Intense- field nonlinear optics. Detectors and diagnostics, Spectroscopy techniques. Ray model and Wave model in fiber Optics, 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. (5) John A Buck, "Fundamentals of Optical Fibers," 2nd edition, Wiley-Interscience, 2004.

1	**Title of the course** (L-T-P-C)	**Nonlinear Optics** **(2-1-0-3)**
2	**Pre-requisite courses(s)**	PH101
3	**Course content**	Origin of nonlinearity, nonlinear optical susceptibilities and interactions, intensity dependent refractive index, linear and nonlinear absorptions, harmonic generation, frequency conversion, phase matching, bistable devices, nonlinear optical materials, sources based on nonlinear optical interactions and their applications.
4	**Texts/References**	1 . Robert W. Boyd, "Nonlinear Optics," 3rd edition, Academic Press, 2008. 2 . Richard L. Sutherland, "Handbook of Nonlinear Optics," CRC Press, 2003. 3 . Michael Bass, Handbook of Optics: Volume IV - Optical Properties of Materials, Nonlinear Optics, Quantum Optics, Third Edition (OSA, vol IV, 2010). 4 . Majid Ebrahim-Zadeh and Irina T. Sorokina, eds., Mid-Infrared Coherent Sources and Applications (Springer, 2008). 5 . Saleh and Teich, "Fundamentals of Photonics," 2nd edition, Wiley- Interscience, 2012.

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)	**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, Time-scale, Development of systems. Quantum Cascade laser: Development and characteristics. Microstructured 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)	**Theory of Laboratory techniques** **2-1-0-6**
2	**Pre-requisite courses(s)**	--
3	**Course content**	Vacuum Techniques: Production and measurement of vacuum, different type 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**	Introduction to Solid State Physics - C Kittel, 7th ed., John Wiley (2005). Electronic Principles, A. Malvino and D. Bates, McGraw Hill Education 7th Edition (2017).

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, dipole approximation, 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)	**Spectroscopy** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	None
3	**Course content**	Review of atomic and molecular physics: One- eletron atom and muti-electron atom, energy levels, Transition probabilities and cross- sections, Lifetime, Line broadening mechanisms, Central field approximation, L-S and j-j coupling schemes, interaction with external fields, Born-Oppenheimer approximation, Hydrogen molecule ion, Electronic structure of diatomic molecules and extension to simple polyatomic molecules,electronic term symbols, Selection rules. Electromagnetic radiation and its interaction with matter. Absorption and emission of radiation. Electromagnetic spectrum and different forms of spectroscopy. Rotational Spectroscopy: Linear, symmetric rotor, spherical rotor and asymmetric rotor molecules, Rotational infrared, millimeter wave and microwave spectra, Rotational Raman spectroscopy. Vibrational Spectroscopy: Diatomic molecules, Polyatomic molecules, infrared spectra, Raman spectra, Ro-vibrational spectroscopy, Anharmonicity. Electronic Spectroscopy: electronic transition, energy of electronic transition, the Franck-condon principle,X-ray and photoelectron spectroscopy,Auger electron spectroscopy.
4	**Texts/References**	1. Modern Spectroscopy, J. M. Hollas, John Wiley & Sons, Inc. 2. Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash, McGraw Hill Education. 3. Molecular Spectroscopy, Ira N Levine, John Wiley & Sons, Inc. 4. Molecular Quantum Mechanics, P. Atkins and R. Friedman, Oxford University press. 5. Physics of Atoms and Molecules, B. H. Bransden and C. J. Joachain, Pearson Education, Ltd. (2003).

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)	**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)	**Introduction to Quantum Information and Computation** **(2-1-0-6)**
2	**Pre-requisite courses(s)**	PH101 – Quantum Physics and Application MA102 - Linear Algebra
3	**Course content**	Framework of Quantum Mechanics: Quantum States, Dirac notation and Hilbert Space, Operators, Spectral Theorem, Functions of operators, Tensor Products, Schmidt Decomposition theorem; Time-evolution of a closed system; composite systems, measurement, pure and mixed states and general quantum operations. Quantum systems: Qubits, qudits, bipartite and multipartite systems, Continuous variable states. Quantum Entanglement: Definition, detection, quantification in various quantum systems Quantum Communication: no-go theorems, quantum teleportation, quantum dense coding, and other quantum communication protocols without security. Quantum Cryptography: essentials of classical cryptography, quantum protocols with security like, BB84, B92, Ekert, etc. Quantum Computation: Quantum gates, quantum algorithms, D-wave quantum computer. Status update for experimental realization on some of these protocols.
4	**Texts/References**	1. Quantum Computation and Quantum Information, M. A. Nielsen & I. L. Chuang, 10th Edition, Cambridge University Press, NY, USA (2011). 2. Quantum Information Theory, M. M. Wilde, Cambridge University Press, 2nd edition, 2017. 3. An introduction to Quantum Computing, P. Kaye, R. Laflamme and M. Mosca, Oxford University Press, (2010). 4. Preskill's lecture notes on Quantum Information and Quantum Computation, http://www.theory.caltech.edu/people/preskill/ph229/ 5. Principles of Quantum Computation and Information (Vol.-1), G. Benenti, G. Casati, and G. Strini, World Scientific, 2004. Classical and Quantum Computation, A. Yu. Kitaev, A. H. Shen, and M. N. Vyalyi, American Mathematical Society, 2002 7. Quantum Computation and Quantum Communication -Theory and Experiments, M. Pavicic, Springer, 2006. 8. Quantum Computer Science, N. D. Mermin, Cambridge, 2007. 9. 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)	**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