Syllabus of Integrated M.Sc. Degree under NEP-2020
School of Physical Sciences

Semester	**Code, credits (lecture hours) Course Name**	**Syllabus**
I	P101 (Ma/Mi) 4 (60 hrs) **Classical Mechanics - I**	▪ Energy, mass, momentum: Definitions & illustrations ▪ Newton's laws, Kinematics: Concepts and Pitfalls ▪ Circular motion (Cartesian, polar) ▪ Principle of Least action, Fermat's principle, extremization problems and laws (Newtons, Snell's and Kirchoff's laws) ▪ Vectors, Scalars, vector calculus & applications ▪ Linear motion (Conservative forces, conservation of energy, motion near equilibrium, damped oscillator, oscillator under simple periodic force, collision problems) ▪ Projectile motion, moments, angular momentum, central forces, conservation of angular momentum ▪ Central conservative forces (Isotropic HO, Inverse square law, orbits) ▪ Rotating Frames (angular velocity, particle in a uniform magnetic field, acceleration, apparent gravity, Coriolis force, Larmor effect) ▪ Two-body problem (CM, CM frame, lab frame) **References:** [1] An Introduction to Mechanics, 1st Edition, D. Kleppner and R. J. Kolenkow, Tata McGraw - Hill Education, 2007 [2] Classical Mechanics, 5th Edition, T. W. B. Kibble, F. Berkshire, World Scientific 2004. [3] Mechanics, Waves and Thermodynamics: an example-based approach, S. R. Jain, Cambridge University Press, 2016.
	P101 (Mi/Oe) 2 (30 hrs) **Classical Mechanics - I**	▪ Energy, mass, momentum: Definitions & illustrations ▪ Newton's laws, Kinematics: Concepts and Pitfalls ▪ Circular motion (Cartesian, polar) ▪ Principle of Least action, Fermat's principle, extremization problems and laws (Newtons, Snell's and Kirchoff's laws) ▪ Vectors, Scalars, vector calculus & applications ▪ Linear motion (Conservative forces, conservation of energy, motion near equilibrium, damped oscillator ▪ Projectile motion, moments, angular momentum, central forces, conservation of angular momentum ▪ Central conservative forces (Isotropic HO, Inverse

		square law, orbits) **References:** [1] An Introduction to Mechanics, 1st Edition, D. Kleppner and R. J. Kolenkow, Tata McGraw - Hill Education, 2007 [2] Classical Mechanics, 5th Edition, T. W. B. Kibble, F. Berkshire, World Scientific 2004. [3] Mechanics, Waves and Thermodynamics: an example-based approach, S. R. Jain, Cambridge University Press, 2016.
	P102 (Ma/Oe) 2 (30 hrs) **Thermal and Modern Physics**	▪ Thermodynamics (Concepts) – States and processes, state functions, thermodynamic potentials, Maxwells Relations, Applications of the laws of thermodynamics – JT cooling, thermodynamic cycles, Clausius Clapeyron equation ▪ Blackbody radiation, Photoelectric effect, Compton effect, Electron interference and diffraction (double slit experiment with electrons and Davisson-Germier experiment). Wavelike properties of particles, de Broglie hypothesis, wave packets, uncertainty relation, bedarken experiment with Heisenberg microscope for measurement of electron position ▪ Concept of wavefunction its probabilistic approach, simple one-dimensional problems, tunnelling and its demonstration **References:** [1] Thermodynamics and Statistical Mechanics, Arnold Sommerfeld [2] Fundamentals of Statistical and Thermal Physics 6th Edition, Frederick Reif [3] Modern Physics, P. A.Tipler and R. Llewelyn, W. H. Freeman & Co. (6th Edition 2012). [4] K. S. Krane, “Introductory Modern Physics”, Wiley (2008).
	PL101 (VSC) 2 (60 hrs) **Physics Labs -I**	• Introduction to experimental physics – conceptual and procedural understanding, planning of experiments; Plots (normal, semi-log, log-log); uncertainty / error in measurements and uncertainty / error analysis. Introduction to measuring instruments – concepts of standards and calibration. • Determination of time periods in coupled strip oscillator system with emphasis on uncertainty in the measurements and accuracy requirements. • Study of projectile motion – understand timing requirements; • Determination of Young’s modulus of a strip of metal by double cantilever method (use of travelling microscope); • Study of thermal expansion of metal – use of thermistor as a thermometer.

		• Study of time dependence of charging and discharging of capacitor using digital multi-meter – use of semi-log plot. • Determination of Inductance of a coil by vector method – concept of phase lag / lead of current with respect to voltage in AC circuits. Awareness of internal resistance of an inductor and enhancement of inductance with ferromagnetic core. Awareness of AC electrical mains. • Skill of Soldering electronic components – make a simple circuit to power a LED. Learn to read datasheet of electronic components and understand the limits of the components, e.g., maximum allowed power dissipated across components, maximum temperature and duration of soldering. Knowledge of estimating value of resistance required to limit the current through the LED, and verification by measurements of voltage and current measurement using DMM. **References:** [1] An Introduction to Error Analysis in experiments – the study of uncertainties in physical measurements, Third Edition, J.R. Taylor, Pub: University Science Books, New York. [2] Handouts based on standard Textbooks on Undergraduate Physics Laboratory Experiments and Experiments developed at HBCSE, TIFR, Mumbai.
	VEC 101 2 (30 hrs) **Digital and Technological Solutions**	• Number systems: binary, octal, hexadecimal. Basic logic gates and their truth tables. • Flip-flops: RS and JK flip-flops and their application as basic memory unit, control element, frequency divider and counter. • Simulation experiments of gates and flip-flops using the open-source software ‘Logisim-evolution’. • Basic Micropython version of computer programming language Python for control of microcontrollers. Introduction to the microcontroller Raspberry Pi Pico-W, as a device for automated data collection and control of experiments. Basic experiments with Pico-W in laboratory. • Basic concepts of 'Internet of Things ' (IoT), their relevance and applications. Implementation of an example IoT with Pico-W and the free (with limited facilities) cloud platform 'Thingspeak' of ‘Matlab’. • A short overview of Digital Initiatives of Government of India, with emphasis on Aadhaar, Digilocker, online availability of PAN, Academic Bank of Credits, UPI (United Payment Interface) digital payments, and Central Bank Digital Currency (CBDC). The course is designed such that there is almost no requirement of hardware knowledge of electronics. **References:**

		[1] Raspberry Pico W Simplified, Luc Volders, Luc Volders 2022. [2] Micropython, for the Raspberry Pi Pico W, Miguel Grinberg, Kindle Book. [2] Getting Started with the Internet of Things, Cuno Pfister, O'Reilly, 2011.
II	P201 (Ma/Mi) 4 (60 hrs) **Electromag netism - I**	• Electrostatics: Coulomb's law and Gauss' law; Electrostatic potential, uniqueness theorem, method of images; Electrostatic fields in matter; Conductors and insulators; Capacitors and capacitance; Electric current. • Magnetostatics: Biot – Savart law, Ampere's law; Electromagnetic induction; Mutual inductance and self-inductance; Magnetic fields in matter. Displacement current; • Maxwell's equations; Alternating current circuits; Electric and magnetic properties of matter; Plane electromagnetic waves in vacuum; Polarisation; Energy and momentum n electromagnetic waves; electromagnetic radiation; diffraction; field of plane of oscillating charges; origin of refractive index; dispersion; Dipole radiation formula; Larmor's formula for radiation due to accelerated charge; radiation damping; Synchrotron radiation • Special Theory of relativity – Lorentz transformations, Time Dilation, Length contraction, mass-energy equivalence **References:** [1] Electricity and Magnetism, Berkeley Physics Course Vol. 2, 2nd Edition, Edward M. Purcell, Tata McGraw Hill Education, 2011. [2] The Feynman Lectures on Physics Vol. 1, R. P. Feynman, R. B. Leighton and M. Sands, Narosa Publications, 2011. [3] The Feynman Lectures on Physics Vol. 2, R. P. Feynman, R. B. Leighton and M. Sands, Narosa Publications, 2010 [4] Waves, Berkeley Physics Course Vol. 3, Frank S. Crawford, Tata McGraw – Hill Education, 2011.
	P202 (Ma/Mi) 2 (30 hrs) **Optics**	▪ Fermat Principle, derivation of laws of reflection and refraction ▪ Waves in two and three dimensions, superposition, Fourier decomposition of a wave, notion of wave packets, phase and group velocity. ▪ Deriving Laws of reflection and refraction using E and B vectors. Reflection and transmission coefficients ▪ Interference of Light – Two beams (Young's double slit, Fresnel biprism, Michelson interferometer, circular fringes), involving multiple reflections (Plane parallel film, Newtons rings, Fabry-Perot Interferometer, Brewsters fringes)

		▪ Diffraction of Light – Fresnel and Fraunhofer, single slit, double slit, grating, Resolving power, Fresnel's half period zones, Zone plates. ▪ Polarization - polarization crystals, birefringence, polarization by scattering double refraction and reflection, elliptically and circularly polarized light, half plate, quarter plates **References:** [1] Optics by E. Hecht & A. R. Ganesan, 5^{th} edition, Pearson, 2019 [2] Fundamental of Optics by F. A. Jenkins and H. E. White, 4^{th} edition, McGraw – Hill Education, 2017
	PL201 (VSC) 2 (60 hrs) **Physics Labs -II**	• Review of uncertainty / error analysis; least squares fit method; • Study of conservation of linear and angular momentum using 'Maxwell's Wheel' apparatus; • Study of vibrations of soft massive spring; • Study of Volume Acoustic Resonance: Helmholtz Resonator; • Energy studies and Study of Solar Photovoltaic Cell; • Study of surface tension of water by capillary method / Study of viscosity of liquid by Poiseuille's method; • Study of very small capacitance and other studies involving small timings, by automated measurements, using expEYES, developed at IUAC, New Delhi, under UGC sponsorship; • Verification of Newton's law of cooling by automated measurement using Pico controller introduced in the earlier semester. **References:** [1] Handouts based on standard Textbooks on Undergraduate Physics Laboratory Experiments and Experiments developed at HBCSE, TIFR, Mumbai. [2] https://www.expeyes.in [3]https://www.raspberrypi.com/documentation/micro-controllers/raspberry-pi-pico.html
	IKS 201 2 (30 hrs)	**Indian Astronomy** • Historical Introduction: Ancient Indian Astronomy, Vedic Period and Vedangajyotishya, Siddhanta Period • Celestial Sphere Diurnal Motion of Celestial Bodies, Concept of Celestial Horizon, Meridian, Pole Star and Directions, Zodiac and Constellations, Equator and Poles, Latitude of a Place and Altitude of Pole Star, Ecliptic and the Equinoxes • Co-ordinate Systems: Altazimuth, Equatorial and Ecliptic, Concept of Hour Angle, Conversion of coordinate systems • Precession: Precessions of equinoxes, Ancient Indian

		reference to precession and modern calculaions, Effects of Precession on Celestial Longitude • Indian Calenders and Panchang: Gregorian Calendar, Hindu Calendar, Islamic Calendar, Panchang - Tithi, Vara, Nakshatra Calculations • Time in Indian Astronomy: Civil Day and Sidereal Day, Solar Year and Civil Calendar, Solar Month and Lunar Month, Luni-Solar Year, Adhikmas and Kshaymas, Yuga System • Mean Positions of the Sun, Moon and Planets: Ahargana, Working Method to find Ahargana, Mean Positions-Computations, Deshantara Correction to Sun, Moon and Planets • True Positions of the Sun and the Moon: Epicyclic Theory - Mandaphala, Equation of Centre (Mandaphala) for the Sun and the Moon, True Daily Motions of the Sun and the Moon **References:** [1] Indian Astronomy- Bhalchandra Rao [2] Textbook to Spherical Astronomy, - W.M Smart [3] Astronomy Principles and Practices- Roy and Clark
	SEC201 2 (30 hrs) **Electronics**	• AC Electricity supply: Knowledge of Single phase and Three phase supplies, Power outlets, Switches, Circuit Breakers, Earth leakage Circuit Breakers, Fuses etc. • Diode and its use as rectifiers as DC power supply (half wave rectifier, full wave rectifier, Bridge rectifier); Capacitor filter and Ripple Factor; Load Regulation and use of Regulated Power ICs. • Transistors; BJT and MOSFET, their application as switches. • Operational Amplifiers and their use as Non-inverting Amplifiers, Inverting Amplifiers and Schmitt Trigger for control applications. • Introduction to Sensors and transducers. • Simulation of electronics circuits using free version software: TINA-TI and Multisim Live. • Four laboratory sessions involving some of the above topics, including automated measurement of output of a sensor, putting the data on Cloud and control of a ‘Thing’ based on the knowledge on gained in VEC101 of previous semester. **References:** [1] Principles of Electronics, A Malvino and D. Bates, [2] Electronic Devices, 10^{th} Ed., T. Floyd. D. Buchla, S. Wetterling, Pearson, 2017

III	P301 (Ma/Mi) 4 (60 hrs) **Classical Mechanics - II**	• Generalized coordinates, The principle of least action, Euler-Lagrange equations, Inertial frames and Galilean invariance, Lagrangian of a free particle, Lagrangian of a system of particles • Energy, Momentum, Angular momentum, Conservation laws and symmetries, Centre of mass, Virial theorem, soluble problems of dynamics with one, two, three degrees of freedom • Rigid body kinematics, angular velocity, motion of a rigid body round a fixed axis, the inertia tensor, principal axes, moments of inertia for simple two- and three-dimensional shapes, rigid body dynamics, equation of motion of rigid body, Euler angles, Euler equations, symmetric rigid body, precession and nutation, asymmetrical top • Small oscillations, free oscillations in one dimension, forced oscillations, oscillations of systems with more than one degree of freedom, damped oscillations, molecular vibrations, forced damped oscillations, resonance, parametric resonance • Hamilton's equations, Routhian, Poisson brackets, Canonical transformations and generating function, Legendre transform, Action, Liouville's theorem, Hamilton-Jacobi equation, Adiabatic invariants **References:** [1] Mechanics, Third Ed., L. D. Landau and E. M. Lifshitz (Elsevier, 1976). [2] Classical Mechanics, Fifth Ed., T. W. B. Kibble and F. H. Berkshire (Imperial College Press, 2010). [3] Introduction to Classical mechanics with problems and solutions, D. Morin (Cambridge University Press, 2007). [4] A treatise on analytical dynamics of particles and rigid bodies: with an introduction to the problem of three bodies, 4th Ed., E. T. Whittaker (Cambridge University Press, 1937). [5] Mechanics, waves and thermodynamics: an example-based approach, S. R. Jain (Cambridge University Press, 2016).
	P302 (Ma) 4 (60 hrs) **Mathematical Physics -I**	• Review of curvilinear coordinates, scale factors, Jacobian. Differential operators in curvilinear coordinates. Vectors, vector algebra, Divergence theorem, Green’s theorems and Stokes theorem. Introduction to tensors: contravariant and covariant notation, Levi-Civita symbol, pseudotensors, quotient rule, dual tensors. Dirac delta distribution: properties, expressions in various curvilinear coordinate systems. • Review of first order differential equations, the notion of Wronskian and its properties, Series solutions of second order differential equations, Frobenius method (theorem due to Fuchs). • Fourier series and simple applications. Fourier

<table>
<tr><td></td><td></td><td>transforms, Parseval's theorem, convolution, and their simple applications. Laplace transforms, initial value problems, simple applications, transients in circuits, convolution.

References:
[1] Differential Equations, G. F. Simmons, McGraw-Hill, 2006
[2] Ordinary Differential Equations, V. I. Arnold, MIT Press 2009
[3] Mathematical Methods for Physicists, 7th Edition, G. Arfken and Hans J. Weber, Elsevier 2012
[4] About Vectors, Banesh Hoffman, Dover 1966.</td></tr>
<tr><td></td><td>PL301
(VSC)
2 (60 hrs)

Physics Labs -III</td><td>• Study of Newton’s Rings.
• Study of Resolving Power of Grating.
• Study of diffraction by single slit, double slit and multiple slits leading to grating, quantitative determination and comparison with simulation;
• Study of Polarization – Malus law, Polarizer.
• Study of Polarization – Quarter-Wave, Half-Wave Plate.
• Study of Faraday Rotation of polarization.
• Study of Double refraction.
• Measurement of e/m ratio of electron.</td></tr>
<tr><td></td><td>P303
(Mi/Oe)

Probability and Statistics</td><td>• Symmetry as measure of probability, Independence, Sample space, conditional probability, randomness.
• Permutations, combinations, Bernoulli trials, random variables, moments, mathematical expectations, generating function, weak law of large numbers, information, statistical assignment of probability.
• Countably infinite sample spaces, continuous sample spaces, St. Petersburg paradox, the castle point paradox, Bertrand paradox, Monte Carlo estimates, normal distribution, reciprocal distribution, Poisson distribution, queueing theory.
• Entropy, Shannon’s entropy, mathematical properties of entropy function, Max entropy principle.
• Applications: Measurement, judgement, psychology in economics, frequency, mathematics, inverse inference, unification, algorithmic randomness, physical chance, induction.

References:
[1] The Mathematical Theory of Probability, J. V. Uspensky, Tata-McGraw Hill, 1971.
[2] The Art of Probability, R. W. Hamming, CRC Press, 2019.
[3] An Introduction to Probability Theory and its applications, Vol. 1, W. Feller, John Wiley and Sons, 1950.
[4] Foundations of the theory of probability, A. N. Kolmogorov, Dover, 2018.
[5] Statistical independence in probability, analysis and number</td></tr>
</table>

		theory, Carus mathematical monographs, M. Kac, Mathematical Association of America, 1964.
IV	P401 (Ma) 4 (60 hrs) **Mathematical Physics - II**	• Complex analysis: Complex numbers, notions of functions, limits, continuity, differentiabilty. Cauchy – Riemann conditions, analyticity, Harmonic functions; Contour integrals, Cauchy theorem, simply and multiply connected domains, Cauchy integral formula, derivatives of analytic functions; Laurent series, uniform convergence; Notion of residues, residue theorem, notion of principal values, applications of residues to evaluation of improper integrals, definite integrals, indentation, branch points and branch cuts, analytic continuation, introduction to Riemann surfaces. • Special Functions: Gamma and Beta functions, Riemann zeta functions, Rodrigues formula and classical orthogonal polynomials, recurrence relations, symmetry properties, special values, orthogonality, normalisation, generating functions. Legendre, Hermite, Laguerre, Bessel and Hypergeometric differential equations. Integral representations of special functions. Expansion of functions in orthonormal basis. • Group Theory: Elementary group theory and group representations, cyclic, permutation groups; isomorphism, homomorphism, subgroups, normal subgroup, classes and cosets; orthogonal, rotation group, Lie group; equivalent, reducible, irreducible; Schur's lemma. **References:** [1] Mathematics for Physicists, P. Dennery and A. Krzywicki, Dover 1996 [2] Mathematics for Quantum Mechanics, 4th Edition, J. D. Jackson, Dover 2009. [3] Lectures on Groups and Vector Spaces for Physicists, C. J. Isham, World Scientific 1989 [4] Group Theory and Its Application to Physical Problems, M. Hammermesh, Dover 1989 [5] Elements of Green's Functions and Propagation, G. Barton, Oxford 1989 [6] Complex Variables and Applications, 8th Edition, R. V. Churchill and J. W. Brown, McGraw-Hill, 2009 [7] Complex Variables: Introduction and Applications, 2nd Edition, M. J. Ablowitz and A. S. Fokas, Cambridge 2003 [8] Special Functions, George E. Andrews, Richard Askey and Ranjan Roy, Cambridge 2013.
	P402 (Ma/Mi) 4 (60 hrs)	• Double-slit experiment with electrons (Tonomura et al.), Wavefunction, Linear superposition, Correspondence principle and Schrodinger equation, states, Hilbert space,

	Quantum Mechanics - I	Axioms of quantum theory of closed systems, probability distributions, observables and linear operators, self-adjointness, unitary operator, wavepacket, uncertainty relation, Ehrenfest theorem (10 hours) • Quantum billiards in two dimensions, Harmonic oscillator, Heisenberg's uncertainty relation for non-commuting operators, common eigenfunctions of commuting operators, angular momentum operator, orbital angular momentum and spherical harmonics, bound states in three dimensional systems, hydrogen atom, rigid rotator (16 hours) • Operators and Matrix representations, Schrodinger representation, Heisenberg representation, Interaction representation, Raising and lowering operators for harmonic oscillators, spin, Stern-Gerlach experiment, Pauli matrices, states and spinors, addition of spin-1/2 operators, orbital angular momentum and spin-1/2 (10 hours) • Scattering theory: one-dimensional potential barrier, tunnelling, collisions in three dimensions, scattering cross-section, CM and lab frames, scattering in a central field, partial wave analysis, phase shifts, scattering matrix, time-delay, resonances (8 hours) • Approximation methods for stationary states: time-independent perturbation theory (non-degenerate and degenerate cases), ground state from variational method, time-dependent perturbation theory for harmonic perturbations, Golden rule for transition probability, Zeeman effect, Stark effect, Aharonov-Bohm effect (12 hours) **References:** [1] L. D. Landau and E. M. Lifshitz, Quantum Mechanics (Pergamon Press, 1965). [2] F. Schwabl, Quantum mechanics (Narosa, 1992). [3] L. I. Schiff, Quantum mechanics, Third Ed. (McGraw-Hill, 1968). [4] B. H. Bransden and C. J. Joachain, Physics of atoms and molecules, @nd Ed. (Pearson, 2006). [5] A. G. Sitenko, Lectures in scattering theory (Pergamon press, 1971).
	PL401 (VSC) 2 (60 hrs) **Physics Labs -IV**	• Study of Electrical Equipotential lines. • Study of Method of Images of electrical potential. • Mechanical Forced Oscillator – Pohl's Pendulum. • Mechanical Coupled Strip Oscillator. • Study of Frequency response and Transient response of C-R, L-R, L-C-R series, L-C parallel circuits, both by simulation and by experiment. • Study of Coupled Electrical Oscillators, by simulation

		and by experiment: Capacitively coupled and inductively coupled. Concept of reflected impedance in mutual inductance. • Study of Atomic Spectra. • Study of Combination of lenses. • Study of Michelson Interferometer.
V	P501 (Ma/Mi) 4 (60 hrs) **Quantum Mechanics - II**	State and measurement in quantum mechanics, density matrix, pure and mixed states, projection operators, The von Neumann equation, spin-1/2 systems, qubits and quantum information, tensor product, entanglement, measurement process, EPR argument, Bell's inequality (8 hours) First and Second quantization approach for many-particle systems: identical particles, bosons, fermions, anyons, relation with symmetric group and braid group, creation and annihilation operators for bosons and fermions, field operators, field equations, momentum representation, inclusion of spin (10 hours) spin-1/2 fermions: noninteracting fermions, Fermi sphere, single-particle correlation functions, pair distribution function and structure factor, Hamiltonian of electron gas and ground state energy, Hartree-Fock approximation (with and without second quantization), modification in electron energy levels due to Coulomb interaction (10 hours) Bosons: pair distribution function for free bosons, photon correlations, Hanbury Brown and Twiss experiment, weakly-interacting dilute Bose gas, Bose-Einstein condensation, Bogoliubov theory, superfluidity (10 hours) Correlation functions, scattering, response: coherent scattering cross-section, density matrix and correlation functions, dynamical susceptibility, dispersion relations, fluctuation-dissipation theorem, applications to harmonic crystal, diffusion (8 hours) Path integral formulation of quantum mechanics, connection with the Schrodinger equation, path integral propagators for simple quantum systems, applications of path integrals, trace formulae (10 hours) **References:** [1] F. Schwabl, Advanced quantum mechanics (Springer, 2003). [2] F. Schwabl, Quantum mechanics (Narosa, 1992). [3] W. Dittrich and M. Reuter, Classical and quantum mechanics (Springer, 2001). [4] C. Itzykson and J. B. Zuber, Quantum Field Theory (McGraw Hill, 1986).
	P502 (Ma) 4 (60 hrs) **Statistical Physics -I**	▪ Elementary probability theory; random walk; binomial, Poisson, log-normal distributions; the Gaussian. ▪ Brief Review of Thermodynamics. ▪ Kinetic theory of dilute gases in equilibrium. ▪ Introduction to Ensembles; micro-canonical ensemble; canonical ensemble, grand canonical ensemble.

		Canonical Ensemble. calculation of thermodynamic quantities; Gibbs paradox; the equipartition theorem; Harmonic Oscillator, two level system and paramagnetism. Energy, density fluctuations, Validity of the classical approximation. ▪ Identical particles and symmetry; quantum distribution functions; Bose-Einstein statistics; Fermi-Dirac statistics. The free electron gas – heat capacity and Pauli paramagnetism; Bose Einstein Condensation. ▪ Interacting systems: Equation of State of the non-ideal gas and virial coefficients; Weiss molecular field approximation. Black body radiation and the Planck radiation law **References** [1] "Fundamentals of Statistical and Thermal Physics", F. Reif, Sarat Book Distributors, 2010. [2] "Statistical Mechanics", 3rd Edition, by R. K. Pathria and Paul D. Beale, Elsevier, 2011. [3] Elementary Statistical Physics, C. Kittel, Dover publications, 2004. [4] The Principles in Statistical Mechanics, R. P. Feynman, Benjamin-Cummings, 1972.
	P503 (Ma) 4 (60 hrs) **Electrodyna mics - I**	• Electrostatics: Coulomb's law, Electric field, Gauss' law in differential and integral forms, Scalar potential, Poisson and Laplace equations, Discontinuities in Electric field and potential: electrostatic boundary conditions, Uniqueness theorem, conductors and second uniqueness theorem, method of images, multipole expansion, work and energy in electrostatics. • Electric Fields in matter: dielectrics, polarisation, bound charges, notion of electric displacement, • Gauss' law in presence of dielectrics, boundary conditions, linear dielectrics: susceptibility, permittivity, dielectric constant, boundary value problems, energy in dielectric systems. • Magnetostatics: Lorentz force law, steady currents, Biot – Savart law, Ampere's law, vector potential, magnetostatic boundary conditions, multipole expansion for vector potential, magnetic scalar potential. Diamagnets, paramagnets and ferromagnets, magnetisation, bound currents, the H field, boundary conditions, magnetic susceptibility and permeability. • Electrodynamics: Electromotive force, electromagnetic induction and Faraday's law, induced electric fields and inductance, energy in magnetic fields. Maxwell's equations: equation of continuity and Modification in Ampere's law, Gauge transformations, Lorentz and Coulomb gauge. Maxwell's equations in matter, integral and differential forms, boundary conditions. Poynting's

		theorem, conservation of momentum, angular momentum. Lossy media, Poynting's theorem for lossy media. • Wave equation, electromagnetic waves in vacuum, plane waves, propagation in lossless and lossy linear media, absorption and dispersion, reflection at the interface of two lossy media, guided waves. **References:** [1] Introduction to Electrodynamics, 4th Edition, D. J. Griffiths, Addison-Wesley 2012 [2] Classical Electricity and Magnetism, 2nd Edition, W.K.H. Panofsky and M. Phillips, Dover 2005. [3] Engineering Electromagnetics, 2nd Edition, Nathan Eda, Springer 2007 [4] Modern Electrodynamics, Andrew Zangwill, Cambridge 2013.
	PL501 (OJT) 4 (120 hrs) **Physics Labs -V**	• Introduction to LabVIEW software for automation and Automated measurements using of NI data acquisition card and Arduino (six sessions). • Calibration of a thermistor (automation with LabVIEW). • Study of thermal diffusivity of Brass (Automated version of CEBS based on Science Academies experiment). • Study of Electron Spin Resonance (ESR) in DPPH. • Demonstration of Frack-Hertz Experiment in Neon. • Ferro-electricity, Piezo-Electricity, Frequency response of a piezo electric disc, Verification of Curie-Weiss law in para-electric material using a ceramic capacitor and observation of ferro-electric loop below the ferro-electric Curie Temperature. • Study of anharmonic oscillator. • Study of Quantum Analog – Cylindrical Resonator. • Study of Quantum Analog- Spherical Resonator. **Reference:** [1] A Manual of Experiments in Physics, R. Srinvasan et al., (Science Academies of India).
	PE501 (Ma) **Numerical Methods**	• Error, its sources, propagation and analysis; Errors in summation, stability in numerical analysis. • Linear algebraic equations: Gaussian elimination, direct triangular decomposition, matrix inversion, SVD. Root-finding: review of bisection method, Newton's method and secant method; real roots of polynomials, Laguerre's method. • Matrix eigenvalue problems: Power method, eigenvalues of real symmetric matrices using Jacobi method, applications. • Interpolation theory: Polynomial interpolation, Newton's

		divided differences, forward differences, interpolation errors, Hermite interpolation, cubic splines. • Approximation of functions: Taylor's theorem, remainder term; Least squares approximation problem, Orthogonal polynomials, Near minimax approximation. • Numerical integration: review of trapezoidal and Simpson's rules, Newton – Cotes integration formulas, Gaussian quadrature; Error estimation. • Numerical differentiation. Random numbers; • Monte Carlo methods, Metropolis algorithm. • Least squares problems: Linear least squares, examples; • Ordinary differential equations: predictor – corrector method, Runge – Kutta methods. **References** [1] An introduction to Numerical Analysis, 2nd Edition, Kendall Atkinson, Wiley 2012 [2] Numerical Methods for Scientists and Engineers, H. M. Antia, Hindustan Book Agency 2012. [3] Numerical Recipes in Fortran, 2nd Edition, W. H. Press et al., Cambridge University Press 2000
VI	P601 (Ma) 4 (60 hrs) **Atoms, Molecules and Nuclear Physics - 1**	Atomic Physics: • Atomic energy levels, electron states in atoms, hydrogen-like energy levels, self-consistent field, Thomas-Fermi statistical model, Periodic table of Mendeleev, Evaluation of the potential, Variational method, Helium atom, Atomic structure and Hund's rules, fine structure and hyperfine structure in one-electron atoms • Multi-electron atoms: doublet separation, doublet intensity in alkali atoms, Zeeman effect in weak and strong magnetic field, Stark effect, Paschen-Back effect, para and ortho states in two-electron atoms, spin wavefunctions, level scheme of two-electron atoms Molecular Physics: • Molecules: classification of energy levels, Born-Oppenheimer approximation, hydrogen molecular ion, hydrogen molecule, electronic spectra of diatomic molecules, von-Neumann Wigner non-crossing rule, rotational and vibrational levels, electronic spin and Hund's cases, Franck-Condon principle, effect of nuclear identity, qualitative discussion of molecular spectra of polyatomic molecules, inversion spectrum of ammonia, interaction between vibration and rotation of molecules Nuclear Physics: • Basic Notions: Nuclear mass, binding energy; nuclear densities and radii; angular momentum in the nucleus; electromagnetic moments; radioactive decay properties, radioactive elements, decay chains; radioactive dating. • nuclear Interactions: alpha decay and its kinematics,

		dynamics of alpha – decay process, barrier penetration and Gamow states; beta decay and its properties, Fermi theory of beta decay, neutrinos, symmetry breaking in beta decay; gamma decay, kinematics of photon emission, electromagnetic interaction Hamiltonian in minimal coupling, one photon emission and absorption (dipole approximation), multipole radiation. • Introductory Nuclear Structure: Liquid drop model, semi-empirical mass formula, nuclear stability, line of stability and drip lines, nuclear fission and its basic properties, fission barrier; spherical shell model, mean field concept, spin – orbit interaction and magic numbers; nuclei with small deformation, axially symmetric modified deformed oscillator potential and single particle states. • Introduction to Nuclear Reactions: Elementary kinematics and conservation laws, types of nuclear reactions, reaction channels, cross sections, centre of mass and laboratory frames, Rutherford scattering. **References:** [1] L. D. Landau and E. M. Lifshitz, Quantum Mechanics (Pergamon press, 1965). [2] B. H. Bransden and C. Joachain, Physics of atoms and molecules (Pearson, 2003). [3] F. Schwabl, Quantum mechanics (Springer, 1992). [4] G. Herzberg, Molecular spectra and molecular structure (Springer, 2013). [5] Spectra of atoms and molecules, P. H. Bernath (Oxford, 2010). [6] Basic Ideas and Concepts in Nuclear Physics: An Introductory Approach, K. Heyde, 3rd Edition, Institute of Physics Publishing, Bristol, 2010. [7] Introduction to Nuclear Reactions, C. A. Bertulani and P. Danielewicz, Institute of Physics Publishing, Bristol, 2004. [8] Shapes and Shells in Nuclear Structure, S. G. Nilsson and I. Ragnarsson, Cambridge University Press, 2005. [9] Nuclear Structure (Volumes 1 and 2), A. N. Bohr and Ben R. Mottelson, World Scientific, 1998.
	P602 (Ma/Mi) 4 (60 hrs) **Solid State Physics - I**	▪ Crystal Structure and X-ray diffraction: Bravais lattices, space groups, reciprocal space, Brillouin zones, X-ray diffraction, structure factor, Diffraction of waves in periodic structures. ▪ Lattice Vibrations: Thermal properties: Einstein's and Debye's theories of specific heats of solids, thermal expansion and thermal conductivity, quantization of lattice vibrations, phonons. ▪ The Free Electron Theory: Drude Model: Electron conductivity, Heat capacity, Somerfield model: Thermal conductivity, AC conductivity and optical properties. ▪ Band theory of solids: Bloch theorem, Kronig-Penny model, Nearly Free electron model, effective mass, Tight binding model, Density of states, Fermi surface; Metals,

		insulators and semiconductors, Intrinsic and extrinsic semiconductors, energy gap, mobility, electrons and holes, Hall effect and cyclotron resonance, carrier lifetime, semiconductor devices. ▪ Magnetic properties of materials: dia, para and ferromagnetism. Quantum theory of paramagnetism, Curie's law. Ferromagnetism, exchange interactions, Heisenberg and Ising models, magnetic ordering and spin waves, anti-ferromagnets. ▪ Superconductivity: Introduction and important properties, Type-I and type-II superconductors, Electrodynamics of superconductivity: London's equation, Thermodynamics of the transition, Flux Quantization, Cooper pairs, BCS theory (qualitative), Josephson effect. **References:** [1] Introduction to Solid State Physics, 8th edition, C. Kittel, Wiley (2012). [2] Solid State Physics, N. W. Ashcroft and N. D. Mermin, Cengage (2003).
	PL601 (OJT) 4 (120 hrs) **Physics Labs -VI**	• Study of Chaos: Non-linear coupled Mechanical Oscillators • Study of Chaos: Non-linear coupled Electronic Oscillator – Chua Circuit; Feigenbaum Circuit • Lock-in Amplifier (LIA): Study of principle of LIA • LIA using commercial IC and its application for measurement of small mutual coupling of two coils. • Study of pulse transmission in a coaxial cable and determination characteristics of the cable. • Hardware simulation of electrical transmission line and study of standing waves. • Thermo-emf, Peltier cooling, thermocouple, temperature sensors. • Automation using Raspberry Pi and observation of Neutral Temperature and Inversion Temperature in Cu-Fe thermocouple. **References** [1] The Art of Experimental Physics, D. W. Preston and D. R. Dietz, Wiley 1991. [2] A Manual of Experiments in Physics, R. Srinvasan et al., (Science Academies of India).