The National College

Department of Post-Graduate Studies in Physics
Jayanagar, Bangalore-70

Approved Syllabus for M.Sc. Physics
OBE- CBCS Scheme
Effective from 2021-2022 Academic Year

Details of the Courses and Credits for the four Semesters:

Semester	Theory (Hardcore)	Credits	Theory Soft Core/Open Elective	Credits	Labs	Credits	Total
I	4	4 x 4 = 16	Soft core-1	1 x 2 = 2	2	2 x 4 = 8	26
II	4	4 x 4 = 16	Soft core-1	1 x 2 = 2	2	2 x 4 = 8	26
III	4	4 x 4 = 16	Open Elective and Project	1 x 2 = 2	2	2 x 4 = 8	26
IV	4	4 x 4 = 16	Project	1 x 2 = 2	1	1 x 4 = 4	22
Total number of credits for the 4 Semester M.Sc. course							100

Total Marks for the 4 semester:
I Semester –700 marks
II Semester – 700 marks
III Semester – 700 marks
IV Semester – 600 marks

Grand Total -- 2700 marks

COURSE DETAILS:

I Semester: 4 Theory (Hardcore)+ 1Theory (soft core) + 2 Labs = 26 credits

Paper Code	Paper Title	Credits	Exam Max. Marks	Internal Assessment marks	Total
P 101	Classical Mechanics	4	70	30	100
P 102	Electronic Circuits and Devices	4	70	30	100
P 103	Quantum Mechanics- I	4	70	30	100
P 104	Mathematical Methods of Physics	4	70	30	100
P 105	Soft Core : Experimental Techniques in Physics	2	70	30	100
P 106 a	General Physics Lab-1	2	35	15	50
P 106 b	General Physics Lab-2	2	35	15	50
P 107 a	Electronics Lab 1	2	35	10	50
107 b	Electronics Lab 2	2	35	15	50

Total Marks: 700

II Semester: 4 Theory (Hardcore)+ 1Theory (soft core) + 2 Labs = 26 credits

Paper Code	Paper Title	Credits	Exam Max. Marks	Internal Assessment marks	Total
P 201	Statistical Mechanics & Thermodynamics	4	70	30	100
P 202	Electrodynamics& Plasma Physics	4	70	30	100
P 203	Quantum Mechanics- II	4	70	30	100
P 204	Numerical Analysis and Computational Physics	4	70	30	100
P 205	Soft Core : Radiation Biophysics & Medical Instrumentation	2	70	30	100
P 206 a	General Physics Lab-3	2	35	15	50
P 206 b	General Physics Lab-4	2	35	15	50
P 207 a	Computer Lab 1	2	35	15	50
P 208 b	Computer Lab 2	2	35	15	50

Total Marks: 700

III Semester: 4Theory (Hardcore)+ 1Theory (Open elective) + 2 Lab = 24 credits

Paper Code	Paper Title	Credits	Exam Max. Marks	Internal Assessment marks	Total
P 301	Atomic and Molecular Physics	4	70	30	100
P 302	Condensed Matter Physics	4	70	30	100
P 303	Nuclear and Particle Physics	4	70	30	100
P 304	Elective-1 (One course to be opted from the group) P304-E1 : Atmospheric & Space Physics P304-E2 : Material Science P 304-E3: Astrophysics	4	70	30	100
P 305	Open Elective Understanding the physical world	4	70	30	100
P 306 (a)	Advanced Physics Lab-I	2	35	15	50
P 306 (b)	Advanced Physics Lab-I	2	35	15	50
P 307	Project	2	100		100
				Total Marks	**700**

IV Semester: 4 Theory (Hardcore) + 2 Lab = 24 credits

Paper Code	Paper Title	Credits	Exam Max. Marks	Internal Assessment marks	Total
P 401	Lasers and Non-Linear Optics	4	70	30	100
P 402	Elective-2(one course to be opted from the group) P402-E4: Advanced Atomic, Molecular and Optical Physics P402-E5: Advanced Materials Science P402-E6: Advanced Mathematical Methods of Physics P402 E7: Advanced Nuclear and Neutron Physics	4	70	30	100
P 403	Elective-3 (One course to be opted from the group) P403-E8: Space and Cloud Physics P403-E9: Physics of Solids P403-E10:Crystal and Semiconductor Physics	4	70	30	100
P 404	Electives-4 (One course to be opted from the group) P404-E11: Properties And Applications Of Thin Films P404-E12: Physics of Nanomaterials P404-E13: Photonics	4	70	30	100
P 405 (a)	Advanced Physics Lab-II	2	35	15	50
P 405 (b)	Advanced Physics Lab-II	2	35	15	50
P 406	Project	4	100		100
		22		Total Marks	**600**

Learning Outcomes

The key learning outcomes of our course are: knowledge and understanding of the concepts, logical as well as abstract thinking and analytical approach, experimental and computational skills, research methodology, values and positive attitude.

Postgraduates should have developed following qualities

Sl. No.	Programme Outcomes
1.	Understanding of basic and advanced concepts in Physics
2.	Theoretical and practical skills along with problem solving ability
3.	Logical, abstract thinking and analytical approach
4.	Ability to apply acquired knowledge and skills to the new and unknown situations to develop new theories, experiments, and technology
5.	Understand the nature in a better way
6.	Understand and appreciate the nuances and beauties in science education
7.	Tenacity, hardworking and ability to work against odds
8.	A new perspective to look at everything from 'Physics' point of view
9.	Get introduced to work environment at industrial scale and at research level
10.	Awareness of the impact of Physics in social, economic and environmental issues.
11.	Willingness to take up responsibility in study and work; confidence in his/her capabilities; and motivation for life-long learning.

I SEMESTER

Paper Code: P101

Paper Title: Classical Mechanics

Number of Credits: 04

Course Outcomes: **After the completion of the course, students will be able to:**	**Suggested Pedagogical Processes:**
1. Setup Lagrangian, for the system and able to solve equations of motion. Further they are exposed to simply the equations using Hamiltonian and Canonical Transformations. 2. Application of Eulers equation like geodesics and brachistochrone problem. 3. The macroscopic and microscopic orbits of particles and hence evaluate certain parameters that are conserved in the Central force field. 4. Study the concept of moment of inertia which in turn describe the nature of motion of planets.	• Lecture cum demonstration methods. • ICT based learning • Demonstration experiments • Group discussion & Problem-solving methods • Hands on experiments related to courses. • Pre-recorded lectures & Open book tests • Study visits at facility centers at universities and national research institutes. • Seminars on different topics

	Title and Content	**No of Lecture Hours**
Unit I	**Classical Formalism** **Lagrangian Formulation**: Constraints and their classification, degrees of freedom, generalized co-ordinates, virtual displacement, D'Alembert's principle, Lagrange's equations of motion of the second kind. **Hamiltonian formulation**: Generalized momenta, canonical variables, Legendre transformation and the Hamilton's equations of motion. **Canonical transformation**: Generating functions (four basic types), examples of canonical transformations, the harmonic oscillator in one dimension, Poisson brackets, equations of motion in terms of Poisson brackets, properties of Poisson brackets (anti-symmetry, linearity and Jacobi identity), Poisson brackets of angular momentum.	**13 Hours**
Unit-II	**Calculus of variations and Non-linear methods:** Concept of variation, Euler's equation, Missing dependent variables, Applications of the Euler equation, Several independent variables, Hamilton's principle and Lagrange's equations, Lagrangian multipliers, Examples. Autonomous and non-autonomous systems, fixed points, their classification, phase space trajectories, limit cycle motion, logistic map	**13 Hours**
Unit-III	**Central forces & Non- central Forces**: Reduction of two particle equations of motion to the equivalent one-body problem, reduced mass of the system, conservation theorems (First integrals of the motion),equations of motion for the orbit, classification of orbits, conditions for closed orbits, the Kepler problem (inverse square law force). **Motion in non-central reference frames**: Motion of a particle in a general non-inertial frame of reference, notion of pseudo forces, equations of motion in a rotating frame of reference, the Coriolis force, deviation due east of a falling body, the Foucault pendulum	**13 Hours**
Unit-IV	**Rigid body dynamics**: Degrees of freedom of a free rigid body, angular momentum and kinetic energy of a rigid body, moment of inertia tensor, principal moments of inertia, classification of rigid bodies as spherical, symmetric and asymmetric, Euler's equations of motion for a rigid body, Torque free motion of a rigid body.	**13 Hours**

	Small oscillations: Types of equilibria, quadratic forms for kinetic and potential energies of a system in equilibrium, Lagrange's equations of motion, normal modes and normal frequencies, examples of (i) longitudinal vibrations of two coupled harmonic oscillators, (ii) Normal modes and normal frequencies of a linear, symmetric, triatomic molecule.	

References

1. Classical mechanics, H. Goldstein, C. Poole, J. Saflco, 3rd edition, Pearson Education Inc.(2002).
2. Classical mechanics, K. N. Srinivasa Rao, University Press (2003).
3. Classical mechanics, N. C. Rana and P. S. Joag, Tata McGraw-Hill (1991).
4. Classical dynamics of particles and systems, J. B. Marian, Academic Press (1970)
5. Classical mechanics, L. D. Landau and E. M. Lifshitz, 4th edition, Pergamon press (1985).
6. Mathematical Methods for Physicists – G. B. Arfken and H. Weber, Seventh Edition, Academic Press, 2012
7. Introduction to Classical Mechanics, R.G. Takawale and P.S. Puranik, Tata McGraw- Hill (1979).

Paper Code: P102 Paper Title: Electronic Circuits & Devices Number of Credits: 04	
Course Outcomes: **After the completion of the course, students will be able to:** 1. Understand the basic concepts of semiconducting devices. 2. Analysis of Op-amp (analog circuits) using IC741. 3. Explore on the digital circuits and understand the physical aspects of flip-flops. 4. Learn the underlying concepts on RAM and ROM.	**Suggested Pedagogical Processes:** • Lecture cum demonstration methods. • ICT based learning • Demonstration experiments • Group discussion & Problem-solving methods • Hands on experiments related to courses. • Pre-recorded lectures & Open book tests • Study visits at facility centers at universities and national research institutes. • Seminars on different topics

	Title and Content	No of Lecture Hours
Unit I	**Physics of devices**: p-n junction, abrupt junction – band structure – thermal equilibrium – Depletion region – depletion capacitance – current and voltage characteristics – BJT – band Structure - transistor action – static characteristics. JFET structure, working, characteristics. MOS structure – MOSFET working – MOSFET characteristics – width of depletion region – Junction capacitance-threshold voltage. Metal semiconductor contacts – ohmic and Schottky Contacts. Principle of operation of photoelectronic devices: photoconductor – efficiency, current gain, response time.	**13 Hours**
Unit-II	**Operational amplifiers**: Block diagram of an operational amplifier – Characteristics of an ideal operational amplifier – comparison with 741 – Operational amplifier as a open loop amplifier - Limitations of open loop configuration – Operational amplifier as a feedback amplifier: closed loop gain, input impedance, output impedance of inverting and non-inverting amplifiers - Voltage follower - Differential amplifier: voltage gain. Applications of op-amp: Linear applications – Phase and frequency response of low pass, high pass and band pass filters (first order), summing amplifier – inverting and non-inverting configurations, subtractor, difference summing amplifier, ideal and practical Differentiator, Integrator. Non – linear applications: comparators, positive and negative clippers, positive and negative clampers, small signal half wave rectifiers	**13 Hours**
Unit-III	**Digital circuits**: Review of gates (AND, OR, NAND, NOR, NOT, EX-OR), - Boolean laws and Theorems – simplification of SOP equations – Simplification of POS equations - Simplification using Karnaugh Map technique (4 variables)-conversion of binary to Grey Code - Flip flops: Latch using NAND and NOR gates- RS flip flop , clocked RS flip flop, JK Flip flop, JK master slave flip flop - racing –Shift Registers basics - Counters: Ripple counters truth Table-timing diagram, Synchronous counters-truth table-timing diagram, Decade counters.	**13 Hours**
Unit-IV	**Digital to Analog converters**: ladder and weighted resistor types. Analog to digital Converters-counter method, successive approximation and dual slope converter. Application of DACs and ADCs. Read Only Memory (ROM) and applications, Random Access Memory (RAM) and Applications. Microprocessors and Microcontrollers basics	**13 Hours**

References

1. Semiconductor Devices Physics and Technology, S M Sze, (Second Edition, 2002), John Wiley and Sons Inc. Asia.
2. Solid State Electronic Devices, Ben G Streetman, Sanjay Banerjee, (Fifth edition, 2000),

Pearson Education, Asia.
3. Semiconductor Optoelectronic Devices, Pallab Bhattacharya, (Second Edition, 1997), Pearson education, Asia.
4. The art of electronics, Paul Horowitz and Winfield Hill, (Second Edition, 1992), Foundation Books, New Delhi.
5. Electronic Principles, A P Malvino, (Sixth Edition, 1999), Tata McGraw Hill, New Delhi.
6. Op-Amps and Linear Integrated Circuits, Ramakant A Gayakwad, (Third Edition, 2004), Eastern Economy Edition.
7. Operational Amplifiers with Linear Integrated Circuits, William Stanley, (1988), CBS Publishers and Distributors.
8. Linear Integrated Circuits, D Roy Choudhury and Shail Jain, ((1991), New Age International (P) Limited.
9. Digital principles and applications, Donald P Leach and Albert Paul Malvino, (Fifth Edition,2002), Tata McGraw Hill.

Paper Code: P103
Paper Title: Quantum Mechanics- I
Number of Credits: 04

Course Outcomes:	**Suggested Pedagogical Processes:**
After the completion of the course, students will be able to: 1. Understand the underlying concepts of quantum mechanics. 2. Time independent Schrodinger Wave equation for different potentials. 3. A preliminary concept on Dirac's dual spaces and Formalism. 4. Exploration on different types of angular momentums viz., orbital and spin angular momentum.	• Lecture cum demonstration methods. • ICT based learning • Demonstration experiments • Group discussion & Problem-solving methods • Hands on experiments related to courses. • Pre-recorded lectures & Open book tests • Study visits at facility centers at universities and national research institutes. • Seminars on different topics

	Title and Content	**No of Lecture Hours**
Unit I	**Introductory concepts:** wave-particle duality, The wave function and its interpretation, free particle wave function, Wave packets, Gaussian wave packet evolution, Heisenberg Uncertainty principle and illustrations, Time - energy uncertainty, complementarity principle Time dependent Schrodinger equation, Conservation of probability, expectation values and operators, Ehrenfest's theorems, Time-independent Schrodinger equation, stationary states, energy quantization, properties of the energy eigenfuntions, general solution for a time-independent potential, Schrodinger equation in momentum space	**13 Hours**
Unit-II	**One-dimensional problems** Free-particle solution, momentum eigen functions, box normalization, particle in square well potential, transmission through a potential barrier, simple harmonic oscillator.	**13 Hours**
Unit-III	**General formalism of quantum theory: operator methods** Review on linear vector spaces and matrices, Hilbert space and observables, linear operators and observables, Dirac notation, degeneracy and simultaneous observables, generalized uncertainty principle for two non-commuting observables, Unitary dynamics, projection operators and measurements, time-dependence of observables: Schrodinger, Heisenberg and interaction pictures, Simple harmonic oscillator by operator method	**13 Hours**
Unit-IV	**Angular momentum:** Orbital angular momentum commutation relations, Eigen values and eigen functions. General operator algebra of angular momentum operators Jx, Jy, Jz. Ladder operators, Eigenvalues and eigenkets of J2 and Jz, Matrix representations of angular momentum operators, Pauli matrices, Addition of angular momentum, Clebsch-Gordan coefficients, computation of Clebsch-Gordan coefficients in simple cases (j1 = j2=1/2).	**13 Hours**

References

1. Introduction to Quantum Mechanics – David J. Griffiths, Second Edition, Pearson PrenticeHall 2005.
2. Quantum Physics – H.C. Verma, Surya Publication, 2012
3. Quantum Mechanics – Aruldhas
4. Quantum Mechanics – V.K. Thankappan, Second Edition, Wiley Eastern Limited, 1993.
5. Quantum Mechanics Vol I & II – C. Cohen-Tannoudji, B. Diu and F. Laloe, SecondEdition, Wiley Inter science Publication, 1977.
6. Quantum Mechanics- L.I. Schiff, Third Edition, McGraw Hill Book Company, 1955.
7. Quantum Mechanics – B.H. Bransden and C.J. Joachain, Second Edition, PearsonEducation, 2007.
8. Modern Quantum Mechanics – J.J. Sakurai, Revised Edition, Addison-Wesley, 1995.

9. Principles of Quantum Mechanics - R. Shankar, Second Edition, Springer, 1994.
10. Quantum Mechanics – E. Merzbacher, John Wiley and Sons, 1998.
11. Quantum Physics – S. Gasiorowicz, John Wiley and Sons.
12. Linear Algebra – Seymour Lipschutz, Schaum Outlines Series

Paper Code: P104
Paper Title: Mathematical Methods of Physics- I
Number of Credits: 04

Course Outcomes:	Suggested Pedagogical Processes:
After the completion of the course, students will be able to: 1. Application of Integral Transformations for different functions. 2. Understand the concepts which uses complex functions. 3. Solve and analyze PDEs of Two Dimensions. 4. Understand the nature of ODEs and solution of particular types of ODEs.	• Lecture cum demonstration methods. • ICT based learning • Demonstration experiments • Group discussion & Problem-solving methods • Hands on experiments related to courses. • Pre-recorded lectures & Open book tests • Study visits at facility centers at universities and national research institutes. • Seminars on different topics

Title and Content		**No of Lecture Hours**
Unit I	**UNIT - I: Integral Transforms: Fourier** Transforms: Properties of Fourier transforms – Fourier sine and cosine transforms- Power in Fourier series – Modulation theorem, Fourier transform of impulse function, Constants, Unit step function and Periodic (square wave, triangular wave &sawtooth wave) functions. Laplace Transforms: Definition and notation – Properties of Laplace transforms – Laplace transforms of Dirac delta function and periodic functions (Square wave, sawtooth wave and triangular wave) – Inverse Laplace transforms – properties – Solution of linear differential equations with constant coefficients	**13 Hours**
Unit-II	**UNIT – II: Complex Variables Functions** – Complex differentiation - Analytic function - Cauchy – Reimann equations –Derivatives of elementary functions – Singular points and classification. Complex integration - Cauchy's theorem – Integrals of special functions – Cauchy's integral formula – Taylor's and Lorentz theorem (statements only) – Residues, calculations of residues - Residue theorem – evaluation of definite integrals	**13 Hours**
Unit-III	**UNIT - III: Partial Differentiations Equations**: Review of ODE's- Properties of Dirac delta Function, Laplace equation – Method of separation of variables – Application of Laplace equation to two dimensional steady state of heat flow in a thin rectangular plate and a long cylinder. Wave equation in two dimensions – Application to the vibration of a rectangular membrane and circular membrane	**13 Hours**
Unit-IV	**UNIT - IV: Special Functions Beta and Gamma Functions** – Definitions and properties – Evaluation of integrals, Legendre, Bessel and Hermite differential equations – Solutions – Generating functions – Orthogonal properties of Legendre, Bessel and Hermite Functions – Recurrence relations - (Proof for Legendre polynomials only)	**13 Hours**

References

1. Mathematical Methods for Physicists – G. B. Arfken and H. Weber, Seventh Edition, Academic Press, 2012
2. Mathematical methods of physics - J. Mathews and R. L. Walker, Second Edition, Addison-Wesley
3. Mathematical Methods in the Physical Science- Mary L Boas, Wiley Publication, (2005)
4. Functions for Scientists and Engineers, W.W. Bell, Van Nostrand Co., London (1968).
5. Fourier Analysis, Hsu P. Jewi, Unitech Division.
6. Laplace Transforms, Murray Spiegle, Schaum's outline series, McGraw Hill, New York.
7. Applied Mathematics for Engineers, Pipes and Harval, III Edition, McGraw Hill Books Co.
8. Theory and Properties of Complex Variables, S. Lipschutz, Schaum's Series, McGraw Hill.
9. Mathematical Physics, H.K. Das and Ramaverma, S. Chand & Co. Ltd., New Delhi (2011).
10. Mathematical Physics, B. Bhattacharyya, New Central Book Agency Pvt. Ltd., (2010).

Paper Code: P105
Paper Title: Experimental Techniques in Physics
Number of Credits: 03

Course Outcomes: **After the completion of the course, students will be able to:** 1. Understand the safety measures of the working environment as well as hazardous radiations. 2. A preliminary courseware on vacuum techniques and overview of thinfilms. 3. Exposure towards the computational data analysis.	**Suggested Pedagogical Processes:** • Lecture cum demonstration methods. • ICT based learning • Demonstration experiments • Group discussion & Problem-solving methods • Hands on experiments related to courses. • Pre-recorded lectures & Open book tests • Study visits at facility centers at universities and national research institutes. • Seminars on different topics

	Title and Content	**No of Lecture Hours**
Unit I	**Safety measures in Experimental Physics** Occupational health and safety, chemical substances, radiation safety, general electrical testing standards, General laboratory and workshop practice. **Instrumentation Electronics** Transducers, Transducer characteristics, selection of an instrumentation transducer, Transducer as an electrical element, modelling external circuit components, circuit calculations, ac and dc bridge measurements.	**13 Hours**
Unit-II	**Vacuum techniques** Units of pressure measurement, characteristics of vacuum, applications of vacuum, Vacuum pumps: Rotary, oil diffusion, turbo molecular pumps, Ion pumps. Vacuum gauges: Pirani and Penning gauges. Pumping speed of a vacuum pump. **Thin film techniques** Thin film techniques(overview), film thickness monitors, film thickness measurement. **Measurement of low temperature** Resistance, thermometers, thermocouples	**13 Hours**
Unit-III	**Error and Computational Analysis.** **Physical measurement** Measurement, result of a measurement, sources of uncertainty and experimental error, Systematic error, random error, Reliability- chi square test, Analysis of repeated measurement, Precision and accuracy, Elementary data fitting. Gaussian Fit, Lorentz Fit, Voigt profile, FWHM, Softwares for Data Analysis – Maple, Mathematica, Origin Pro (Qualitative)	**13 Hours**

References

1. Measurement, Instrumentation and Experimental design in Physics and Engineering-
2. Michael Sayer and AbhaiMansingh, Prentice Hall of India 2005
3. Data Reduction and Error Analysis for the Physical Sciences, P.R. Bevington and K.D Robinson, McGraw Hill, 2003
4. Electronic Instrumentation- H.S. Kalsi, TMH Publishing Co. Ltd. 1997
5. Instrumentation Devices and Systems-C.S. Rangan, G.R. Sharma, V.S.V. Mani, 2nd Edition, Tata McGraw Hill, New Delhi, 1997
6. Instrumentation Measurement Analysis-B.C. Nakra, K.K. Chaudhary.

II SEMESTER

Paper Code: P201
Paper Title: Statistical Mechanics & Thermodynamics
Number of Credits: 04

Course Outcomes:	Suggested Pedagogical Processes:
After the completion of the course, students will be able to: 1. Different forms of energy in the thermodynamic system and their inter-relations. 2. The concept of hypothetical ensembles to build the bridge between the thermodynamic and statistical mechanics. 3. Different types of distributions available for bosons and their condensation. 4. Different types of distributions available for fermions and behavior of parameter in the non-equilibrium system.	• Lecture cum demonstration methods. • ICT based learning • Demonstration experiments • Group discussion & Problem-solving methods • Hands on experiments related to courses. • Pre-recorded lectures & Open book tests • Study visits at facility centers at universities and national research institutes. • Seminars on different topics

	Title and Content	No of Lecture Hours
Unit I	**Thermodynamics:** Postulates of equilibrium thermodynamics, Intensive and extensive variables, Thermodynamic definition of Entropy –Calculation of entropy changes irreversible processes, Equilibrium between two thermodynamic systems, Thermodynamic potentials –Enthalpy, Helmholtz and the Gibbs functions, The Maxwell relations, Exergy Analysis	**13 Hours**
Unit-II	**Statistical Formulation :** Phase space – Concept of ensembles – Types of ensembles - Ensemble average - Liouville's Theorem – Micro canonical ensemble: ideal gas – Gibb's paradox – Entropy and probability – Canonical ensemble – Ideal gas in canonical ensemble – Grand canonical ensemble – Ideal gas in grand canonical ensemble – Comparison of various ensembles. Canonical partition function	**13 Hours**
Unit-III	**Maxwell – Boltzmann and Bose – Einstein Statistics** Maxwell - Boltzmann distribution - Distribution of velocities – Experimental verification - Calculation of mean values – Equipartition theorem. Bose – Einstein distribution, Bose – Einstein condensation, Black body radiation and the Planck's radiation law - Dulong and Petit's law - Einstein and Debye's theories of heat capacities.	**13 Hours**
Unit-IV	**Fermi – Dirac Statistics & Fluctuations** Fermi - Dirac distribution – Electrons in metals – Thermionic emission – Magnetic susceptibility of free electrons. Fluctuations in ensembles, Onsagar's one dimensional and reciprocal rotations and their applications to thermoelectric phenomena, Kelvin's first and second equations: One dimensional random walk – Random walk and Brownian motion.	**13 Hours**

References

1. K. Huang, Statistical Mechanics,Wiley Eastern Limited, New Delhi, (1963).
2. F. Reif, Fundamentals of Statistical and Thermal Physics, McGraw Hill, Singapore(1985).
3. R.K. Pathria, Statistical Mechanics, Bufferworgh Heinemann (2ndEdition)
4. Silvio R A Salinas, Introduction to Statistical Physics, Springer, (2001)
5. B.B.Laud, Fundamentals of Statistical Mechanics, New Age International Publication
6. Statistical Physics, Bhattacharjee
7. Thermal Physics, Kittel and Kremer
8. Statistical Mechanics, B.K. Agarwal, Melvin Eisner, 2nd Edition, New Age International (P)Ltd.
9. Statistical Mechanics and properties of Matter by ESR Gopal — Student Edition (EllisHorwood)

Paper Code: P202
Paper Title: Electrodynamics & Plasma Physics
Number of Credits: 04

Course Outcomes:	**Suggested Pedagogical Processes:**
After the completion of the course, students will be able to: 1. Understand the preliminary concepts on electrostatics and magnetostatics. 2. Analysis of Maxwell's equations and its applications. 3. Understand the interaction of Lienard- Wiechert Potential and Review of Lorentz transformations. 4. Understand the electromagnetic wave interaction in an electrical fluid.	• Lecture cum demonstration methods. • ICT based learning • Demonstration experiments • Group discussion & Problem-solving methods • Hands on experiments related to courses. • Pre-recorded lectures & Open book tests • Study visits at facility centers at universities and national research institutes. • Seminars on different topics

Title and Content		**No of Lecture Hours**
Unit I	**Electrostatics and Magnetostatics**: Gauss's law and applications, Electric potential, Poisson's equations, Work, Energy in electrostatics, Laplace and Laplace's equation in one, two and three dimension cartesian co-ordinates, boundary conditions and uniqueness theorem, Method of images with applications, Multipole expansion of potential, Dipole field, Field inside dielectrics, Biot - Savart law and applications, Ampere's law and applications, Magnetic vector potential, Multipole expansion of the vector potential, Magnetic field inside matter.	**13 Hours**
Unit-II	**Electrodynamics and Electromagnetic waves**: Review of Maxwell's equations, scalar and vector potentials, Gauge transformations, Coulomb and Lorentz gauges, energy and momentum of c waves, propagation through linear media, reflection and transmission of electromagnetic waves, plane waves in conducting media, dispersion in non-conductors, wave guides, TE waves in rectangular wave guide.	**13 Hours**
Unit-III	**Electromagnetic Radiation**: Fundamentals of Radiation: Waves in Free space, Radiation & Reception. **Radiation effects:** Reflection, Refraction, Interference of electromagnetic waves & Diffraction of radio waves. **Interaction of electromagnetic radiation:** Retarded potentials, electric and magnetic dipole radiation, Lienard -Wiechert potentials, fields of a point charge in motion, power radiated by a point charge, Review of Lorentz transformations. **Propagation of Electromagnetic Radiation:** Ground wave, Sky- wave, Space wave, Extra-terrestrial Communication	**13 Hours**
Unit-IV	**Plasma physics**. Definition of Plasma, Debye shielding, charged particle motion in electric and magnetic fields at right angles, time varying E and B fields, Adiabatic invariants, Dielectric constant of a plasma, the equations of motion of a plasma fluid, Drift velocities, plasma oscillations, plasma waves, propagation of electromagnetic waves in plasma.	**13 Hours**

References

1. Introduction to electrodynamics, D.J. Griffths, PHI, Third Edition.(2004).
2. Electromagnetics, B.B. Laud, New Age International PVT. LTD.(1987).
3. Electromagnetic fields and waves. P. Lorrain and D. Corson, CBS (1986)
4. Electromagnetism, I.S Grant and W.R Phillips, John Wiley and Sons Ltd.(1975).
5. Electromagnetism, Pramanik, PHI
6. Electronic Communication Systems, George Kennedy & Bernard Davis, Fourth Edition, TMH Publication, (1999)

Paper Code: P203
Paper Title: Quantum Mechanics- II
Number of Credits: 04

Course Outcomes:	**Suggested Pedagogical Processes:**
After the completion of the course, students will be able to: 1. Exposure towards the fundamental correction factors for time independent quantum system. 2. Elucidate on understanding the second and third order correction factors contributing towards Scattering Phenomena. 3. Distinguish between Continuous and Discrete symmetries and further emphasize on fundamental quantum systems. 4. Explore on the relativistic quantum mechanics.	• Lecture cum demonstration methods. • ICT based learning • Demonstration experiments • Group discussion & Problem-solving methods • Hands on experiments related to courses. • Pre-recorded lectures & Open book tests • Study visits at facility centers at universities and national research institutes. • Seminars on different topics

	Title and Content	**No of Lecture Hours**
Unit I	**Approximation methods for stationary problems** Time independent perturbation theory*:* Time independent perturbation theory for a non-degenerate energy level, time independent perturbation theory for a degenerate energy level, Applications: (1) one dimensional harmonic oscillator subjected to a perturbing potential in x, x_2 and x_3.Variational Method*:* Bound states (Ritz Method), Expectation value of the energy, ground state of Helium WKB approximation: the ―classical region‖, connection formulae, tunneling	**13 Hours**
Unit-II	**Time dependent perturbation theory**: Statement of the problem, approximate solution of the Schrodinger equation, constant perturbation, harmonic perturbation, transition to a continuum, the Fermi golden rule **Scattering theory**: The scattering experiment, relationship of the scattering cross section to the wave function, scattering amplitude and scattering cross-section, Born approximation, scattering by a spherically symmetric potential, cross-section for scattering in a screened, coulomb potential, validity of Born's approximation.	**13 Hours**
Unit-III	**Symmetry principles and conservation laws** Continuous symmetries: Spatial translation symmetry and conservation of linear momentum, time translation symmetry and conservation in energy, Rotations in Space: Conservation of angular momentum Discrete symmetries: Parity, Time reversal, Permutation symmetry, symmetric and antisymmetric wave functions, scattering of identical particles, ortho and para helium states.	**13 Hours**
Unit-IV	**Relativistic quantum mechanics** Klein-Gordan equation for a free relativistic particle, Plane wave solutions, probability density and probability current density. Dirac Hamiltonian for a free relativistic particle, properties of alpha and beta matrices, probability density and probability current, positive and negative energy solutions, orthogonality and completeness of the solutions, intrinsic spin of the Dirac particle, Negative energy sea, gamma matrices, covariant form of Dirac equation.	**13 Hours**

References

1. Introduction to Quantum Mechanics – David J. Griffiths, Second Edition, Pearson Prentice Hall 2005.
2. Quantum Physics – H.C. Verma, Surya Publication, 2012
3. Quantum Mechanics – Aruldhas
4. Quantum Mechanics – V.K. Thankappan, Second Edition, Wiley Eastern Limited, 1993.
5. Quantum Mechanics Vol I & II – C. Cohen-Tannoudji, B. Diu and F. Laloe, Second Edition, Wiley Inter science Publication, 1977.
6. Quantum Mechanics- L.I. Schiff, Third Edition, McGraw Hill Book Company, 1955
7. Quantum Mechanics – B.H. Bransden and C.J. Joachain, Second Edition, Pearson Education, 2007.
8. Modern Quantum Mechanics – J.J. Sakurai, Revised Edition, Addison-Wesley, 1995.
9. Principles of Quantum Mechanics - R. Shankar, Second Edition, Springer, 1994.
10. Quantum Mechanics – E. Merzbacher, John Wiley and Sons, 1998.
11. Quantum Physics – S. Gasiorowicz, John Wiley and Sons.

Paper Code: P204

Paper Title: Numerical Analysis & Computational Physics

Number of Credits: 04

Course Outcomes:	**Suggested Pedagogical Processes:**
After the completion of the course, students will be able to: 1. Solve system of equations, differentiate and integrate functions numerically. 2. Understand the concepts and properties of Probability Distributions and Statistics. 3. Understand the elementary codes and write simple codes for applications. 4. Solve the system of equations, integration of functions and solve ODE using Computational Methods.	• Lecture cum demonstration methods. • ICT based learning • Demonstration experiments • Group discussion & Problem-solving methods • Hands on experiments related to courses. • Pre-recorded lectures & Open book tests • Study visits at facility centers at universities and national research institutes. • Seminars on different topics

	Title and Content	**No of Lecture Hours**
Unit I	**Numerical methods** Interpolation, solution of linear algebraic equations using Gauss elimination method, Curve Fitting by least square fit method, Numerical integration, Trapezoidal and Simpson's rules, Numerical differentiation, Euler and Runge-Kutta methods, Finding roots, bisection method, Newton-Raphson method.	**13 Hours**
Unit-II	**Probability and Statistics** Radom Variables,Fundamental probability laws; permutation and combinations,binomial distributions, Poisson distributions, Gauss normal distribution and general properties of distributions, multivariate Gaussian distributions, Errors of observation and measurements, Fitting of experimental data	**13 Hours**
Unit-III	**Programming-I** Elementary information about digital computer principles, compilers, interpreters and Operating systems, Constants and variables, arithmetic expressions, data types, input and Output statements, control statements, switch statements, the loop statements, format Specifications, arrays, algorithms, flowcharts, functions and some simple programming, Examples in C Programming	**13 Hours**
Unit-IV	**Programming -II** C program for (i) finding roots using Newton-Raphson method, Bisection method, (ii) solving Simultaneous linear algebraic equations, (iii) evaluating integrals using Simpson's and Trapezoidal rules, (iv) solving ordinary differential equations using Euler and Runge-Kutta Method, (v) least square fitting (vi) Lagrange's interpolation	**13 Hours**

References

1. Mathematical methods of physics - J. Mathews and R. L. Walker, Second Edition, Addison-Wesley

2. Mathematical methods for Physicists – G. B. Arfken and H. Weber, Seventh Edition, Academic Press, 2012

3. Introductory Methods of Numerical analysis – S.S. Sastry, Third Edition, Prentice – Hall of India, 2003

4. Programming in ANSI – C, E. Balaguruswamy, Second Edition, Tata McGraw Hill, 1992

5. Computational *Physics* - The University of Texas at Austin

6. Web link: http://www.phys.unsw.edu.au/~mcba/phys2020/#numint

Paper Code: P 205

Paper Title: Radiation Biophysics & Medical Instrumentation

Number of Credits: 02

Course Outcomes:	Suggested Pedagogical Processes:
After the completion of the course, students will be able to: 1. Radiation effects on living systems comprising of biological macromolecules and further introduced to understand the medical applications of radiations. 2. Understand the science of biomedical applications of sensors. 3. Exposure towards the working principle of biomedical lasing devices.	• Lecture cum demonstration methods. • ICT based learning • Demonstration experiments • Group discussion & Problem-solving methods • Hands on experiments related to courses. • Pre-recorded lectures & Open book tests • Study visits at facility centers at universities and national research institutes. • Seminars on different topics

	Title and Content	No of Lecture Hours
Unit I	**Radiation biophysics:** Radiation sources, Interaction of radiation with matter (general discussion), energy transfer process, measurement of radiation, Dosimetry, effect of radiation on living systems, radiation protection and radiation therapy. **Medical applications of nuclear radiations:** Radioisotopes for diagnosis and medicines, gamma camera, positron emission tomography, single photon emission computed tomography (SPECT), principle of magnetic resonance imaging (MRI), boron neutron capture therapy and ion beam in cancer therapy.	**13 Hours**
Unit-II	**Biomedical Applications of Sensors:** Physical Sensors: Variable Resistance Sensor, Strain Gauge, Force & Pressure Measurement, Bio potential Electrodes: Sensing Bioelectric Signals, Electrical Characteristics, pH Sensors, Diagnostic Devices: Mass Spectrometry and Electrophoresis	**13 Hours**
Unit-III	**Medical Instruments:** Bio electrical Devices: Biomedical Lasers- Interaction and Effects of UV IR Laser Radiation on Biological Tissues: Absorption & Scattering process, Effects of Continuous & Pulsed visible laser radiation & Associated Temperature rise. Cardiac Pacemakers- Block diagram of Pacemaker, Pulse Generators, Sensing mechanism and output measurements, Blood Glucose Monitoring- Development of Colorimetric Test Strips, Emergence of Electrochemical Strips and Optical reflectance meters.	**13 Hours**

References

1. Medical Devices & Human Engineering, Joseph D Borinzo & Donald R Peterson, CRC Press,4th Edition, 2016 .
2. Aspects of Biophysics- William Hughes, John Wiley and Sons, 1979
3. Biochemistry of Nucleic acids- Adams et al. Chapman and Hall, 1992

III SEMESTER

<table>
<tr><td colspan="2">Paper Code: P 301
Paper Title: Atomic & Molecular Physics
Number of Credits: 04</td></tr>
<tr><td>Course Outcomes:
After the completion of the course, students will be able to:
1. Describe theories explaining the structure of atoms and the origin of the observed spectra. Identify atomic effect such as Zeeman effect and Stark effect.
2. To understand the fundamental key aspects of rotational and Raman spectroscopy and apply the knowledge in elucidation of spectra.
3. To understand the fundamental aspects of vibrational spectroscopy and to correlate with structure-property relationship.
4. To develop the elementary idea on broadening of spectral lines</td><td>Suggested Pedagogical Processes:
• Lecture cum demonstration methods.
• ICT based learning
• Demonstration experiments
• Group discussion & Problem-solving methods
• Hands on experiments related to courses.
• Pre-recorded lectures & Open book tests
• Study visits at facility centers at universities and national research institutes.
• Seminars on different topics</td></tr>
</table>

Title and Content		No of Lecture Hours
Unit I	**Atomic Physics:** Brief review of early atomic models. Hydrogenic atoms: Energy levels andselection rules, Relativistic corrections and fine structure, hyperfine structure, Lamb shift andisotope shift. Interaction with external fields: Zeeman effect, Paschen-Back effect, Starkeffect. **Two electron atom:** Ortho and para states and role of Pauli's exclusion principle, levelschemes of two electron atoms. Many electron atoms: LS and JJ coupling schemes, Lande interval rule.	13 Hours
Unit-II	**Molecular Physics-A**: Born-Oppenheimer approximation, **Rotational spectroscopy:** Classification of rotors. Diatomic molecule as a rigid rotator, Centrifugal distortion and non –rigid rotator, energy levels and spectra, Intensity of rotational lines, Experimental technique: Microwave Spectrometer. **Raman Spectroscopy:** Raman scattering, Polarizability, Rotational and Vibrational Raman spectroscopy (diatomics). Experimental technique: Laser Raman Spectrometer. Qualitative discussions on CARS and SERS	13 Hours
Unit-III	**Molecular Physics-B**: **Vibrational Spectroscopy:**Diatomic molecule as a simple harmonic oscillator,anharmonicity,effect of anharmonicity on vibrational terms, energy levels and selection rules. Vibrating rotator-energy levels and ro-vibrionic spectra, Experimental technique and IR spectrometry. Applications of IR spectroscopy. Mutual exclusion principle. **Electronic spectra of diatomic molecules:**vibrational coarse structure and rotational finestructure in electronic spectra, intensity of vibrational bands in electronic spectra – Frank-Condon principle.Dissociation and pre-dissociation, Jablonski Diagram	13 Hours
Unit-IV	**Absorption and emission of radiation:** Interaction of radiation with matter: Einstein'scoefficients, Beer's law for attenuation and amplification of light. The width and shape ofspectral lines: natural broadening, Doppler broadening-estimation of half width, Generaltreatment of other broadening mechanisms-collision and power broadening.	13 Hours

References

1. Atomic Spectra and radiative transition – Igor Sobelman, Springer Publication.
2. Physics of atoms and molecules, Bransden and Joachain, (2nd Edition) PearsonEducation,2004
3. Fundamentals of Molecular Spectroscopy, Banwell and McCash, Tata McGraw Hill,1998.
4. Modern Spectroscopy, J.M. Hollas, John Wiley, 1998.
5. Molecular Spectroscopy, Jeanne L. McHale, Pearson Education, 2008
6. Molecular Quantum Mechanics, P.W. Atkins and R.S. Friedman, 3rd Edition, OxfordPress (Indian Edition), 2004.
7. Molecular Structure and Spectroscopy: G. Aruldhas, Prentice Hall of India, New Delhi,2001

Paper Code: P 302 Paper Title: Condensed Matter Physics Number of Credits: 04	
Course Outcomes: **After the completion of the course, studentswill be able to:** 1. An overview on crystal structure and X-ray diffraction. 2. A detailed description of free theory of metals and band theory solids. 3. To understand the physics of semiconductors and superconductors. 4. Gain detailed knowledge on physical aspects of magnetism and dielectrics	**Suggested Pedagogical Processes:** • Lecture cum demonstration methods. • ICT based learning • Demonstration experiments • Group discussion & Problem-solving methods • Hands on experiments related to courses. • Pre-recorded lectures & Open book tests • Study visits at facility centers at universities and national research institutes. • Seminars on different topics

	Title and Content	No of Lecture Hours
Unit I	**Crystal structure:** Crystalline state - periodic arrangement of atoms-lattice translation vectors. The basis and crystal structure, primitive and non-primitive lattice cell-fundamental types oflattice, -2d and 3-d Bravias lattice and crystal systems. Elements of symmetry operations pointsand spacegroups-nomenclature of crystal directions and crystal planes-miller indices. **X-ray diffraction**: Scattering of x-rays, Laue conditions and Bragg's law, atomic scatteringfactor, geometrical structure factor, Reciprocal lattice andits properties.	13 Hours
Unit-II	**Free electron theory of metals:** Free electron model, Electrons moving in one dimensionalpotential well, three-dimensional potential well, quantum state and degeneracy, the density ofstates, theelectronic specific heat. Electrical conductivity of metals, relaxation time and mean free path, electrical conductivity and Ohm's law, Thermal conductivity, Widemann - Franz law, thermionic emission, Hall effect.	13 Hours
Unit-III	**Semiconductors**: Introduction to semiconductors, band structure of semiconductors,Intrinsic and extrinsic semiconductors, expression for carrier concentration (only for intrinsic), ionization energies, charge neutrality equation, conductivity-mobility and their temperaturedependence, Hall effect in semiconductors. **Superconductors**: Critical temperature-persistent current-occurrence of super conductivity idealand non-ideal superconductors-Destruction of super conductivity by magnetic field -Meissner effect- heat capacity-energy gap-microwave and infrared properties- Isotope effect-BCS theory (qualitative)-Josephson tunneling-exotic superconductors- high $T_c$superconductors.	13 Hours
Unit-IV	**Dielectrics**: Introduction, Review of basic formulae, Dielectric constant, and displacement vector -different kinds of polarization-local electric field-Lorentz field-Clausius-Mossatti relation- expressions for electronic, ionic and dipolar polarizability, ferroelectricity and piezo electricity. **Magnetism**: Review of basic formulae -classification of magnetic materials-Langevin theoryof diamagnetism, para-magnetism and Ferromagnetism – domains-Weiss molecular fieldtheory (classical)-Heisenberg exchange interaction theory- Antiferro-magnetism and ferrimagnetism	13 Hours

References

1. A.R. Verma and O.N. Srivastava: Crystallography Applied to Solid State Physics, 2nd edition, New Age International Publishers, 2001
2. Solid State Physics- A. J. Dekker, Macmillan India Ltd., Bangalore, 1981.
3. Solid State Physics- C. Kittel, V Ed., Wiley Eastern Ltd., 1976.
4. Elementary Solid state physics,- M.A. Omar, Addissonwesley, New Delhi,2000.
5. Solid state Physics- S.O. Pillai. New Age International Publication. – 2002.
6. Solid state Physics- M.A. Wahab, Narosa Publishing House, New Delhi.- 1999.
7. Modern theory of Solids- Seitz.
8. Semiconductors Devices-Physics and Technology- S.M. Sze.
9. Introduction to Solids – L. Azoroff.
10. Solid State Physics- H.C. Gupta- Vikas Publishing House, New Delhi.-2002

<table>
<tr><td colspan="3">Paper Code: P 303
Paper Title: Nuclear and Particle Physics
Number of Credits: 04</td></tr>
<tr><td colspan="2">Course Outcomes:
After the completion of the course, studentswill be able to:
1. To understand the basic concept of interaction ofradiation with matter.
2. To emphasize and understand the working principle of nuclear detectors.
3. To learn the nuclear models and nuclear decay.
4. In detail study related to particle physics.</td><td>Suggested Pedagogical Processes:
• Lecture cum demonstration methods.
• ICT based learning
• Demonstration experiments
• Group discussion & Problem-solving methods
• Hands on experiments related to courses.
• Pre-recorded lectures & Open book tests
• Study visits at facility centers at universities and national research institutes.
• Seminars on different topics</td></tr>
<tr><td colspan="2">Title and Content</td><td>No of Lecture Hours</td></tr>
<tr><td>Unit I</td><td>Interaction of nuclear radiation with matter:(a) Interaction of charged particles: Energy loss of heavy charged particles in matter, Bethe-Bloch formula, energy loss of fast electrons, Bremsstrahlung. (b) Interaction of gamma rays: Photoelectric, Compton, and pair production processes. Nuclear forces: Characteristics of nuclear forces, Ground state of the deuteron using square well potential, relation between the range and depth of the potential, Inadequacies of the central force, experimental evidence for the tensor force, magnetic moment and quadrupole moment of the deuteron, deuteron ground state as an admixture of s and d states.</td><td>13 Hours</td></tr>
<tr><td>Unit-II</td><td>Nuclear detectors and Nuclear electronics: Nuclear detectors: Scintillation Detectors-NaI(Tl), Scintillation spectrometer, Semiconductor detectors: Surface barrier detectors, Li ion drifted detectors, relation between the applied voltage and the depletion region in junction detectors. Nuclear electronics: Preamplifiers: voltage and charge sensitive preamplifiers, Linear pulse amplifier, Schmitt trigger as a discriminator, differential (single channel analyzer) & integral discriminators, Analog to digital converters (ADC), multichannel analyzer (MCA): functional block diagram and its working and use in data processing.</td><td>13 Hours</td></tr>
<tr><td>Unit-III</td><td>Nuclear models and Nuclear decay: Nuclear models: Liquid drop model: Semi-empirical mass formula, stability of nuclei against beta decay, mass parabola, Shell model: Evidence for magic numbers, prediction of energy levels in an infinite square well potential, spin-orbit interaction, prediction of ground states pin, parity and magnetic moment of odd-A nuclei, Nordheim's rules.
Beta decay: Fermi's theory of beta decay, Kurie plots and ―ft‖ values, selection rules.
Gamma decay: Multipolarity of gamma rays, Selection rules, Internal conversion (qualitative treatment).</td><td>13 Hours</td></tr>
<tr><td>Unit-IV</td><td>Elementary particle physics: Types of interactions between elementary particles, hadrons and leptons, detection of neutrinos. Symmetries and conservation laws: conservation of energy, momentum, angular momentum, charge and isospin, parity symmetry, violation of parity in weak interactions - handedness of neutrinos, Lepton number conservation, Lepton family and three generations of neutrinos. Charge conjugation symmetry, CP violation in weak interactions, Strange particles, conservation of strangeness in strong</td><td>13 Hours</td></tr>
</table>

	interactions, Baryon number conservation, Gell-Mann Nishijima formula, eight fold way (qualitative only), quark model, quark content of baryons and mesons.	

References

1. Atomic and Nuclear Physics, S N. Ghoshal: Vol. II.,2000.
2. The Atomic Nucleus, Evans R. D.: Tata McGraw Hill, 1955.
3. Nuclear Physics, R. R. Roy and B. P. Nigam: Wiley-Eastern Ltd. 1983.
4. Nuclear Physics- an Introduction, S.B.Patel: New Age international (P) Limited, 1991.
5. Radiation Detection and Measurements, G.F. Knoll: 3rd edition, John Wiley and Sons,2000.
6. Nuclear Radiation Detectors, S.S. Kapoor and V.S. Ramamurthy: Wiley-Eastern, New Delhi, 1986.
7. Nuclear Interaction, S. de Benedetti: John Wiley, New York, 1964.
8. Nuclear Radiation Detection, W.J. Price: Mc Graw Hill, New York, 1964.
9. Introduction to Elementary particles, D. Griffiths: John Wiley, 1987.
10. Elementary Particles, J. M. Longo, II Edition, McGraw-Hill, New York, 1973.
11. Introduction to Nuclear Physics, Wong, PHI

<table>
<tr><td colspan="3">Paper Code: P 304
Paper Title: Materials Science (Elective – 01)
Number of Credits: 04</td></tr>
<tr><td colspan="2">Course Outcomes:
After the completion of the course, students will be able to:
1. To understand the fundamental aspects on formation and selection of materials.
2. To learn elastic properties of materials.
3. To elucidate on structural – compositional aspects of materials through phase diagram.
4. Introduction to methods employed in characterization of materials.</td><td>Suggested Pedagogical Processes:
• Lecture cum demonstration methods.
• ICT based learning
• Demonstration experiments
• Group discussion & Problem-solving methods
• Hands on experiments related to courses.
• Pre-recorded lectures & Open book tests
• Study visits at facility centers at universities and national research institutes.
• Seminars on different topics</td></tr>
<tr><td colspan="2">Title and Content</td><td>No of Lecture Hours</td></tr>
<tr><td>Unit I</td><td>Formation and Structure of Materials: Introduction to materials science-engineering, materials-structure-property relationship. Forces between atoms-binding energy-cohesion of atoms and cohesive energy-calculation of cohesive energy, Review of ionic, covalent and molecular binding's bond angle, bond length and bond energy of NaCl molecule. Lattice energy: calculation of lattice energy of ionic crystals, Madelung constant: calculation of Madelung constant of ionic crystals, cohesive energy. Vander Waal's interaction. Lennard – Jones potential.</td><td>13 Hours</td></tr>
<tr><td>Unit-II</td><td>Elastics and plastics behavior of materials:
Atomic model of elastic behavior-rubber like Elasticity-anelastic behavior, viscoelasticbehavior, fracture of materials-Ductile and brittle fracture – Ductile brittle transitionprotectionagainst fracture, Plastic deformation by slip-shear strength of perfect and real crystals- CRSS ratio, maximum, stress to move dislocation. Griffith Crack Theory</td><td>13 Hours</td></tr>
<tr><td>Unit-III</td><td>Phase diagrams and Phase transformations
Phase diagrams-Gibb's phase rule and its applications to binary alloy systems – isomorphous, eutectic and peritectic-the Lever rule. Typical phase diagrams-Cu-Zn, Al-Cu, Fe-C systems. Heat treatment processes-annealing, hardening and tempering. Time temperature Transformation Diagrams, Glass Transition, Phase transformations-Nucleation and growth-nucleation kinetics transformations in steel. Solidification and crystallization-recovery, recrystallization and grain growth.</td><td>13 Hours</td></tr>
<tr><td>Unit-IV</td><td>Testing Of Materials: Mechanical Testing – Universal Testing Machine, Hardness- Brinnel, Vicker and Rockwell, Impact testing and Fatigue Testing, Creep Testing.
Optical Microscopy – Metallurgical Microscopes-sample preparation and grain size measurements. Electron microscopy – transmission microcopy (TEM), Scanning microscopy (SEM)-principle, sample preparation techniques and its applications.
Non-Destructive Testing – Visual, Liquid Penetration, Eddy Current Test, Magnetic inspection Ultrasonic Testing, X-ray radiography, Neutron radiography.</td><td>13 Hours</td></tr>
</table>

References

1. Elements of Materials Science and Engineering: Lawrence H. Van Vlack, Addison Wesley, (1975).
2. Foundations of Materials Science and Engineering-William F. Smith, McGraw HillsInternational Edition, (1986)
3. Materials Science and Engineering, V. Raghavan, Prentice Hall (1993)
4. Structure & Properties of materials-Vol I-IV Rose, Shepard and Wulff (1987)
5. Testing of Materials – Vernon John(1987)

Paper Code: P 304 (b)
Paper Title: Atmospheric and Space Science (Elective – 02)
Number of Credits: 04

Course Outcomes:	Suggested Pedagogical Processes:
After the completion of the course, studentswill be able to: 1. To understand the fundamental aspects atmospheric science. 2. To learn importance of sun and to understand their physics 3. To elucidate on radiative transfer and emphasize on underlying mechanism in atmosphere 4. Introduction to climate science and the role of environment in climate	• Lecture cum demonstration methods. • ICT based learning • Demonstration experiments • Group discussion & Problem-solving methods • Hands on experiments related to courses. • Pre-recorded lectures & Open book tests • Study visits at facility centers at universities and national research institutes. • Seminars on different topics

	Title and Content	No of Lecture Hours
Unit I	**Fundamentals of Atmospheric Sciences:** Elementary concepts of weather and climate; earth-sun relationship; structure and composition of the atmosphere; Atmospheric pressure, temperature, wind, relative humidity, solar and terrestrial radiation, clouds, different forms of precipitation; diurnal variation of surface pressure and variation of pressure with height; diurnal variation of surface temperature and variation of temperature with height; Categorization of wind: squall, land and sea breeze, katabatic and anabatic winds, winds associated with storms, gustiness, gale, Beaufort scale, Buys-Ballot's law, geostrophic wind; basic ideas of general circulation.	13 Hours
Unit-II	**Solar Physics:**Composition and structure of sun, solar interior and seismology, Sunspots and solar rotation, Solar Cycle, Magnetically controlled solar phenomena, Magnetic fields in solar interior and flux emergence. Photosphere, Chromospheres and Coronae Solar Flares and Coronal Mass Ejections Solar Corona and Solar Wind - Optical, radio and X-ray data.Sun in radio wavelength- solar radio bursts, noise storms Sun in X-ray wavelength-Data from recent satellites: GOES, SOHO, STEREO, SDO, etc.	13 Hours
Unit-III	**Radiative Transfer***:* The spectrum of Radiation; Quantitative description of Radiation; Blackbody Radiation-The Plank Function-Wiens displacement Law-The Stefan-Boltzmann Law; Radiative properties of Non Black Materials-Kirchoff's Law, Radiative equilibrium, The Greenhouse Effect, Atmospheric Window, Albedo; Physics of Scattering and Absorption and Emission-Scattering by Air molecules and particles-Absorption by particles-Absorption and Emission by Gas molecules; Radiative Transfer in Planetary Atmosphere-Beers Law- Reflection and Absorption by a layer of the Atmosphere-Absorption and Emission of Infrared Radiation in Cloud-Free Atmosphere-Vertical profiles of Radiative Heating rate, Radiativetransfer in a plane parallel atmosphere; Radiative Balance at the top of the Atmosphere, the role of radiation in climate.	13 Hours

Unit-IV	**Fundamentals of Climate:** Climate System - Roles of various components of the Earth System in determining Climate. Feedback processes in Climate System - concept of feedback, applications of feedback to the climate system; Weather vs Climate, Environmental change concepts, Natural Climate Variations (slow and quick); Unnatural Changes (Ozone depletion and Global Warming); Over view of Climate and Twentieth Century Climate Change; Physics of the Greenhouse Effect and Global Radiation Budget; Greenhouse Effect of Trace Gases; Atmospheric Radiative Transfer - Albedo, Radiative forcing and climate Feedbacks, Aerosols, Clouds, Radiation interactions, Atmospheric Pollution and Visibility; Urban heat island effect and Urban Climate change; Anthropogenic forcing of climate change; Hydrological cycle, Carbon cycle.	**13 Hours**

References

1. Introduction to Space Physics: M. G. Kevilson and C. T. Russell
2. An Introduction to Atmospheric Physics: D. G. Andrews, CUP
3. Advances in Meteorology, Climatology and Atmospheric Physics: D. D. Alexakis.
4. Atmospheric Chemistry and Physics: John H. Sienfield.
5. Atmospheric Electrodynamics: H. Volland

Paper Code: P 304 (c)
Paper Title: Astrophysics (Elective – 03)
Number of Credits: 04

Course Outcomes:	**Suggested Pedagogical Processes:**
After the completion of the course, studentswill be able to: 1. Analyze the fundamental aspects of coordinate systems and telescopes 2. Understand age, class and type of stars 3. Emphasize on the solar system and their classification. 4. Description of galaxies, universe and emphasizes on stellar evolution.	• Lecture cum demonstration methods. • ICT based learning • Demonstration experiments • Group discussion & Problem-solving methods • Hands on experiments related to courses. • Pre-recorded lectures & Open book tests • Study visits at facility centers at universities and national research institutes. • Seminars on different topics

	Title and Content	**No of Lecture Hours**
Unit I	**Basic Concepts:** Coordinate systems, Time systems, Trigonometric parallaxes, parsec, Apparent and absolute magnitudes, Atmospheric extinction, Angular radii of stars, Michelson's Stellar interferometer, Binary stars and their masses, Radial and transverse velocities, types of optical telescopes and their characteristics, modern telescopes like Gemini, KECK etc.	13 Hours
Unit-II	**Properties of Stars:** Spectra of stars, Spectral sequence-temperature and luminosity classifications, H-R diagram, Saha's ionization formula and application to stellar spectra, Virial theorem, Stellar structure equations, Star formation and main sequence evolution, mass luminosity relation, White dwarfs, Pulsars, magnetars, Neutron stars and Black holes, Variable stars.	13 Hours
Unit-III	**The Solar System:** The surface of the sun, solar interior structure, solar rotation, sunspots, the active sun, Properties of interior planets and exterior planets, Satellites of Planets, comets, asteroids, meteorites, Kuiper Belt Objects and Oort Cloud. Theories of formation of the solar system.	13 Hours
Unit-IV	**Star clusters, Galaxies and the Universe:** Open and global clusters, the structure and contents of milky way galaxy, Hubble's classification of galaxies, Galactic structure and dark matter, galactic motions, Hubble's law, Olber's paradox, Big bang theory and the origin of the early universe, nucleosynthesis, cosmic microwave background radiation and evolution of the universe.	13 Hours

References

1. The New Cosmos, A. Unsold: Springer Verlag, 1977.
2. Introduction to Stellar Astrophysics, E. Bohm-Vitense: 3rd volume, CUP, 1989.
3. Astrophysics and Stellar Astronomy, T.L. Swihart: Wiley 1968.
4. The Stars; their Structure and Evolution, R.J. Taylor: CUP, 1994.
5. Introduction to Cosmology. V. Narlikar: y, CUP, 1993.
6. Principles of Physical Cosmology, Peebles P.J.E.: Princeton U.P. 1993.
7. Galaxies; their Structure and Evolution, R.J. Taylor: CUP, 1993.
8. Solar System Astrophysics, Brandt J.C. and Hodge: McGraw-Hill, 1964.
9. The Physical Universe, F. Shu: Sopress, 1987.
10. Introduction to Modern Astrophysics, Ostlie and Carroll: Addison Wesley,1997
11. Astrophysics Concepts, M. Herwit: John Wiley, 1990.

12. An Introduction to Astrophysics Baidyanath Basu:, PHI
13. A textbook of Astrophysics and cosmology, V.B.Bhatia: New Age
14. Our solar system:Rana etc.
15. Stars and Galaxies K.D. Abhyankar:,UniversityPress
16. Astrophysics. Krishnaswamy (ed):
17. Pulsar Astronomy, A.G.Lyne and G.Smith, Cambridge Univ. press.

IV SEMESTER

Paper Code: P 401
Paper Title: Lasers & Nonlinear Optics (Elective – 03)
Number of Credits: 04

Course Outcomes:	**Suggested Pedagogical Processes:**
After the completion of the course, students will be able to: 1. Understand the fundamental aspects of wave optics (viz., interference and diffraction). 2. Emphasis on key aspects on laser mechanism. 3. An introductory course on Nonlinear optical phenomenon. 4. Fundamental research aspects on nonlinear optics	• Lecture cum demonstration methods. • ICT based learning • Demonstration experiments • Group discussion & Problem-solving methods • Hands on experiments related to courses. • Pre-recorded lectures & Open book tests • Study visits at facility centers at universities and national research institutes. • Seminars on different topics

	Title and Content	**No of Lecture Hours**
Unit I	**Wave optics:** Interference: Planar wave description of light, two-beam interference, Michelson interferometer, Multi-beam interference, Fabry-Perot interferometer. Diffraction: Kirchhoff's diffraction theory, regimes of diffraction, Fresnel and Fraunhofer diffraction, rectangular slit, circular aperture, single and multiple slit diffraction	**13 Hours**
Unit-II	**Lasers**: Light amplification, Spatial and temporal coherence, Threshold condition, Rate equations for 2 and 3 level systems, Laser pumping requirements, Output coupling, Cavity modes, quality factor, Mode selection and mode locking, Q-switching. Some laser systems: He-Ne, Nd:YAG, Dye lasers, Semiconductor lasers.	**13 Hours**
Unit-III	**Non-linear OpticsA**: Interaction of radiation with a dielectric medium, dielectric susceptibility, nonlinear optical effects, nonlinear optical materials, wave equations of Nonlinear medium: Time Domain and Frequency domain expressions for isotropic and anisotropic medium, Polarization and susceptibility of Non-linear medium, Kramers-Kronig relation, Electro-optic effects: Pockel effect, Kerr effect-Single Phase Modulation and Cross Phase Modulation.	**13 Hours**
Unit-IV	**Non-linear Optics B**:Nonlinear Absorption: Theory of Single Photon Absorption and Two Photon Absorption, Three wave coupled equations in anisotropic medium, second harmonic generation: Optical Sum Frequency: Up-Conversion, Optical Difference Frequency: Down-Conversion, third harmonic generation: Four wave mixing, Saturable Absorbers and Reverse Saturable Absorbers.Z-scan Measurement of Nonlinear Optical Parameter: Experimental Method of Z-scan Measurement.	**13 Hours**

References
1. Optical Electronics by A. Ghatak and K. Thyagarajan, Cambridge University Press, 2004
2. Optics –Principles and Applications by K. K. Sharma, Academic Press, MA, 2006
3. Optics 4th Ed. by E. Hecht, Addison-Wesley, NY, 2001
4. Introduction to Modern Optics(2nd Ed), by G. R. Fowles, Dover
5. Principles of Optics by Born and Wolf.
6. Schaum's Outline of Theory and Problems of Optics, E. Hecht, McGraw-Hill
7. Laser Fundamentals, Silfvast, Cambridge Press, 1998
8. Lasers and Nonlinear Optics: B.B,. Laud, 2/e, New Age International (P) Publishers, 2000

Paper Code: P 402 Paper Title: Advanced Atomic, Molecular and Optical Physics (Elective – 04) Number of Credits: 04	
Course Outcomes: **After the completion of the course, students will be able to:** 1. An extensive understanding on vibrational and electronic spectroscopy. 2. Detailed understanding of NMR spectroscopy 3. Detailed understanding of ESR spectroscopy 4. An introductory course on contemporary topics on Laser spectroscopy.	**Suggested Pedagogical Processes:** • Lecture cum demonstration methods. • ICT based learning • Demonstration experiments • Group discussion & Problem-solving methods • Hands on experiments related to courses. • Pre-recorded lectures & Open book tests • Study visits at facility centers at universities and national research institutes. • Seminars on different topics

	Title and Content	No of Lecture Hours
Unit I	**Vibrational and electronic spectroscopy of polyatomics:** Elements of molecular symmetry, Point Groups, Character tables for C_{2v},$C_{3v}$and $C_{\infty v}$ groups, symmetry and dipole moments, Polyatomic vibrations, Normal modes, Vibrational selection rules for IR and Raman spectra.Molecular Orbitals, Electronic states and Hunds coupling cases, Vibrational structure inelectronic spectra (diatomics), Dissociation and pre-dissociation-mixing of Born-Oppenheimer states.	13 Hours
Unit-II	**Spin resonance spectroscopy-A**: Basic principles NMR absorption and resonance condition,Relaxation processes: concepts of spin-lattice relaxation and spin-spin relaxation, Linebroadening and dipolar interaction, Magical Angle Spin (MAS) experiment, chemical shift, spin-spin coupling,First order spectra, nomenclature for spin systems, Chemical equivalence and magneticequivalence of nuclei. Techniques for observing nuclear resonances in bulk materials,continuous wave, pulsed and FT NMR, Block diagram of NMR Instrumentation,Chemical analysis using NMR.	13 Hours
Unit-III	**Spin resonance spectroscopy-B**: Electron spin and magnetic moment, Basic concepts ofESR, characteristics of g-factor and its anisotropy, nuclear hyperfine interaction, SpinHamiltonian, ESR of organic and inorganic radicals: equivalent and non-equivalent set ofnuclei, experimental technique. Basic principles of NQR, nuclear quadrupole interaction,fundamental requirements of NQR. Electron Nuclear Double Resonance(ENDOR)-generaltreatment.	13 Hours
Unit-IV	**Precision spectroscopy of atoms:** Sub Doppler laser spectroscopy- Molecular beams andreduction of Doppler width using collimator, Lamb dip and Saturation Absorptionspectroscopy, Elementary ideas of laser cooling of atoms- Doppler cooling, polarizationgradient cooling, MOTIon Traps- Penning and RF traps, Single ion motion in a Penning trap, Side band cooling,Quantum jumps	13 Hours

References

1. Physics of atoms and molecules, Bransden and Joachain, (2nd Edition) Pearson Education,2004
2. Symmetry of Atoms of Molecules - Randhwa
3. Fundamentals of Molecular Spectroscopy, Banwell and McCash, Tata McGraw Hill,1998.
4. Modern Spectroscopy, J.M. Hollas, John Wiley, 1998.

5. Molecular Quantum Mechanics, P.W. Atkins and R.S. Friedman, 3rd Edition, Oxford Press(Indian Edition), 2004
6. Vibrational Spectroscopy – F A Cotton.
7. Spectra of Atoms and Molecules, *P.* Bernath, Oxford Press, 1999
8. Molecular Spectroscopy, *J.L. McHale*, Pearson Education, 1999
9. Atomic Physics, C.J. Foot, Oxford University Press, 2008
10. Introduction to Magnetic Resonance Spectroscopy: ESR, NMER NQR, II Edition, D. N. Sathyanarayana, I.K. International Publishing House Ltd. 2014.
11. Basic Principles of Spectroscopy: Raymond Chang, McGraw-Hill Kogakusha Ltd.

Paper Code: P 402
Paper Title: Advanced Materials Science (Elective – 05)
Number of Credits: 04

Course Outcomes:	Suggested Pedagogical Processes:
After the completion of the course, studentswill be able to: 1. Emphasize on the nature and material aspects of metals and alloys 2. An introductory towards the polymer science 3. A bird eye view on ceramics and glasses. 4. General description on Composite materials.	• Lecture cum demonstration methods. • ICT based learning • Demonstration experiments • Group discussion & Problem-solving methods • Hands on experiments related to courses. • Pre-recorded lectures & Open book tests • Study visits at facility centers at universities and national research institutes. • Seminars on different topics

	Title and Content	No of Lecture Hours
Unit I	**Metals &Alloys:** Processing of Metals and Alloys - Casting of Metals & Alloys, Hot & Cold Rolling of Metals & Alloys, Extrusion of Metals & Alloys, Forging, Other Metal- Forming Processes. Solid-Solution Strengthening of Metals, Recovery & Recrystallization of plastically Deformed Metals, Structure of Heavily Cold- Worked Metal before Reheating, Recovery, Recrystallization, Super plasticity in Metals, Nanocrystalline Metals. Low Alloy Steels, Aluminum Alloys, Copper Alloys, Magnesium, Titanium and Nickel Alloys, Special Purpose Alloys and Application- Intermetallics, Shape Memory Alloys, Amorphous Metals, Biometals.	13 Hours
Unit-II	**Elements of Polymer Science:** Monomers – Polymers – Classification of polymers. Syntheses of polymers – chain polymerization, step Polymerization, industrial polymerization methods. Average molecular weight – weight, number and viscosity, size of polymer molecule.Microstructure of polymers – chemical, geometric, random, alternating, block and graft polymers, stereo regular polymers. Phase transition-polymer melting and glass transition; polymer crystallinity-degree of crystallinity, crystallization and stereo isomerism. Processing of Plastic Materials-Molding-compression, injection, blow, extrusion, spinning.	13 Hours
Unit-III	**Ceramics and Glasses:** Ceramics and their structure – Silicate structure, Preparation-forming and thermaltreatments, Classification of ceramics-traditional and engineering, dielectric, ferroelectric and piezoelectricproperties of ceramics with specific examples, ceramic magnets, Mechanical properties – strength, toughness, fatigue failure, abrasion. Basic refractory materials.Glasses: Preparation and structure, Types of glasses – borates, silicate, oxide, metallic and semiconducting glasses; tempered glass and chemically strengthened glass.	13 Hours
Unit-IV	**Composite Materials**: General Introduction, Matrix Materials – polymer, metals, ceramics, Reinforcing materials – fibers, particles, concrete-concrete making materials, structure,composition, properties and applications, polymer-concrete composites, fabrication, structure, interface, properties, applications of polymer matrix composites, metal matrix composites, ceramic matrix composites and carbon fibre composites, wood-plastic composites, dispersion strengthened, particle reinforced, fibre and laminate reinforced composites with fabrication, interface, properties and applications.	13 Hours

References

1. Textbook of Polymer Science, Fred.W.Billmeyer, John Wiley & Sons, Inc (1984)
2. Polymer Science, V.R.Gowariker, N.V.Vishwanathan, JayadevShreedhar, Wiley Eastern (1987).
3. Electronic properties of Materials – Rolf E.Hummel, Springer Verlag, Springer Verlag (1985).
4. Foundations of Materials Science and Engineering-William F.Smith, McGraw Hill International Editions,(1988).
5. Elements of Materials Science and Engineering, Lawrence H. Van Vlack, Addison Wesley (1975).
6. Introduction to Ceramics – W.D.Kingery, H K Bower and U R Uhlman, John Wiley (1960)

Paper Code: P 402 Paper Title: Advanced Mathematical Methods of Physics (Elective – 06) Number of Credits: 04	
Course Outcomes: **After the completion of the course, studentswill be able to:** 1. Solve solutions for homogeneous and inhomogeneous differential equation and application of fluid mechanics 2. Analyze and apply tensor notations and a detailed picture on dual spaces. 3. Application of spectral theory and detailed description on operators 4. Emphasize on group theory and correlate space groups with the crystal structure.	**Suggested Pedagogical Processes:** • Lecture cum demonstration methods. • ICT based learning • Demonstration experiments • Group discussion & Problem-solving methods • Hands on experiments related to courses. • Pre-recorded lectures & Open book tests • Study visits at facility centers at universities and national research institutes. • Seminars on different topics

	Title and Content	No of Lecture Hours
Unit I	**Green's functions and integral equations:** Boundary value problems, The Sturm-Liouvilledifferential operator, Green's function of one-dimensional problems, discontinuity in thederivative of Green's functions, Properties of Green's functions, Construction of Green'sfunctions in special cases and solutions of inhomogeneous differential equations, Eigenfunction expansion of Green's function. Examples of linear integral equations of first and second kind, Relationship between integral and differential equations, Solution of the Fredholm and Volterra integral equations by Neuman series method (method of successive approximations), Separable kernels, Fredholm alternate method.	13 Hours
Unit-II	**Tensors and Spaces:** Definition of tensors, contra variant and covariant components of tensors, raising and lowering of tensor indices, sum, outer, inner products and contraction of tensors, Quotient law, symmetric, antisymmetric tenors, Euclidian Spaces Norms, Orthogonality orthogonal complements and its projections, Best approximation of elements in a Euclidean space by elements in a finite dimensional subspace - Hilbert Spaces – Geometry of Hilbert spaces, Riesz Lemma, Orthonormal Bases, Tensor Products of Hilbert Space, Banach Spaces –Definitions and Examples, Duals and Double Duals, The Hann- Banach Theorem, Operations on Banach Spaces, The Baire Category Theorem and its consequences.	13 Hours
Unit-III	**Spectral Theory and Unbounded Operators:** The spectral Measures, continuous functional analysis, Spectral projections, Spectral Theorem, Symmetric and Self adjointness, Stone's Theorem, Quadratic forms, Convergence of unbounded operators, The Trotter product formula, Polar decomposition for closed operators, Tensor Products.	13 Hours
Unit-IV	**Group Theory**: Lie Groups and Infinitesimal generators, Lie groups to Lie algebra, Definition, properties and application, Young Diagrams, Reducible and irreducible representations, Schur's lemma, Elementary ideas of Continuous groups GL(n), SO(3), SU(2), SO(3,1), SL(2,C), Real Representation and its complexifications.	13 Hours

References

1. Mathematical methods of physics - J. Mathews and R. L. Walker, Second Edition,Addison-Wesley.
2. Mathematical methods for Physicists – G. B. Arfken and H. Weber, Seventh Edition,Academic Press, 2012.
3. Linear Algebra and Group theory for Physicists – K. N. Srinivasa Rao,
4. Mathematical Methods - Barry Simons and Michel Reed, Academics Press (1980)
5. An Introduction to Tensors and Group Theory for Physicists - Nadir Jeevanjee (2010)

Paper Code: P 402 (Elective- 07)
Paper Title: Advanced Nuclear and Neutron Physics
Number of Credits: 04

Course Outcomes:	Suggested Pedagogical Processes:
After the completion of the course, students will be able to: 1. Understand in detail on the neutron sources 2. Gain thorough knowledge on neutron detectors and spectrometers 3. A detailed emphasis on the nuclear reactors and programme in India. 4. An overall perspective on neutron interaction.	• Lecture cum demonstration methods. • ICT based learning • Demonstration experiments • Group discussion & Problem-solving methods • Hands on experiments related to courses. • Pre-recorded lectures & Open book tests • Study visits at facility centers at universities and national research institutes. • Seminars on different topics

	Title and Content	No of Lecture Hours
Unit I	Discovery of neutron-properties of neutrons-neutron spin-classification of neutrons according to energy, radioactive sources-neutron sources, Po-Be, Ra-Be, Pu-Be, Am-α-Bo neutron sources, photo neutron sources, accelerators as a source of neutrons-mono energetic sources, nuclear reactor as a source of neutrons- (p,n) and (d,n) mechanisms for neutron production.	13 Hours
Unit-II	Neutron detectors and spectrometers- Principle of neutron detection-thermal neutron detectors-BF^3 counters-foil activation techniques-the long counter-fission chambers-threshold detectors-He^3 counters, scintillation spectrometers-LiI spectrometer-sandwich spectrometer-the Bonner sphere-nuclear emulsions-time of flight technique-proton recoilment-H_2 gas proportional counters-proton radiators-liquid organic scintillation spectrometers.	13 Hours
Unit-III	Nuclear reactors-Neutron multiplication-fission chain reaction-four factor formula-multiplication factor-slowing down of neutrons in matter-moderating ratio-diffusion of thermal neutrons, neutron age, reactor control-effect of delayed neutrons-research reactors-power reactors-nuclear reactor programme in India.	13 Hours
Unit-IV	Neutron interactions with matter and neutron shielding-neutron elastic and inelastic scattering, n-n and p-p scattering, thermal capture- fast neutron reactions (n, α), (n, β), (n, γ)reactions-neutron resonance-Breit-Wigner formula-neutron cross-sections-neutron diffraction. Methods of neutron absorption, choice of shielding materials, neutron streaming and shielding experiments-reactor shielding.	13 Hours

References

1. Nucleon-Nucleon Interaction, *G.E. Brown and A.D. Jackson:* North-Holland, Amsterdam,
2. Nuclear Interaction, *S. de Bendetti:* John Wiley, New York, 1964.
3. Physics of Nuclei and Particles, *P. Marmier and E. Sheldon:* Vol. I and II, Academic Press, 1969.
4. Nuclear Physics- *R. R. Roy and B. P. Nigam:* Theory and Experiments, John Wiley, 1967.
5. Introduction to Nuclear Reactions, *G. R. Satchler*: Macmillan Press, 1980.

Paper Code: P 403
Paper Title: Space & Cloud physics (Elective – 08)
Number of Credits: 04

Course Outcomes:	Suggested Pedagogical Processes:
After the completion of the course, studentswill be able to: 1. Detailed understanding on physical aspects that occur in space/atmosphere 2. Analytical aspects of Monsoon in India 3. Understand the basics of clouds and elucidates on experiments associated with atmosphere 4. A Qualitative picture on understanding the mechanisms of Remote sensing.	• Lecture cum demonstration methods. • ICT based learning • Demonstration experiments • Group discussion & Problem-solving methods • Hands on experiments related to courses. • Pre-recorded lectures & Open book tests • Study visits at facility centers at universities and national research institutes. • Seminars on different topics

	Title and Content	No of Lecture Hours
Unit I	**Space physics**: Basics of ionosphere formation, D-, E- and F-layers, composition of the ionosphere, effect of terrestrial and solar radiation on earth's atmosphere, photochemical processes, currents in ionosphere, electrical conductivity, techniques of ionosphere measurements – ionosonde and Langmuir probes; Earth's magnetic field and its extension into space, structure ofmagnetosphere, polar and equatorial cross sections, potential drops in magnetosphere, interactionof solar wind with the geomagnetic field, magnetospheric tail, radiation belts, trapping of charged particles, trajectory of charged particles, trapped radiation.	13 Hours
Unit-II	**Monsoon over India:** Morphology of monsoon circulation, symmetric and asymmetricmonsoon, Formation of monsoon disturbances, Structure of monsoon disturbances, Wind, temperature and pressure distribution over India in the lower, middle and upper atmosphere during pre, post and mid-monsoon season; Intra-seasonal variability of monsoon, Inter-annual variability of monsoon – anomalous over India and Asia, El Nino Southern Oscillation and dynamical mechanism for their existence.	13 Hours
Unit-III	**Cloud Physics and Atmospheric electricity:** Cloud morphology, Warm Cloud Microphysics (Homogeneous and Heterogeneous nucleation, Kohler theory,,CCN, Collision and Coalescence Process, Formation of rain). Cold Cloud Microphysics (Ice Nucleation, Hail formation, Bergeron-Findeisen Process.) Structure and Dynamics of different cloud systems: Shallow layer clouds, Nimbostratus, Cumulus clouds, Thunderstorms and Tornadoes, Meso-scale convective systems, Clouds in Hurricanes and cyclones, Orographic Clouds. Cloud Seeding experiments.Ions and electrical conductivity, Fair weather electricity, Electrical currents in the atmosphere,Global Electric Circuit.Electrical structure of storms, Theories and experiments on Cloud Electrification. Lightning discharges and mechanism, Lightning Electric fields, lightning location systems. Upward lightning and sprites.Nitrogen fixation by lightning.	13 Hours
Unit-IV	**Remote Sensing:** Principles and basic concepts of remote sensing, physics of remote	13 Hours

	sensing.Effects of Atmosphere, Principles and Geometry of scanners, CCD arrays and platforms.Rainfall estimation techniques, cyclone analysis techniques & synoptic weather analysis using visible, Near Infrared.	

References

1. Physics and Chemistry of Clouds: Dennis Lamb
2. Physics and Dynamics of Clouds and precipitation: P. K. Wang
3. Physics of Precipitation: W. E. Smith.
4. Advanced space plasma physics: R. A. Treumann

Paper Code: P 403
Paper Title: Physics of Solids(Elective – 09)
Number of Credits: 04

Course Outcomes:	Suggested Pedagogical Processes:
After the completion of the course, studentswill be able to: 1. Overall perspective of imperfection in crystals, Burger vector and dislocation in crystals 2. A detailed analysis of lattice vibrations and phonons, thermal properties such as specific heat capacities 3. Understanding of inter atomic forces and bonding in solids, an introduction to diffusion in solids. 4. An introduction towards optical and elastic properties of solids.	• Lecture cum demonstration methods. • ICT based learning • Demonstration experiments • Group discussion & Problem-solving methods • Hands on experiments related to courses. • Pre-recorded lectures & Open book tests • Study visits at facility centers at universities and national research institutes. • Seminars on different topics

	Title and Content	No of Lecture Hours
Unit I	**Imperfections in crystals:** Classification of imperfections, crystallographic imperfections, point defects – concentrations of Schotky and Frenkal defects, line defects- edge dislocations, screw dislocation, Burgervectors, dislocation motion, stress fields around dislocations, observation of dislocations,plane defects- grain boundaries, tilt and twin boundaries –surface imperfections-role ofdislocations in crystal growth.	13 Hours
Unit-II	**Lattice vibrations and phonons:** Elastic vibrations of continuous media, Group velocity ofharmonic wave trains, Wave motion of one dimensional atomic lattice, lattice with two atomswith primitive cell, Some facts about diatomic lattice, number of possible normal modes ofvibrations in a band, phonons, momentum of phonons, **Thermal properties:** Classical calculations of lattice specific heat, Einstein theory of specificheats, Debye’s model of lattice specific heat, Debye approximation, An-harmonic crystalinteractions, thermal expansion, lattice thermal conductivity of solids- Umklapp process.	13 Hours
Unit-III	**Band theory and Diffusion in solids:** Elementary ideas of formation of energy bands. Bloch function. Kronig-Penney model, number of states in a band, Energy gap. Distinction between metals, insulators, and intrinsic semiconductors. Concept of holes, equation of motion for electrons and holes, effective mass of electrons and holes. **Diffusion in solids:** Fick’s law of diffusion, Determination of diffusion coefficients, diffusion couple.	13 Hours
Unit-IV	**Optical properties:** Absorption process, photoconductivity, photoelectric effect, photovoltaiceffect, photoluminescence, color centers, types of color centers, generation of color centerproperties- models and applications. **Elastic constants:** Stress components. Analysis of elastic strains, elastic compliance andstiffness constants, elastic energy density, stiffness constants of cubic crystals.	13 Hours

References

1. A.R.Verma and O.N. Srivastava: Crystallography Applied to Solid State Physics, 2nd

edition, New age International publishers, 2001
2. Solid State Physics- A. J. Dekker, Macmillan India Ltd., Bangalore, 1981.
3. Solid State Physics- C. Kittel, V Ed., Wiley Eastern Ltd., 2013.
4. Elementary Solid state physics,- M.A. Omar, Addissonwesley, New Delhi,2000.
5. Solid state Physics- S.O. Pillai. New age international publication. – 2002.
6. Solid state Physics- M.A. Wahab, Narosa publishing house, New Delhi.- 1999.
7. Modern theory of Solids- Seitz.
8. Semiconductors Devices-Physics and Technology- S.M. Sze.
9. Introduction to Solids – L. Azoroff.
10. Solid State Physics- H.C. Gupta- Vikas publishing house, New Delhi.-2002.

Paper Code: P 403
Paper Title: Crystal and Semiconductor Physics(Elective – 10)
Number of Credits: 04

Course Outcomes:	**Suggested Pedagogical Processes:**
After the completion of the course, studentswill be able to: 1. To understand and elucidate on the fundamental aspects of crustal physics. 2. To understand the energy bands in solids 3. To emphasize on physics of semiconducting materials 4. To ideate on thin film techniques and characterization.	• Lecture cum demonstration methods. • ICT based learning • Demonstration experiments • Group discussion & Problem-solving methods • Hands on experiments related to courses. • Pre-recorded lectures & Open book tests • Study visits at facility centers at universities and national research institutes. • Seminars on different topics

	Title and Content	**No of Lecture Hours**
Unit I	**Crystal Physics:** Introduction-symmetry elements of crystals-concept of point groups-derivation of equivalentpoint position-experimental determination of space groups-powder diffraction interpretation expression for structure factor-analytical indexing-Weisenberg and rotating crystal method. Determination of relative structures-amplitudes from measured intensities-Multiplicity factor-Lorentz polarization factor. Reciprocal lattices-concept of reciprocal lattice-geometricalconstruction-relation between reciprocal lattice vector and inter-planar spacing-properties ofreciprocal lattice.	**13 Hours**
Unit-II	**Energy bands in solids**: Nearly free electron approximation-Tight binding method of energybands (applications to cubic system)- orthogonalized plane wave method (OPW)-Wigner-Seitzmethod--pseudo-potential method. Fermi surface studies and Brillouin zones characteristics ofFermi-surfaces-effect of electric and magnetic field on Fermi surface-anomalous skin effect cyclotronresonance-De Hass-van Alphen effect	**13 Hours**
Unit-III	**Semiconductors:** Fermi level in intrinsic and extrinsic semiconductors-temperaturedependence-carrier concentration-Charge neutrality equation-mobility-diffusion-Nernst-Einstein equation-Donor states-Acceptor states-Thermal ionization of donors and acceptors. Conductivity in semiconductors.Devices-p-n-junction-fabrication-contact potential- equilibrium fermi levels-space charge at ajunction-depletion width-I-V characteristics-generation-recombination-continuity equation rectification-saturation-Zener break down. Negative conductive device-tunnel diode-Transistors (bipolar)-energy band diagram.	**13 Hours**
Unit-IV	**Films and surfaces:**Preparation-TVD, CVD-laser ablation-MBE -Study of surface topography by multiple beaminterferometry, conditions for accurate determination of step height and film thickness (Fizeaufringes).Electrical conductivity of thin films, difference of behavior of thin films from bulkmaterial, Boltzmann transport equation for a thin film (for diffuse scattering), expression forelectrical conductivity for thin film. Enhancement of magnetic anisotropy due to surfacepinning.	**13 Hours**

References

1. A.R.Verma and O.N. Srivastava: Crystallography Applied to Solid State Physics, 2nd edition, New age International publishers, 2001
2. Solid State Physics- A. J. Dekker, Macmillan India Ltd., Bangalore, 1981.

3. Solid State Physics- C. Kittel, V Ed., Wiley Eastern Ltd., 2013.
4. Elementary Solid state physics,- M.A. Omar, Addissonwesley, New Delhi,2000.
5. Solid state Physics- S.O. Pillai. New age international publication. – 2002.
6. Solid state Physics- M.A. Wahab, Narosa publishing house, New Delhi.- 1999.
7. Modern theory of Solids- Seitz.
8. Semiconductors Devices-Physics and Technology- S.M. Sze.
9. Introduction to Solids – L. Azoroff.
10. Solid State Physics- H.C. Gupta- Vikas publishing house, New Delhi.-2002.

Paper Code: P 404
Paper Title: Properties and Applications of Thin Films (Elective – 11)
Number of Credits: 04

Course Outcomes:	Suggested Pedagogical Processes:
After the completion of the course, studentswill be able to: 1. A detailed characterization on thinfilms. 2. To understand and the transport properties of thin films. 3. A detailed perspective on optical properties of thin films. 4. Emphasis on the application of thin films.	• Lecture cum demonstration methods. • ICT based learning • Demonstration experiments • Group discussion & Problem-solving methods • Hands on experiments related to courses. • Pre-recorded lectures & Open book tests • Study visits at facility centers at universities and national research institutes. • Seminars on different topics

	Title and Content	No of Lecture Hours
Unit I	**Chemical and Physical Characterization of Thin Films:** Auger Electron Spectroscope (AES), Secondary Ion Mass Spectroscopy (SIMS), Secondary Neutral Mass Spectroscope (SNMS) and Rutherford Back Scattering Spectroscope (RBS).UV-Vis-NIR and IR spectrophotometers, Fourier Transform Infrared Spectroscope (FTIR) and Raman spectroscope.Tolansky technique, Talystep (styles) method, Quartz crystal microbalance, Stress measurement by optical method, Gravimetric method.	13 Hours
Unit-II	**Transport Properties of Thin Films:** Theory of growth of thin films: Nucleation, condensation, Capillarity model, Atomistic model, comparison of models, various stages of film growth. Metallic Films: Sources of resistivity in metallic conductors – sheet resistance and temperature coefficient of resistance of thin films – Influence of thickness on the resistivity of structurally perfect thin films – Fuchs Sondhemier theory – Hall effect – Annealing, agglomeration and oxidation.Dielectric films: Electrical conduction in insulator films – Schottky emission – Tunneling, Poole-Frenkel emission.	13 Hours
Unit-III	**Optical Properties of Thin Films:** Reflection and transmission at an interface – Reflection and transmission by single film – Reflection from an absorbing film - Multilayer films – Optical absorption – Determination of optical constants by Ellipsometry.Optical devices: Beam splitters – Reflection and antireflection coatings- Optical filters: Neutral filters, Broad band filters, Narrow band filters – Thin film polarizers.	13 Hours
Unit-IV	**Applications of Thin Films:** Photolithography: Photoresists, Mask and pattern generation. Thin film resistors – Thin film capacitors – Thin film diodes and transistors – Thin film solar cells, Thin film micro batteries – Thin film sensors: Gas sensors, Bolometers – Transparent conducting oxide coatings - Thin films for superconducting devices – Metallurgical coatings. Hard coatings andTribologicalcoatings.	13 Hours

References

1. Thin Film Fundamentals, A. Goswami, New Age International. Publications, 1996..
2. Preparation of Thin Films, J. Goege, Marcel Dekker, New York, 1992.
3. Hand Book of Thin Film Technology, L.I. Maissel and R.L. Glang, McGraw HillBook Co.,, 1970.
4. Thin Film Phenomena, K.L. Chopra by McGraw Hill book Co., New York, 1969.
5. Introduction to Semiconductor Materials and Devices, M.S. Tyagi, John Wiley & Sons Pvt.

Ltd. Singapore, 2000.
6. Thin Film Solar Cells, K.L. Chopra and S.R. Das, Plenum Press, New York, 1983.
7. The Materials Science of Thin Films, M. Ohring, Academic Press, New York, 1992.

Paper Code: P 404 Paper Title: Physics of Nanomaterials (Elective – 12) Number of Credits: 04	
Course Outcomes: **After the completion of the course, studentswill be able to:** 1. Overall perspective of nanomaterials in field of hydrogen storage, gas sensors and storage devices 2. A qualitative picture on optical properties of nanomaterials 3. A birds eye view on concurrent techniques in synthesis of nanomaterials. 4. An introduction towards methods to assess the nature of nanomaterials.	**Suggested Pedagogical Processes:** • Lecture cum demonstration methods. • ICT based learning • Demonstration experiments • Group discussion & Problem-solving methods • Hands on experiments related to courses. • Pre-recorded lectures & Open book tests • Study visits at facility centers at universities and national research institutes. • Seminars on different topics

	Title and Content	No of Lecture Hours
Unit I	**Introduction to nanomaterials**: Definition, reason for interest in nanomaterials, classificationof nanostructures – 1D, 2D and 3D confinement.**Gas reactive applications of nanostructured materials**: Catalysis, electrocatalysisprocesses, impact of nanostructure, **Gas Sensors**: physical principles of semiconductorsensors and nanostructure design,**Hydrogen storage**: properties of hydrogen storage compounds and nanostructuredesign. **Nanomagnetic materials and applications**: Domain and domain walls – bulk andnanostructures, magnetization processes in particulate nanomagnets and layered nanomagnetsapplications.	13 Hours
Unit-II	**Overview of semiconductors**: Electronic band structure, concept of the effective mass,optical processes, direct and indirect band gapsemiconductors, exciton formation,superlattice-heterostructure. **Quantum size effect:** Quantum confinement in one dimension: quantum wells, Electronconfinement in infinitely deep square well square, square well of finite depth, opticalabsorption in quantum well in the case of heterostructure consisting of thin layer of GaAs sandwiched between thick layers of AlGaAs. Quantum confinement in 2 dimensions: quantum wires, Quantum confinement in 3dimensions: quantum dots. **Tunnelling transport**: T-matrices for potential step and square barrier, current andconductance. Resonant tunneling.	13 Hours
Unit-III	**Methods for preparation of Nano-materials**: Bottom Up: Nano Particles (metal and semiconductor) – nucleation – growth – chemical bathdeposition – capping techniques. Nano Structures: quantum dots, quantum well structures- Thin film deposition techniques. –molecular beam epitaxy methods of growth –MOVPE – MOCVD. Physical vapour depositionfor nanoparticles. Top Down: Ball milling: details, size and time of milling, shaker mills, planetary mills,attrition mills. Electron Beam, Lithography – resists- use of positive and negative resists – liftof process.Ion-beam lithography-main chemical reaction – use. Self-assembled molecular materials: principles of self-assembly – micellar and vesicularpolymerization – self organizing inorganic nanoparticles. Langmuir Blodgett techniques.	13 Hours

Unit-IV	**Characterization of nanomaterials**: **Diffraction techniques:** X-ray Diffraction (XRD) – Crystallinity, particle/crystallite sizedetermination and structural analysis **Microscopic techniques**: Scanning Electron Microscopy (SEM) – Morphology, grain size and EDX; Transmission Electron Microscopy (TEM) – Morphology, particle size and electron diffraction. **Scanning probe techniques**: Scanning Tunneling Microscopy (STM) – surface imaging and roughness ,Atomic Force Microscopy (AFM) - surface imaging and roughness; otherscanning probe techniques. **Spectroscopy techniques**: Photoluminescence – Emission (PL) and Excitation (PLE)spectroscopy; Infrared (IR) and Raman spectroscopy; X-ray Absorption (XAS).	**13 Hours**

References:

1. Introduction to Solid State Physics, Charles Kittel, VII edition, 1996.
2. Nanostructured Materials-Processing, Properties and Applications, Edited by Carl. C. Koch, William Andrew Publishing, Norwich, New York, USA, 2004.
3. Nanoscale Science and Technology, Edited by Robert W Kersall, Ian W Hamley and Mark Geoghegan, John Wiley and Sons, UK, 2005.
4. Physics of Semiconductor Nanostructures, K P Jain, Narosa, 1997.
5. Nanostructures and Nanomaterials-Synthesis, Properties and Applications, 2nd Edition by Guozhong Cao and Ying Wang.
6. Nanomaterials and Devices by Donglu Shi, ZizhengGuo and Nicholas Bedford.

Paper Code: P 404
Paper Title: Photonics(Elective – 13)
Number of Credits: 04

Course Outcomes:	Suggested Pedagogical Processes:
After the completion of the course, studentswill be able to: 1. Learn detailed description on fibre optic components. 2. Understand the science of integrated fibre optic materials. 3. Emphasize on optical signal processing. 4. A detailed description on photonic crystals.	• Lecture cum demonstration methods. • ICT based learning • Demonstration experiments • Group discussion & Problem-solving methods • Hands on experiments related to courses. • Pre-recorded lectures & Open book tests • Study visits at facility centers at universities and national research institutes. • Seminars on different topics

	Title and Content	No of Lecture Hours
Unit I	**Fibre Optic Components and Sensors:** Connector principles, Fibre end preparation, Splices, Connectors, Source coupling, Distribution networks, Directional couplers, Star couplers, Switches, Fiber optical isolator, Wavelength division multiplexing, Time division multiplexing, Fiber Bragg gratings. Advantage of fiber optic sensors, Intensity modulated sensors, Mach-Zehnder interferometer sensors, Current sensors, Chemical sensors – Fiber optic rotation sensors. Optical biosensors: Fluorescence and energy transfer sensing, molecular beacons and optical geometries of bio-sensing, Bio-imaging, Biosensing.	13 Hours
Unit-II	**Integrated Optics:** Introduction – Planar wave guide – Channel wave guide – Y-junction beam splitters and couplers - FTIR beam splitters – Prism and grating couplers – Lens wave guide – Fabrication of integrated optical devices - Integrated photodiodes – Edge and surface emitting laser – Distributed Bragg reflection and Distributed feedback lasers - Wave guide array laser.	13 Hours
Unit-III	**Optical Signal Processing:** Introduction, Effect of lens on a wavefront, Fourier transform properties of a single lens, Optical transfer function, Vanderlugt filter, Image spatial filtering, Phase-contrast microscopy, Pattern recognition, Image de-blurring, Photonic switches, Optical transistor, Optical Gates-Bistable systems, Principle of optical Bistability, Bistable optical devices, Self electro-optic effect device.	13 Hours
Unit-IV	**Photonic Crystals:** Introduction-Features of photonic crystals, Methods of fabrication, Photonic crystal optical circuitry, Nonlinear photonic crystals, Photonic crystal fibers, Photonic crystals and optical communications, Photonic crystal sensors.	13 Hours

References:

1. Fibre Optic Communication, Joseph C. Palais, Pearson Education Asia, India, 2001
2. Introduction To Fibre Optics, A.Ghatak And K.Thyagarajan, Cambridge University Press, New Delhi, 1999
3. Optical Guided Wave Signal Devices, R.Syms And J.Cozens. Mcgraw Hill, 1993.
4. Optical Electronics, A Ghatak and K. Thyagarajan, Cambridge University Press, New Delhi,1991
5. Fundamentals of Photonics, B.E.A. Saleh and M.C. Teich, John Willy and Sons,1991
6. Introduction to Fourier Optics, Joseph W. Goodman, McGraw-Hill, 1996.
7. Nanophotonics, P.N.Prasad, Wiley Interscience, 2003.
8. Biophotonics, P.N.Prasad, Wiley Publications, 2004.