



Vidyasagar University
Midnapore-721102, West Bengal

**The SYLLABUS for
POST-GRADUATE Programme**

in

PHYSICS

NEP 2020
(Semester Programme)



[w.e.f. 2025-26]

Preamble

The Department of Physics at Vidyasagar University started its journey in the year 1989. The Department offers M.Sc. Physics course and Ph.D. programme. The Department is well established with eight sanctioned faculty positions. Extramural grants from DST-FIST, CSIR, UGC-SAP and AICTE, as well as intramural grants from the University, have strengthened the Department's research and teaching learning infrastructure. The well-established department is equipped with neat and clean lecture galleries, laboratory rooms with modern instruments, a rich departmental library, ICT enabled seminar room, a modern computer lab and different high end research labs. The M.Sc. Physics programme offered by University is two years in duration and is divided into four semesters. The present syllabus is as per the guidelines of National Education Policy (NEP) 2020. The courses are synchronized with the UGC model syllabus and the assigned credits are fixed on the basis of teaching hours, which in turn is linked to course content and structure. The course is designed to include classroom teaching and practical teaching. It also emphasizes project work on the subject, Field Visit / Industry Visit /Case Study /Hands- on Practical/ Skill Enhancement Course and Internship / Capstone Project / Applied Field or Industry Project/ Innovation & Incubation/ Entrepreneurship/ Start-up Proposal or Practice, students' seminars for the holistic development of the student community. Alumni of the department span all over the national as well as some international academic institutions. The bonding between the hard-working & meritorious students and responsible & careful teachers is the recipe of the success of the department.

Programme Objectives (POs)

The Master of Science in Physics programme is designed to train students through theory and practical courses so that they are ready for advanced research and specialized careers in Physics. Our objectives span three core areas, namely, mastering the fundamentals, building specialized knowledge, and developing a research mindset.

The programme's foundation is built on an in-depth understanding of core physics principles. Through mandatory courses, students will achieve conceptual mastery in key areas: Classical Mechanics, Quantum Mechanics, Mathematical Physics, Statistical Mechanics, and Classical Electrodynamics, Condensed Matter Physics, Electronics, Nuclear and Particle Physics and Molecular Spectroscopy and Applied Optics.

Along with this the students are offered elective special papers to gain in-depth knowledge

according to their choice. These special papers include, Advanced Condensed Matter Physics, Applied Electronics, Astrophysics, Quantum Field Theory, Particle Physics and General Theory of Relativity.

Beyond theory, our other objective is to cultivate problem solving skills through tutorials, practical applications through the lab-based courses and computational proficiency through the computer lab course.

Dissertations in both theoretical and experimental streams offer a crucial firsthand experience in the research process, giving students a genuine taste of how new findings are generated.

Ultimately, the M.Sc course is structured to provide a robust academic platform, serving as the essential foundation for students (i) to pursue doctoral studies (Ph.D.) in Physics or allied fields (ii) to be ready for a teaching profession in Physics (iii) to enter related industry.

Programme Specific Outcomes (PSOs)

1. Conceptual Mastery and Reasoning

- **Fundamental Understanding:** Upon completion of the course, students will be able to master the core concepts of physics.
- **Specialized Knowledge:** Students will grasp the foundational ideas within advanced and specialized sub-fields.

2. Experimental and Applied Competence

- **Laboratory Skills:** Students will acquire the proficiency to design and execute experiments across fundamental and advanced areas such as nuclear physics, condensed matter, nanoscience, lasers, and electronics.
- **Practical Application:** Students will possess the hands-on experience necessary to contribute effectively in various applied fields within the industry or technology sector.

3. Critical Thinking and Professional Readiness

- **Analytical Mindset:** The program will train students to develop critical thinking, enabling them to effectively analyze and solve problems in diverse professional domains beyond physics.

- Teaching and Research Proficiency: Graduates will obtain a comprehensive and deep command of the subject matter, qualifying them to teach physics competently at both the school and college levels or pursue doctoral studies.

COURSE STRUCTURE OF M.Sc. IN PHYSICS

Semester	COURSE NO.		COURSE TITLES	Full Marks	No. of Lectures (hours)	CREDIT (Lecture – Tutorial - Practical)
I	PHSC401X0	DSC 1	Mathematical Physics	50	40	4(3-1-0)
	PHSC402X0	DSC 2	Classical Mechanics	50	40	4(3-1-0)
	PHSC403X1 & PHSC403X8	DSC 3	Research Methodology and Ethics (Theory & Practical)	50	80	4(1-0-3)
	PHSC404X0	DSC 4	Quantum Mechanics I	50	40	4(3-1-0)
	PHSC405X0	DSC 5	Electronics I	50	40	4(3-1-0)
	PHSO406VC	IKS	Indian Knowledge System	25	20	2(2-0-0)
	PHSO407NC		Life and Philosophy of Vidyasagar	25	20	Compulsory Non-credit
	TOTAL				275	
II	PHSC451X0	DSC 6	Quantum Mechanics II	50	40	4(3-1-0)
	PHSC452X0	DSC 7	Statistical Mechanics	50	40	4(3-1-0)
	PHSC453X0	DSC 8	Classical Electrodynamics	50	40	4(3-1-0)
	PHSC454X0	DSC 9	Molecular Spectroscopy and Applied Optics	50	40	4(3-1-0)
	PHSC455X9	DSC 10	General Lab I	50	80	4(0-0-4)
	PHSO456X9		Field Visit / Industry Visit /Skill Enhancement Course	25	60	2(0-0-2)
TOTAL				275		22
III	PHSO501X0	MOOC	MOOCs from SWAYAM	50		4(3-1-0)
	PHSC502X0	DSC 11	Condensed Matter Physics	50	40	4(3-1-0)
	PHSC503X0	DSC 12	Nuclear and Particle Physics	50	40	4(3-1-0)
	PHSC504X0	DSC 13	Electronics II	50	40	4(3-1-0)
	PHSC505X9	DSC 14	General Lab II	50	80	4(0-0-4)
	PHSO506X9		Social Service / Community Engagement	25		2(0-0-2)
TOTAL				275		22
IV	PHSE551A0 to PHSE551E0	DSE 1	Special Paper: Theory	50	40	4(3-1-0)
	PHSE552A9 to PHSE552D9	DSE 2	Special Paper: Lab	50	80	4(0-0-4)
	PHSC553X0		Research Project/Dissertation	100		8
	PHSO554X9		Internship / Industry Project/ Innovation	50	120	4
	PHSO555X9		Intellectual Property Right (IPR) / Skill Enhancement Course	25	20	2(0-0-2)
TOTAL				275		22

Special paper options

Semester IV	
PHSE551A0: Applied Electronics	PHSE552A9: Applied Electronics Lab
PHSE551B0: Advanced Condensed Matter Physics	PHSE552B9: Advanced Condensed Matter Physics Lab
PHSE551C0: Astrophysics	PHSE552C9: Astrophysics Lab.
PHSE551D0: Quantum Field Theory	PHSE552D9: Advanced Computer Lab
PHSE551E0: General Theory of Relativity	

Full Marks : 50 = END SEMESTER EXAMINATION (40) + INTERNAL ASSESSMENT (10)
25 = END SEMESTER EXAMINATION (20) + INTERNAL ASSESSMENT (5)

SEMESTER- I

Course No: PHSC401X0

Course Name: Mathematical Physics

Marks: 50

Classes: 40 Hours

1. Vector spaces and matrices: Vector spaces of n dimensions, inner product, Schmidt's orthogonalisation, Schwarz and Bessel inequality.
2. Hermitian and unitary matrices, eigenvectors and eigenvalues, diagonalization, unitary transformation. Cayley Hamilton theorem.
3. Complex variable: Cauchy Reimann conditions, Cauchy's integral and residue theorem, singularities, poles, branch points, contour integration. Taylor & Laurent series expansion, Principle value of an integral Riemann Surface.
4. Tensor analysis, Coordinate transformations, scalars, Covariant and Contravariant tensors. Addition, Subtraction, Outer product, Inner product and Contraction. Symmetric and antisymmetric tensors. Quotient law. Metric tensor. Conjugate tensor. Length and angle between vectors. Associated tensors. Raising and lowering of indices. The Christoffel symbols and their transformation laws. Covariant derivative of tensors.
5. Partial differential equations: Elliptic, parabolic and hyperbolic type equations, Lagrange's formula for 2nd order partial differential equation, Dirichlet Neumann and Cauchy Boundary value problem. Greens function with applications.
6. Integral transforms: Fourier series, Fourier transforms, Laplace transformation inverse Laplace transform. Solution of differential equations using LT and FT. Dirac delta function and its FT.
7. Group theory: Definition, nomenclature and examples. Rearrangement theorem. Cyclic groups. Subgroups and Cosets. Conjugate elements and class structure. Factor groups. Isomorphy and Homomorphy. Direct product groups. Symmetric groups, Cayley's theorem, Representation of finite groups- Definition, Unitary representation, Schur's Lemma, Orthogonality theorem, Reducible and irreducible representations, Characters, Regular representation, Product representation, Character table, Examples of S_3 and

C_4v. Introduction to Lie groups and Lie algebra. Clebsch-Gordon coefficients.

8. Integral equations. Fredholm and Volterra equations of the first and second kinds. Fredholm's theory for non-singular kernels.

Books Recommended

1. Spiegel, M.R. (2000) Theory and Problems of Complex Variables (Schaum's outline series). McGraw-Hill Publishing Co.; Metric ed ed., United States.
2. Arfken, G.B. and Weber, H.J. (2005) Mathematical Methods for Physicists, 16th ed., Elsevier Academic Press, USA.
3. Mathews, J. and Walker, R.I. (1971) Mathematical Methods of Physics, 2nd ed., Pearson Addison-Wesley, United States.
4. Dennery, P. and Krzywicki, A. (1996) Mathematics for Physicists, 1st ed., Dover Publications Inc., United States.
5. Grewal, B.S. (1965) Higher Engineering Mathematics, 1st ed., Khanna Publisher, India.
6. Joshi, A.W. (2018) Group Theory for Physicists, 5th ed., New Age International Publishers, India.
7. Hamermesh, M. (1989) Group Theory and Its Application to Physical Problems, 1st ed., Dover Publications Inc., United States.
8. Dass, T. and Sharma, S.K. (1998) Mathematical Methods in Classical and Quantum Physics, 1st ed., Universities Press Pvt. Ltd., India.
9. Joshi, A.W. (1995) Matrices and Tensors, 3rd ed., New Age International Publishers, India.

COURSE OUTCOME:

Students will be:

1. Familiar with the vector spaces and matrices
2. Understand the Hermitian and unitary matrices

3. Understand the Complex variable
4. Know the Tensor analysis
5. Familiar with the partial differential equations and Green's functions
6. Understand the integral transforms
7. Know the concepts of symmetry and group theory
8. Understanding of the integral equations

Course No: PHSC402X0

Course Name: Classical Mechanics

Marks: 50

Classes: 40 Hours

1. Recapitulation of Mechanics of System of particles, Lagrange and Hamiltonian of different systems. Lagrange & Hamiltonian for Non conservative system: Velocity dependent potential, dissipation function, charge particle is moving in an electromagnetic field. Small Oscillations
2. Variational Principles, Hamilton's Principle from Newton's equation & D'Alembert's Principle, Lagrange's equation from Hamilton's Principle, Modified Hamilton's Principle, Hamilton's Canonical equations.
3. Gauge function for Lagrangian, Canonical Transformations, Legendre Transformation, Generating Functions, Infinitesimal Contact Transformations, Poisson Bracket, Lagrange Bracket.
4. Hamilton – Jacobi Theory, Hamilton – Jacobi equation for Hamilton's principal function, Physical significance of Hamilton's principal function, Hamilton – Jacobi equation for Hamilton's characteristic function, Physical significance of Hamilton's characteristic function Hamilton-Jacobi equation from Schrodinger equation, Action-angle variables.
5. Dynamics of rigid bodies: Euler angles, rigid body problems and the Euler equations of motion, torque free motion of rigid bodies, the symmetrical top.
6. Introduction to Classical Chaos: Periodic Motion, Attractors, Chaotic Trajectories and Lyapunov Exponents, Poincare Map, Logistic Equation, classification of fixed points, limit cycles.
7. Systems with infinite degrees of freedom : Lagrangian and Hamiltonian formulations for continuous systems and fields, equations of motion. Symmetries and invariance principles, Noether's theorem.

Books Recommended:

1. Goldstein, H. (2011) Classical Mechanics, 3rd ed., Narosa Publishing Home, India.

2. Jose J. V., Seletan E. J. (1998) , Classical Dynamics: A contemporary approach, 1st ed., Cambridge University Press
3. Thornton, S., and Marion, J. (2003) Classical Dynamics of Particles and Systems, 5th ed., Horoloma Book Jovanovich College Publisher. UK.
4. Rana, N. C., and Joag, P. S. (1991) Classical Mechanics, 1st ed., Tata McGraw-Hill Pub. Co., India.
5. Takawale, R. G., and Puranik, P. S. (1979) Introduction to Classical Mechanics, 1st ed., Tata Mc- Graw Hill Publishing Company Limited, India.
6. Upadhyaya, J. C. (2019) Classical Mechanics, 1st ed., Himalaya Publishing House, India.
7. Morlin, D. (2008) Introduction to Classical Mechanics, 1st ed., Cambridge University Press, UK.
8. Calkin, M. G, (1996) Lagrangian and Hamiltonian Mechanics, World Scientific Publishing Co Pte Ltd, Singapore
9. Richards D. Percival I. C. Introduction to Dynamics (1982) 1st Ed., Cambridge University Press

COURSE OUTCOME:

In the era of modern physics, this course in classical mechanics remained absolutely essential in the way it is designed. Firstly this course acts as the stepping stone for the various branches of modern physics. e.g. the technique of action-angle variable is needed for older quantum mechanics, the Hamilton Jacobi formalism and the principle of least action paved the way to wave mechanics and the Poisson Bracket and canonical transformation leads to the justification of commutator formalisms and equations of motions. This course also provides an opportunity for students of physics to master many of the mathematical techniques.

Course No: PHSC403X1 & PHSC403X9

Course Name : Research Methodology and Ethics

Marks: 50

Classes: 40 Hours

Theory (PHSC403X1)

1. Basics of Research

Definition, importance, and characteristics of research; distinction between method and methodology; types of research – basic, applied, qualitative, quantitative, descriptive, analytical, experimental.

2. Research Problem and Literature Review

Identification and formulation of research problems; research questions and objectives; survey of literature – importance, sources, and research gaps.

3. Hypothesis and Research Process

Hypothesis – meaning, role, and types (null, alternative, simple, complex, directional, causal); research process – steps from problem identification to report writing.

4. Introduction to Ethics

Definition, nature, and scope of ethics; different branches of ethics; importance of ethics in research and academic life.

5. Research Ethics

Meaning and significance; responsibilities of researchers towards fellow researchers, public, and academic community; concept of academic integrity.

Practical (PHSC403X8)

Group A : Computer programming using C/Python:

1. Finite and infinite series. Finding roots using Bisection, Secant and Newton-Raphson methods.
2. Solving first and second order differential equations using Euler and Runge Kutta methods. Integration using Trapezoidal, Simpson methods.
3. Matrices: Use of arrays, Matrix Operations, Eigenvalues & Eigenvectors, Matrix Inversion, Solving Systems of Linear Equations.
4. Partial differential equations. Finite Difference method; Forward and Backward difference methods, Finite Element method. Examples:
 - (i) Quantum Mechanics: Solving Schrodinger's equations in a few potentials (box, triangle, one dimensional harmonic oscillator).
 - (ii) Electromagnetism: Poisson and Laplace's equation.
 - (iii) Heat equation and Wave equation.
5. Use of various software packages like, Gnuplot, Origin, Mathematica.

Group B : Electronics

1. To develop a LC filter (L type and π type) circuit having different cut-off frequencies and to find out frequency response characteristics.
2. To study the drain characteristics & transfer characteristics ($I_{D\text{ sat}}$ vs V_{gs} with V_{DS} as parameter) of a FET/MOSFET and to find out the drain resistance, mutual conductance and amplification factor.
3. To construct and design a regulated power supply using Op-Amp as comparator and power transistor as pass element and to find out its ripple factor and percentage of regulation.
4. To design various counter circuits.
5. To design a 4 bit shift register in SISO and SIPO mode.
6. To design adder/subtractor and BCD adder.

COURSE OUTCOME:

1. Students will be able to (i) understand the fundamental concepts of research, including types of research, research problems, hypothesis formulation, and the research process. (ii)

gain knowledge of research ethics and publication ethics.

2. The students will get good training in computer programming with applications to various numerical methods. The programming knowledge can be used in various branches of physics. Students will also get to learn about various software packages that would be useful for research.

3. With this part of the course, students will be able to design and fabricate various digital and analog electronic circuits, e.g. Op-Amp amplifiers, oscillator circuits.

Course No: PHSC404X0

Course Name : Quantum Mechanics-I

Marks: 50

Classes: 40 Hours

1. **Abstract formulation:** Properties of linear vector spaces. Bra-ket notation. Hermitian operators, eigenvalues and eigenvectors. Stern-Gerlach experiment. Postulates of quantum mechanics. Matrix representation, measurements, observables, and the uncertainty relations, Change of basis and unitary transformation, Position and momentum representations: Wave-functions in Position and Momentum Space. Expectation values. Ehrenfest theorem.
2. **Quantum Dynamics:** Time evolution and the Schrodinger equation, Schrodinger picture, Heisenberg picture, Heisenberg equation of motion. Solution of simple harmonic oscillator by the operator method.
3. **Angular Momentum:** Spin 1/2 system. Rotation matrices. General commutation relations of angular momentum operators. Eigenvalues, eigenvectors. Ladder operators and their matrix representations. Orbital angular momentum. Addition of angular momenta. Clebsch-Gordan coefficients. Tensor operators and Wigner-Eckart theorem.
4. **Symmetries in Quantum Mechanics:** Symmetries and conservation laws, Degeneracies, Discrete spatial translation, time translation. parity, time reversal.

Books Recommended:

1. Sakurai J. J. and Napolitano J. (2020) Modern Quantum Mechanics, 3rd ed., Addison-Wesley.
2. Schiff L. I., (1969) Quantum Mechanics, 3rd ed., McGraw-Hill Book, New York.
3. Schwabl F. (2007) Quantum Mechanics, 4th ed., Springer.
4. Griffiths D. J. & Schroeter D. F. (2019) Introduction to Quantum Mechanics, 3rd ed., Cambridge Univ. Press.
5. Ghatak A. K. & Lokanathan S. Quantum Mechanics: Theory and Applications, Macmillan India Ltd..

6. Cohen- Tannoudji C., Diu B. & Laloe F. (2019) Quantum Mechanics, Vol I & II, 2nd Ed., Wiley.
7. N. Zettili N. (2009) Quantum Mechanics: Concepts and Applications, 2nd ed., Wiley India
8. Singh J., (1996) Quantum Mechanics: Fundamentals and Applications

COURSE OUTCOME:

Quantum mechanics is a foundational mathematical formulation that describes the behavior of particles that make up the universe. It is the branch of physics relating to the very small. This course is a substantial introduction to advanced quantum mechanics and its applications. It is specifically designed to be accessible to students with an exposure to courses at undergraduate level. At the end of the course, students will be able to learn about the abstract mathematical formulation in the language of linear vector space. Concepts such as base change, momentum and position representations, operators and matrix representations would be introduced. Time evolution, connection to wave mechanics and Schrodinger's equation will also be discussed. Students will also learn to use operator methods for solving problems such as the harmonic oscillator. Students will be able to apply the developed techniques to rotational motion. He/She will understand the link between the angular momentum operator and the generator of rotations, the concept of spin, Pauli spin matrices. Angular momentum algebra will be introduced. Students will learn the addition of angular momenta. Clebsch-Gordon coefficients and their recursion relations and the Wigner-Eckart theorem. In the final part of the course the students will learn about the formal connection between symmetries and conservation laws and the roles played by discrete symmetries.

Course No: PHSC405X0

Course Name : Electronics-I

Marks: 50

Classes: 40 Hours

Group A : Analog Electronics-I

1. Operational Amplifiers: Revision of Op-amp circuits, Differential amplifier, OP-AMP architecture, Constant current sources, Input stage of an Op-Amp, OP-AMP characteristics and parameters.
2. Elements of Communication: Principle of amplitude modulation (AM) and frequency modulation (FM), AM spectrum and FM spectrum, channel band width and signal band width, side band frequency, Generation of transmitted carrier and suppressed carrier type AM signals with necessary circuits, Principles of detection of different types of modulated signals (TC and SC types), Principle of generation of FM wave with necessary circuits, Detection of FM wave-Discriminators. Modulation techniques in some practical communication systems: Superheterodyne AM and FM radio receivers, FM stereo receiver principle, VSB AM technique.
3. Radio wave propagation: Ground wave, Ionospheric wave and space wave and their characteristics, reflection and refraction of radio waves in ionosphere, critical frequency, skip distance, Maximum usable frequency, fading, Secant law, duet propagation.
4. Antenna: Dipole antenna, half wave antenna, antenna with two half elements, N elements array, induction field and radiation field, radiation resistance of an antenna.
5. Radar: Radar range equation, Basic pulsed radar system-Modulators, duplexers, indicators, radar antenna, CW radar, MTI radar, FM radar, Doppler radar.

Books Recommended:

1. Ryder, J.D. (1975) Electronics fundamental and application, 5th ed., PHI, India.
2. Gayakwad , R.A. (2015) Op- Amps and Linear Integrated Circuits, 4th ed., Pearson Education, India.
3. Roddy, D. and Coolen, J. (2008) Electronic Communications, 4th ed., Pearson Education,

India

4. Chattopadhyay, D. and Rakshit, P.C. (2020) Electronics Fundamentals And Applications, 16th ed., New Age International Publishers, India
5. Millman, J. and Grable, A. (2017) Microelectronics, 2nd ed., McGraw Hill Education, India.
6. Terman, F. E. (1955) Electronic and Radio Engineering, 4th ed., McGraw-Hill Book Company Inc., Europe.

COURSE OUTCOME:

At the end of the course, students will be able to

1. impart basic knowledge on Analog and Digital Electronics.
2. clarify and exemplify the previous knowledge of electronics in B.Sc. courses.
3. learn the basics of Op-Amp circuits and Analog communication systems.
4. gain knowledge on Radar, Antenna and MOSFET circuits.

Group B: Digital Electronics-I

1. Review of logic gates: Combinational logic gates: Karnaugh mapping : Methods of minimization (reduction) of Product of Sum (POS) and Sum of Products (SOP) expressions of 2, 3 4 and 5 variables Boolean expression, Logical implementations.
2. Sequential Circuit: Revision of Flip-Flops, Conversion of Flip-Flops.
3. Registers: Shift Register, Serial in Serial out, Parallel in Serial out, Parallel in parallel out registers, Bi-directional and Universal registers.
4. Counter: Synchronous and Asynchronous counter, modulo-Counter, decade counter, ring counter and twisted ring counter, Up/Down Counter.
5. Multivibrators: Astable and monostable (principles, Circuits and operation), Internal circuit of IC 555, Timer circuit with 555. Digital display: Seven segment display system, developing of display system for decimal, octal number system.

Books Recommended:

1. Jain, R. P. (2010) Modern digital electronics, 4th ed., Tata McGraw Hill, India
2. Anand Kumar, A. (2016) Fundamentals of Digital Circuits, 4th ed, PHI, India
3. Millman J. , Halkias C. C. and Parikh C. D. (2017) Integrated electronics, McGraw Hill, India
4. Sivakumar M. S. (2014) 1st ed., Fundamental of Digital Design, S. Chand & Company, India
5. Kothari D. P. and Dhillon (2015) J. S. Digital Circuits and Design 1st ed., Pearson Education India, India
6. Mano M. (2016) Digital Logic and Computer Design, 1st ed., Pearson Education India, India
7. Tocci, R. J. and Widmer, N. S. (2005) Digital Systems : Principles and Applications, 8th ed., Pearson New Int. Edition.

COURSE OUTCOME:

At the end of the course, students will be able to

1. gain basic knowledge of application of Digital Logic gates.
2. learn the structure and use of flip flops, counters, registers etc

Course No: PHSO406VC

Course Name : Indian Knowledge System

Marks: 25

Classes: 20 Hours

Common syllabus for all students of the science faculty

IKS-I: Physics in India

Theoretical framework for the practice of science in ancient India , Concept of Matter, Sāṅkhya-Pātañjala system, Evolution of different forms of matter (Pañcīkaraṇa) from the Vedāntic view, The atomic theory of the Buddhists and Jains, Gravity, Sage Agastya's Model of Battery, Velocity of Light, Vimana: Aeronautics, Vedic Cosmology and modern Concept, An overview of Indian contributions to technology, Technological Innovations.

IKS- II: Chemistry in India

The atomic theory of the Buddhists and Jains, Nyāya- Vaisesika chemical theory, Chemistry in practice as gleaned from the medical schools of ancient India, Qualities of compounds; formation of molecular properties in chemical compounds, Chemistry of colors, measures of weight and capacity, size of the minimum visible, Ideas of chemistry as in bṛhatsamhitā Metallurgical heritage: Arthaśāstra as the earliest text describing gold, silver, and other metals; Processing of gold, silver, copper, iron, tin, mercury, and lead as mentioned in the Indian texts in the ancient and Medieval Period, Zinc distillation as mentioned in Rasārṇava and Rasaratnasamukāyā. Concepts of acid and bases in Indian chemistry from organic fruit, vegetable-based. Acids, plant-ash-based bases to mineral acids of the medieval period.

IKS- III: Mathematics in India

Mathematics in the Vedas and Śulva Sūtras: Mathematical references in Vedas. The extant Śulbasūtra texts & their commentaries. The meaning of the word Śulbasūtra. Qualities of a Śulbakāra. Finding the cardinal directions. Methods for obtaining perpendicular bisector. Bodhāyana's method of constructing a square. The Bodhāyana Theorem (so-called Pythagoras Theorem) Applications of Bodhāyana Theorem. Constructing a square that is the difference of two squares. Transforming a rectangle into a square. To construct a square that

is n times a given square. Transforming a square into a circle (approximately measure preserving). Rational approximation for $\sqrt{2}$. Construction of Cities. Details of fabrication of bricks, etc. Pāṇini's Aṣṭādhyāyī, Piṅgala's Chandaḥśāstra & Mathematics in the Jaina Texts Āryabhaṭa, his period and his work Āryabhaṭīya, Area of a circle, trapezium, and other planar figures. Approximate value of π . Computation of tabular Rsines (geometric and difference equation methods), Ekavarṇa-samikaraṇa and anekavarṇa- samikaraṇa. Development of Combinatorics Līlāvati of Bhāskarācārya, Bījagaṇita of Bhāskarācārya & Gaṇitakaumudī of Nārāyaṇa Paṇḍita Magic Squares, Trigonometry and Spherical Trigonometry.

IKS- IV: Astronomy in India

The science of Astronomy and the different units of time discussed in the texts, Systems employed for representing numbers, Spherical trigonometry & Celestial Sphere Division of the celestial sphere/ecliptic, significance by pointing out their basis, five elements that constitute Pañcāṅga– and their astronomical significance, computation of elements in a Pañcāṅga. Key concepts pertaining to planetary computations and Computation of the true longitudes of planets Precession of equinoxes – sāyana and nirayaṇa longitude Finding the cardinal directions and the latitude of a place. Determination of the variation of the duration of the day at a given location Lagna and its computation, Eclipses and their computation.

IKS- V: Economy in India

History of Indian Economy Thoughts, New Indian Economic Model & Sectorial Contribution Past vs Present History of Indian Economy Thoughts: Context from Dharmashastras, Shukraniti, Mahabharata, and Arthashastra. Kautilya's Economic thoughts in specific. India and Global GDP: Ancient India Beyond Capitalism and Communalism, Dharmic, Caste as Social Capital, Black Money, and Tax Heaven. Agriculture: Ancient India, Manufacturing: Ancient India, Education in India, Wealth in India, Governance, and Business in India, Where India Stands Globally. Indian Business Model: Based on 10-point formula: Family Base, High Level of savings, Self-Employment, Highly Entrepreneurial Nature, Non-corporate Sector as the Core of the Economy, Community Orientation and Higher Social Capital, Faith and Relationship in Economic Affairs, A Society-driven Economy, Driven by Norms and Values.

IKS- VI: Life, Environment, Ecology and Health in India

Ethnic Studies, Life Science in Plants, Anatomy, Physiology, Agriculture, Ecology, Environment, Ayurveda, Integrated Approach to Healthcare, Medicine, Microbiology, Surgery and Ygo.

IKS-VII: Geography in India

Geography of Bharatvarsh and Civilizational Journey, Origin of Sthapatyaveda, Concept of Space and Time, Vedic Yajna: Recreating the microcosmos, Vastu Purusha, Six Limbs of Indian Art and Architecture Harappan Town Planning, Early Historical Cities and Early Text (Arthshastra), Mud Forts of Chhattisgarh, Concept of Sacred and Profane, Techno-Typological Evolution & Regional Variations in Temple Architecture, Rock Cut Architecture, Structural Temple Architecture, Tirthkshetra- Kashi, Dwaraka, Kanchi, Avantika, Ayodhya, Prabhas-kshetra etc., Continuity of Traditional Town Planning: Jaipur, Madurai, Srirangam etc. Functional Aspects of Temples Sacred Forest (Naimisaranya, Panchvati, Dandkaranya etc.), Sacred Groves (Aaramika, Devkunj, etc.), Rainwater Harvesting System: Vav, Kund, Talavetc, Sacred Hills and Mountains (Kailash, Vindhyaachal, Sahyadri, Satrunjay, Goverdhan), Kumbha: assimilation of ritual, myth, symbology, and cosmology. Anand K. Coomaraswamy, Patrick Geddes, Alice Boner, Kapila Vatsayayan, Stella Kramrisch and Adam Hardy Forest Management and Urban Planning: Agroforestry, Tank, Lakes, and Stepwells.

Books Recommended:

1. Dr. Subhash Kak, Computation in Ancient India, Mount, Meru Publishing (2016)
2. Dharampal, Indian Science and Technology in the Eighteenth Century, Academy of Gandhian Studies, Hyderabad, 1971, republic. Other India Bookstore, Goa, 2000
3. Alok Kumar, Sciences of the Ancient Hindus: Unlocking Nature in the Pursuit of Salvation, CreateSpace Independent Publishing, 2014
4. B.V. Subbarayappa, Science in India: A Historical Perspective, Rupa, New Delhi, 2013
5. S. Balachandra Rao, Indian Mathematics and Astronomy: Some Landmarks, Jnana Deep Publications, Bangalore, 3rd edn, 2004

6. S. Balachandra Rao, Vedic Mathematics and Science in Vedas, Navakarnataka Publications, Bengaluru, 2019
7. J. McKim Malville & Lalit M. Gujral, Ancient Cities, Sacred Skies: Cosmic Geometries and City Planning in Ancient India, IGNCA & Aryan Books International, New Delhi, 2000).
8. Clemency Montelle, Chasing Shadows: Mathematics, Astronomy and the Early History of Eclipse Reckoning, Johns Hopkins University Press, 2011
9. Thanu Padmanabhan, (ed.), Astronomy in India: A Historical Perspective, Indian National Science Academy, New Delhi & Springer (India), 2010
10. Acharya Prafulla Chandra Ray, A History of Hindu Chemistry, 1902, republ., Shaibya Prakashan Bibhag, centenary edition, Kolkata, 2002
11. R. Balasubramaniam, Marvels of Indian Iron through the Ages, Rupa & Infinity Foundation, New Delhi, 2008
12. Fredrick W. Bunce: The Iconography of Water: Well and Tank Forms of the Indian Subcontinent, DK Printworld, New Delhi, 2013
13. The Positive Sciences of the Ancient Hindus; Brijendra Nath Seal; 4 th Edition; 2016
14. A Concise History of Science in India, ed. D M Bose, S N Sen and B V Subbarayappa; INSA; 2009
15. Scientific and Technical Education in India, 1781-1900 by S N Sen; 1991
16. Dwivedi D.N., Essentials of Business Economics, Vikas Publications, Latest Edition.
17. Economic Sutras by Prof. Satish Y. Deodhar, IIMA Books series
18. Black Money Tax Heaven by R Vaidyanathan, Westland ltd. Publication.
19. Goswami Anandajit, Economic Modeling, Analysis, and Policy for Sustainability, IGI Global, Latest Edition.
20. Ganguly Anirban, Redefining Governance, published by Prabhat Prakashan, Latest Edition.

21. Vatasayyan, Kapila. 1997. The Square and the Circle of the Indian Arts, Abhinav Publication.
22. Hardy, Adam. 2015. Theory and Practices of Temple Architecture in Medieval India: Bhoja's Samrangansutrādhara and The Bhojpur Line Drawings, Dev Publishers & Distributors.
23. B. Datta and A. N. Singh, History of Hindu Mathematics, 2 Parts, Lahore 1935, 1938; Reprint, Asia Publishing House, Bombay 1962; Reprint, Bharatiya Kala Prakashan, Delhi 2004.
24. G. G. Emch, M. D. Srinivas and R. Sridharan, Eds., Contributions to the History of Mathematics in India, Hindustan Book Agency, Delhi, 2005.
25. G. G. Joseph, Indian Mathematics Engaging the World from Ancient to Modern Times, World Scientific, London 2016.
26. P. P. Divakaran, The Mathematics of India Concepts Methods Connections, Hindustan Book Agency 2018. Rep Springer New York 2018.
27. Gaṇitayuktibhāṣā (c.1530) of Jyeṣṭhadeva (in Malayalam), Ed. with Tr. by K. V. Sarma with Explanatory Notes by K. Ramasubramanian, M. D. Srinivas and M. S. Sriram, 2 Volumes, Hindustan Book Agency, Delhi 2008.
28. S. Balachandra Rao, Indian Astronomy an Introduction, Universities Press, Hyderabad, 2000
29. History of Astronomy: A Handbook, Edited by K. Ramasubramanian, Aniket Sule and Mayank Vahia, S and HI, IIT Bombay, and T.I.F.R. Mumbai, 2016.
30. B.V. Subbarayappa and K.V. Sarma, Indian Astronomy: A Source Book, Nehru Centre, Bombay, 1985.
31. Tantrasaṅgraha of Nīlakaṇṭha Somayājī, Translation and Notes, K. Ramasubramanian and M. S. Sriram, Hindustan Book Agency, New Delhi 2011.

COURSE OUTCOME

Upon successful completion of this course, students will be able to:

1. Understand the foundational concepts, philosophical principles, and historical evolution of the Indian Knowledge System.
2. Analyze the contributions of IKS to various scientific domains such as mathematics, astronomy, medicine, and environmental studies.
3. Apply knowledge of IKS in combination with modern scientific approaches to foster interdisciplinary problem-solving and innovation.

Course No: PHSO407NC

Course Name: Life and Philosophy of Vidyasagar

Marks: 25

Classes: 20 Hours

SEMESTER- II

Course No: PHSC451X0

Course Name: Quantum Mechanics II

Marks: 50

Classes: 40 Hours

1. **Approximation Methods for Stationary Systems:** Time-independent perturbation theory: nondegenerate and degenerate. Stark effect, Zeeman effect. Variational and WKB methods and applications.
2. **Approximation Methods for time-dependent perturbations:** Interaction picture. Time-dependent perturbation theory. Transition to a continuum of final states–Fermi’s Golden Rule. Constant and harmonic perturbations. Sudden and adiabatic approximations.
3. **Identical particles:** Permutation Symmetry. Symmetrization postulate: symmetric and antisymmetric wave function, Pauli’s exclusion Principle. Slater determinant. Two-Electron System- The Helium atom, ground state of Helium atom. (5)
4. **Non-relativistic Scattering:** Lippmann-Schwinger Equations, Green’s function method. Born approximation, S-Matrix, Optical theorem, Method of Partial Waves, Phase shifts.
5. **Relativistic quantum mechanics:** Historical survey. Klein-Gordon and Dirac equations. Properties of Dirac matrices. Plane wave solutions of Dirac equation. Spin and magnetic moment of the electron, non-relativistic limits.

Books Recommended:

1. Sakurai J. J. and Napolitano J. (2020) Modern Quantum Mechanics, 3rd ed., Addison-Wesley.
2. Schiff L. I., (1969) Quantum Mechanics, 3rd ed., McGraw-Hill Book, New York.
3. Schwabl F. (2007) Quantum Mechanics, 4th ed., Springer.
4. Griffiths D. J. & Schroeter D. F. (2019) Introduction to Quantum Mechanics, 3rd ed., Cambridge Univ. Press.

5. Ghatak A. K. & Lokanathan S. Quantum Mechanics: Theory and Applications, Macmillan India Ltd..
6. Cohen- Tannoudji C., Diu B. & Laloe F. (2019) Quantum Mechanics, Vol I & II, 2nd Ed., Wiley.
7. N. Zettili N. (2009) Quantum Mechanics: Concepts and Applications, 2nd ed., Wiley India
8. Singh J., (1996) Quantum Mechanics: Fundamentals and Applications to Technology, 1st Ed., Wiley VCH.

COURSE OUTCOME:

This course builds on the first part of the course Quantum Mechanics I. In this part the students will learn to solve problems using approximate methods for stationary systems and time dependent perturbations. Variational and WKB methods will also be introduced. Methods for addressing systems of identical particles will be addressed. Important applications such as the Stark effect, Zeeman effect, Helium atom, transition to a continuum of final states and Fermi's Golden Rule and quantum theory of scattering will be discussed at length. These techniques are widely used in nuclear physics, particle physics and condensed matter systems. Towards the end of the course relativistic quantum mechanics will be introduced with a view to opening up students' interest in quantum field theory, particle physics and modern applications in condensed matter systems.

Course No: PHSC452X0

Course Name: Statistical Mechanics

Marks: 50

Classes: 40 Hours

1. **Scope and aim of statistical mechanics.** Transition from thermodynamics to statistical mechanics. Review of the ideas of phase space, phase points, Ensemble, Density of phase points. Liouville's equation and Liouville's theorem.
2. **Stationary ensembles:** Microcanonical, canonical and grand canonical ensembles. Partition function formulation. Fluctuation in energy and particle. Equilibrium properties of ideal systems: ideal gas, Harmonic oscillators, rigid rotators. Paramagnetism, concept of negative temperature.
3. **Density matrix:** Idea of quantum mechanical ensemble. Statistical and quantum mechanical approaches, Properties. Pure and Mixed states. Density matrix for stationary ensembles. Application to a free particle in a box, an electron in a magnetic field. Density matrix for a beam of spin $\frac{1}{2}$ particles. Construction of the density matrix for different states (pure and mixture) and calculation of the polarization vector
4. **Distribution functions:** Bose-Einstein and Fermi-Dirac statistics. General equations of state for ideal quantum systems.
5. **Ideal quantum systems:**
 - (i) Properties of ideal Bose gas: Bose-Einstein condensation: Transition in liquid He-4, Superfluidity in He-4. Photon gas: Planck's radiation law. Phonon gas: Debye's theory of specific heat of solids.
 - (ii) Properties of ideal Fermi gas: Review of the thermal and electrical properties of an ideal electron gas. Landau levels, Landau diamagnetism. White dwarf.
6. **Interacting systems:**
 - (i) Ising model. Idea of exchange interaction and Heisenberg Hamiltonian. Ising Hamiltonian as a truncated Heisenberg Hamiltonian.
 - (ii) Exact solution of one-dimensional Ising system. Bragg-William approximation (Mean field theory).
 - (iii) Introduction to 2D XY model and Kosterlitz-Thouless Transition
7. **Phase transition:** General remarks. Phase transition and critical phenomena. Critical

indices. Landau's order parameter theory of phase transition.

8. **Fluctuations:** Thermodynamic fluctuations. Spatial correlations in a fluid.
Brownian motion: Einstein-Smoluchowski's theory.

Books Recommended:

1. Pathria, R.K. (2001) Statistical Mechanics, 2nd ed., Butterworth-Heinemann, Oxford, England.
2. Huang, K. (1987) Introduction to Statistical Mechanics, 2nd ed., John Wiley & Sons, Inc., United States.
3. Blundell, S.J. and Blundell, K.M. (2006) Concepts in Thermal Physics, 2nd ed., Oxford University Press, Oxford University Press, England.
4. Reif, F. (2010) Fundamentals of Statistical and Thermal Physics, 56946th ed., Sarat Book Distributors, India.
5. Kadanoff, L.P. (2000) Statistical Mechanics: Statics, Dynamics and Renormalization, 1st ed., World Scientific Publishing Co. Pvt. Ltd., India.
6. Kubo, R. (1988) Statistical Mechanics: An Advanced Course with Problems and Solutions, 17th ed., Elsevier, Netherlands.
7. Ma, S.K. (1985) Statistical Mechanics, World Scientific Publishing Co. Pvt. Ltd., United Kingdom.
8. Ishihara, A. (1971) Statistical Physics, 1st ed., Elsevier, Netherlands.

COURSE OUTCOME:

1. Students will have knowledge the concepts of phase space
2. Understanding different ensembles with application to condensed matter and other branches of physics
3. describe the features and examples of Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac statistics
4. Learning the Modern aspects of equilibrium and non- equilibrium statistical Physics.
5. Work with various models of phase transitions and thermodynamical fluctuations.

6. Describe physical quantities in quantum systems.
7. Familiar with the ideal quantum distributions
8. Know the applications to interacting systems and evaluation of phase transitions
9. Understand different quantum statistics for explanation of B.E. condensation, Black body radiations, Pauli paramagnetism, Landau diamagnetism and electron gas systems for thermionic and photoelectric emission.
10. Use and develop mean field theory for first and second order phase transitions in one and two dimensional Ising model

Course No: PHSC453X0

Course Name: Classical Electrodynamics

Marks: 50

Classes: 40 Hours

1. **Revisions of electrodynamics:** Maxwell's field equations; Electromagnetic scalar and vector potentials; Wave equations; Wave guides – TE, TM and TEM modes; Rectangular and cylindrical waveguides; Resonant cavities.

2. **Field of moving charges and radiations:** Green function for relativistic wave equation. Retarded potentials; Lienard-Wichert potentials; Fields produced by arbitrarily and uniformly moving charged particles; Radiations from an accelerated charged particle at low velocity and at high velocity (Larmor's formula); Angular distribution of radiated power; Radiation due to an oscillating electric dipole; Electric quadrupole radiation; Radiation due to small current element; Radiation from linear (thin) and half-wave antennas; Antenna arrays.

3. **Radiation in material media:** Cherenkov radiation; Scattering of electromagnetic wave – Thomson, Rayleigh and resonant scattering; Polarization of scattered light; Coherence and incoherence scattered light; Dispersion and absorption of radiations in media; Elementary theory of dispersion – dispersions in gas, liquid and solid.

4. **Relativistic electrodynamics:** Lorentz transformation of space and time in 4-vector form; Transformations for charge and current densities; Transformation equations for field vectors; Covariance of Lorentz condition; Invariance of Maxwell's field equations under relativistic transformation; Covariance of Maxwell's field equations in 4-vector form; Electromagnetic field tensor; Maxwell's stress tensor; Maxwell's field equations in covariance 4-tensor form; Transformation equations for magnetic field induction components; Invariance of electromagnetic fields; Covariance of Lorentz force equation; Transformation law of Lorentz force.

5. **Radiation loss of energy by free charges of plasma:** Radiation emitted by excited atoms and ions; Cyclotron or Betatron radiation; Bremsstrahlung radiation; Recombination radiation; Black body radiation; Transport of radiation.

6. **Fundamental concepts about plasma:** Mean free path and collision cross section; Electron and ion temperatures; Effect of magnetic field on mobility of ions and electrons; Diffusion of ions and electrons; Ambipolar diffusion.

7. **Elements of Plasma Kinetic theory:** Boltzmann equation – Collision less and collisional; Conservation of particles, mass and charges; Vlasov Equation; Application of B-V equation to longitudinal waves.

Books Recommended:

1. Jackson, J.D. (2007). Classical Electrodynamics, 3rd ed., John Wiley & Sons, Inc., United States.
2. Griffiths, D.J. (1999). Introduction to Electrodynamics, 3rd ed., New Jersey, United States.
3. Biro, T. (1992). Phase-space description of plasma waves: Linear and nonlinear theory, 1st ed., Swedish Institute of Space Physics, Umed Division, Sweden, pp. 1-7.
4. Engel, V. (1994). Ionized gases, 1st ed., American Institute of Physics Melville, United States.
5. Goswami, S.N. (2005). Elements of Plasma Physics, 1st ed. (Reprint), New Central Book Agency (P) Ltd., India.
6. Chakraborty, B. (2003). Principles of Plasma Mechanics, 4th ed., New Age Internationals, India.
7. Lorrain, P. and Corson, D. (2003). Electromagnetic Fields and Waves, 2nd ed., CBS Publishers & Distributors Pvt. Ltd., India, pp. 424-436.
8. Heald, M.A. and Marion, J.B. (1995). Classical Electromagnetic Radiation, 3rd ed., Saunders College Publishing, Harcourt Brace College Publishers, United States.
9. Miyamoto, K. (2011). Fundamentals of Plasma Physics and Controlled Fusion, 3rd ed., National Institute of Fusion Science (NIFS), Toki, Japan, pp. 39-43.
10. Panofsky, W.K.H. and Phillips, M. (2012). Classical Electricity and Magnetism, 2nd ed., Dover Publications, United States.
11. Sen, S.N. (2016). Plasma Physics: Plasma State of Matter, 11th ed. (Reprint), Pragati Prakashan, India.

COURSE OUTCOME:

Students will be able to:

1. Use of mathematical tools for understanding the pre-requisite of electrodynamics
2. Gain insights into various modes in waveguides
3. Evaluate fields and forces in electrodynamics
4. Know the concepts of retarded phenomena and radiation
5. Gain the knowledge on various mechanisms for emission of radiation from moving charged particles
6. Know the radiation interaction including scattering and dispersion in material media
7. Acquire knowledge of relativistically covariant formulation of electrodynamics
8. Know the fundamental concepts about plasma dynamics

Course No: PHSC454X0

Course Name: Molecular Spectroscopy and Applied Optics

Marks: 50

Classes: 40 Hours

1. Microwave spectroscopy: Conversation of different spectroscopic units, Basic idea about the generation of electromagnetic spectrum from radio frequency to v-ray.
2. Rotations of molecules, Diatomic molecular rotational spectroscopy of rigid and non- rigid diatomic molecules, Intensity of spectral lines, microwave spectroscopy of symmetric type of molecules, Stark effect.
3. Infra-red spectroscopy: Diatomic molecular vibrational spectroscopy with harmonic and anharmonic vibration, vibrational and rotational spectroscopy, anharmonic oscillation constant, rotational constant, Dissociation energy.
4. Visible and ultraviolet spectroscopy: Molecular electronic spectroscopy, Frank Condon principle, Molecular electronic vibrational-rotational spectroscopy, Born-Oppenheimer approximation, Fortrat diagram, Band head.
5. Laser: Spontaneous and stimulated emission, Laser resonator, population inversion, active and passive laser resonator, Threshold condition, saturation condition, Quality factor, Burger's law, classification of laser Three level laser and four level laser system, equation of population inversion and threshold power calculation for the laser systems. Q switching, Application of laser.
6. Fiber optics: Different types (single and multi mode) of step index and graded index optical fiber, ray path in graded index optical fiber, Multipath broadening, Modal analysis of Electromagnetic waves in planer waveguide. Application of fiber in digital communication.
7. Holography: Coherent light and application of coherent light in holography. Recording and reconstruction of wave front.
8. Non-linear Optics: Non-linearity of medium, second and higher harmonic generation, phase matching condition, frequency addition and frequency subtraction, self- focusing, Pokels & Kerr type of nonlinear materials, Examples of Organic and inorganic nonlinear materials. Photo dynamical therapy.
9. Photonics Information Processing: Optical logic operations, Optical arithmetic operation with binary, optoelectronic logic gates, all optical logic gates, tristate logic system and tristate AND & OR gate.

10. Photosensors, different types of photo-detectors, Graphene and graphene based photodetectors, photo sensitivity, photoresponsivity.

Books Recommended:

1. Banwell, C. N., and McCah, E. M. (2017) Fundamentals of Molecular Spectroscopy, 4th ed., Tata McGraw - Hill Publishing Company Limited, India.
2. Aruldas, G. (2007) Molecular Structure and Spectroscopy, 2nd ed., PHI Learning Private Limited, India.
3. Hertzberg, G. (1951) Molecular Structure and Molecular Spectra: vol. 1, Spectra of Diatomic Molecules, 2nd ed., Van Nostrand.
4. Herzberg, G. (1945) Molecular Structure and Molecular Spectra: vol. 2, Infrared and Raman Spectra of polyatomic Molecules, 16th printing ed., Van Nostrand.
5. Barrow, G. M. (1962) Molecular Spectroscopy, 1st ed. McGraw-Hill Inc., US.
6. Ghatak, A., and Thyagarajan, K. (2007) Optical Electronics, Special ed. for sale in South Asia, Cambridge University Press India Pvt. Ltd, India.
7. Bhattacharya, P. (1996) Semiconductor optoelectronic devices, 2nd ed., Prentice Hall publication, India.
8. Yariv, A. (1984) Optical Electronics, 3rd ed., Holt McDougal.
9. Tarasov, L. V. Laser Physics and Applications, Mir Publishers, USSR
10. Pipker, J. (2003) Semiconductor Optoelectronic Devices: Introduction to Physics and Simulation, 1st ed., Academic Press, USA
11. Bhattacharya, P. (2017) Semiconductor Optoelectronic Devices, end ed., Pearson, India.
12. Rosencher, E., and Vinter, B (2002) Optoelectronics, 1st ed., Cambridge, University Press.
13. Mukhopadhyay, S. (2000) Optical computation and parallel processing, 1st ed., Classique Books Publisher, India.

COURSE OUTCOME (CO):

After successful completion of this course, students will be able to:

CO1. Demonstrate an understanding of microwave, infrared, visible, and ultraviolet spectroscopy, and interpret rotational, vibrational, and electronic spectra of molecules.

CO2. Analyze the rotational and vibrational energy levels of diatomic molecules—both rigid and non-rigid—and determine spectroscopic constants, dissociation energies, and line intensities.

CO3. Apply fundamental principles such as the Franck–Condon principle, Born–Oppenheimer approximation, Fortrat diagram analysis, and Stark effect to explain molecular spectral features.

CO4. Explain the principles of laser action including spontaneous and stimulated emission, population inversion, resonator design, threshold conditions, Q-switching, and evaluate different laser systems and their applications.

CO5. Describe the structure, guiding mechanisms, and dispersion characteristics of optical fibers, and analyze modal propagation in step-index and graded-index fibers for communication applications.

CO6. Explain the concepts of holography, coherent wavefront recording, and reconstruction, and their practical significance.

CO7. Understand nonlinear optical processes—such as harmonic generation, frequency mixing, and self-focusing—and identify materials used in NLO applications, including PDT.

CO8. Perform basic photonic information-processing operations, including optical logic and arithmetic, using optoelectronic and all-optical logic gates.

CO9. Identify and compare different photosensors and photodetectors, including graphene-based devices, and evaluate parameters such as photosensitivity and photoresponsivity.

Course No: PHSC455X9
Course Name: General Lab I

Marks: 50

Classes: 80 Hours

1. To design a 4 bit ripple up/down counter and to develop different modulo counters from it.
2. To design a 4 bit Ring counter and Twisted Ring counter.
3. To obtain the frequency response characteristic of an inverting operational amplifier and to find out its band width.
4. To obtain the frequency response characteristic of a non-inverting operational amplifier and to find out its band width.
5. Design and study of 2 bit binary comparator.
6. Band gap measurement of a Semiconductor using P-N junction.
7. Study of the Time Response of a Light Dependent Resistor (LDR) under ON/OFF Modulated Incident Light
8. Determination of Planck's Constant by Using a Solar Cell.
9. Study of the Temperature Dependence of Resistivity of a Semiconductor and Determination of Its Band Gap
10. Study of NMR spectrometer.
11. Measurement of electronic charge using Millikan's oil drop experiment (Dynamic method).
12. Estimation of the separation between two plates of a Fabry-Perot interferometer.
13. Study of the characteristics of a G.M. tube.
14. Verification of inverse square law using G.M. counter.
15. Determination of particle size of a given material using LASER diffraction method.

COURSE OUTCOME:

This course will help the students to design and fabricate various digital and analog electronic circuits, e.g. counters, multivibrators, oscillator circuits. The practical course structure is designed to impart the students to provide strong hands-on laboratory training on various apparatus, devices or instruments utilizing in modern and currently active areas of Physics particularly in optics, X-rays, radiation, electric, magnetic, semiconductor-physics and nuclear-physics.

Course No: PHSO456X9

Course Name: Field Visit / Industry Visit /Skill Enhancement Course

Marks: 25

Classes: 60 Hours

SEMESTER- III

Course No: PHSO501X0

Course Name: MOOCs from SWAYAM

Marks: 50

Classes: 40 Hours

Course No: PHSC502X0

Course Name: Condensed Matter Physics

Marks: 50

Classes: 40 Hours

1. Polycrystalline, single crystalline and amorphous materials, Symmetry elements, point group, Space group, Scattering of X-ray by a crystal, Laue equation, atomic form factor, Structure factor and Experimental Diffraction Methods.
2. Quantization of lattice vibrations, Phonons, Anharmonic Crystal Interactions, Debye Waller effect.
3. Energy Bands: Physical origin of the energy gap, Bloch function, Essential features of Kronig Penny model, Effective mass. Nanocrystals.
4. Density of States, Density of electrons and Holes for Nondegenerate and Degenerate Semiconductors, Intrinsic Semiconductor, Electric Neutrality Condition, n- type and p-type semiconductor. p-n Junction in equilibrium, Einstein relation, Contact Potential, Diffusion length, Derivation of Diode equation, Junction Capacitance. Photoconductivity, Relaxation Time, Solar Cell, p-n-p Transistor under common base configuration.
5. Diamagnetism, Quantum theory of Paramagnetism, Weiss Molecular Field Theory of Ferromagnetism.
6. Superconductivity: Normal metal and alloy, Superconducting material, Resistivity: Normal metal, perfect metal, superconductor, Thermodynamics of a super conductors: Gibbs Free Energy, Entropy, Specific heat, Order of Phase Change, Resistance less circuit, Meissner Effect, Consequence of zero resistance, London Theory, Magnetic Levitation, Macroscopic Quantum Description of the Supercurrent, The Quantum Mechanical Current: Perfect Conductivity - First London Equation, Perfect Diamagnetism - Second London Equation, The Two-Fluid Model, Propagation characteristics at finite temperatures of a superconductor, Josephson Tunnelling, D. C. Josephson Tunnelling, A.C. Josephson Tunnelling.
7. Dielectrics: Complex dielectric constant and dielectric losses, dielectric losses and relaxation time.

Books Recommended:

1. Michael M. Woolfson, An Introduction to X-ray Crystallography, Cambridge University Press Publisher
2. C. Kittel, Introduction to Solid State Physics, John Wiley & Sons Inc (Sea) Pte Ltd (Publisher)
3. A. J. Dekker, Solid State Physics, Macmillan Student ed., Pan Macmillan, India (Publisher)
4. N. W. Ashcroft, and N. D. Mermin, Solid State Physics, Thomson Learning (Publisher)
5. J. Richard Christman, Fundamentals of Solid State Physics, John Wiley & Sons (Publisher)
6. B. E. Warren, X-ray Diffraction, Dover Publications Inc. (Publisher)
7. A. C. Rose-Innes and E. H. Rhoderick, Introduction to Superconductivity, 1st ed., Paragon Press, UK (Publisher).
8. M. A. Omar, Elementary Solid State Physics- Principles & Applications, 1st ed. Pearson India (Publisher).
9. N. David, C. University, and N. W. Ashcroft, Solid State Physics, 1st ed., Cengage, India (Publisher)
10. F. Annett, Superconductivity, Superfluids, and Condensates: 5 (Oxford Master Series in Physics,), 1st ed. OUP Oxford, UK (Publisher).
11. H. Ibach, and H. Lüth, Solid-State Physics: An Introduction to Principles of Materials Science, 4th ed. Springer, Germany (Publisher)
12. P.S. Kireev (Author), M. Samokhvalov (Translator), Semiconductor Physics, Central Books Ltd (Publisher) or P.S. Kireev, Semiconductor Physics, Mir (Publishers)
13. B. G. Streetman, and S. K. Banerjee, Solid State Electronic Devices, 7th Edition, Pearson Education Asia (Publisher)
14. Robert Allan Smith, Semiconductors, 2 Ed, Cambridge University Press (Publisher)

COURSE OUTCOME :

CO1: Understand crystal structures, symmetry, and X-ray diffraction principles.

CO2: Explain lattice vibrations, phonons, and thermal effects in solids.

CO3: Analyze energy band formation and electronic behavior in crystalline and nanomaterials.

CO4: Apply semiconductor theory to carrier statistics and electronic devices.

CO5: Explain magnetic, dielectric, and superconducting properties of materials.

Course No: PHSC503X0

Course Name: Nuclear and Particle Physics

Marks: 50

Classes: 40 Hours

1. Revisions of general properties of Nuclei and classification of nuclides:

Recapitulation of nuclear properties and types of nuclides; Nuclear magnetic moment determination by the method of Rabi and colleagues; Mass spectrometry – basic components of mass spectrometers and double focusing mass spectrometer of Nier and Roberts.

2. Radioactive decay of nuclei:

Alpha decay: Consideration of actual barrier in explaining the Gamow's theory of alpha decay; Hindrance and formation factors; Energy loss of alpha particles in matter; Theoretical calculation of alpha-particle range in matter and straggling of range.

Beta decay: Fermi's theory of beta decay; Kurie plot; Comparative half-life; Absorption of beta particles in matter – ionization loss, radiation loss, and range; Simple ideas of parity violation in β -decay; Inverse and double β -decay.

Gamma decay: Passage of gamma-rays through matter – absorption and scattering; Radiative transitions in nuclei – multipole radiations and modes of gamma-rays transition; Nuclear resonance fluorescence; Mossbauer effect – recoil free gamma-ray spectroscopy and applications of Mossbauer effect.

3. **Nuclear reactions:** Reaction channels; Nuclear energy levels; Nuclear reaction kinematics – mass and energy balance in nuclear reactions; Concept of direct and pre-equilibrium reaction mechanisms; Compound nuclear model; Breit-Wigner one level formula; Basic ideas on continuum theory.

4. **Nuclear forces and two-nucleon problem:** Basic of nuclear forces; Properties of deuteron; Ground and excited states of deuteron, Schrodinger wave equation for deuteron and its solution, and normalization of deuteron wave function; Deuteron radius; Neutron-proton (n-p) scattering at low energies – partial wave method, energy limits, phase shift, scattering cross-section, scattering length and nature of wave functions; Proton-proton (p-p) scattering at low energies – partial wave method, phase shift and effect of nuclear forces; Basic concept on neutron-neutron (n-n) scattering.

5. **Nuclear models:** Nuclear shell structure – evidence for existing of magic numbers and experimental evidences for shell effect; Single particle states in nuclei – square-well, harmonic oscillator and spin-orbit coupling potentials; Single particle shell model; Nordheim's rule; Collective model of Bohr and Mottelson.

6. **Neutron Physics:** Classification and sources of neutrons; Neutron monochromators – mechanical velocity selector, time of flight velocity selector and crystal spectrometer; Thermal neutrons – energy distribution and diffusion of thermal neutrons; Elements of neutron optics.

7. **Reactor physics:** Reactor materials – fuels, moderators, reflectors and coolants; Slowing down of neutrons in matter – energy loss in moderator, scattering angles, average energy loss per collision, transport mean free path, scattering cross-section, average logarithmic energy decrement, slowing-down power, moderating ratio and slowing down time.

8. **Elementary Particles:** Relativistic kinematics, fundamental classification of elementary particles and study of their different properties. Conservation Laws. Isospin, Hypercharge. Review of Lie Groups, representations of SU(2), SU(3), Isospin, Gell-mann and Nishijima SU(3) Quark model, wavefunctions of mesons and baryons, the need for color quantum number. Charm and other flavors. Introduction to the standard model. Electroweak interaction-W & Z Bosons.

Books Recommended:

1. Elton, L.R.B. (1965). Introductory Nuclear Theory, 2nd ed., Sir Isaac Pitman & Sons Ltd, United Kingdom.
2. Gasiorowicz, S. (1966). Elementary Particle Physics, 1st Ed., John Wiley & Sons Inc.
3. Roy, R.R. and Nigam, B.P. (1967). Nuclear Physics – Theory and Experiment, John Wiley & Sons, New York, United States.
4. Segre, E.G. (1977). Nuclei and Particles: An Introduction to Nuclear and Subnuclear Physics, 2nd ed., Basic Books, United States.
5. Cohen, B. (1974). Concepts of Nuclear Physics, 1st ed., McGraw Hill Higher Education, United States.
6. Blatt, J.M. and Weisskopf, V.F. (1979). Theoretical Nuclear Physics, 1st ed., Springer, Germany.
7. Krane, K.S. (1987). Introductory Nuclear Physics, Rev. 3rd ed., John Wiley & Sons, New York, United States.
8. Lim, Y.K. (2000) Problems and Solutions on Atomic, Nuclear and Particle Physics, 1st ed., World Scientific Publishing Co. Pte. Ltd., Singapore.
9. Kaplan, I. (2002). Nuclear Physics, 19th ed., Narosa Publishing House, India.
10. Wong, S.S.M. (2004). Introductory Nuclear Physics, 2nd ed., WILEY-VCH Verlag Gmbl I & Co. KGaA, Weinheim, Germany.

11. Halzen, F. & Martin, A.D. (2008). Quarks & Leptons: An introductory Course In Modern Particle Physics, John Wiley (India).
12. Griffiths, D. (2008). Introduction to Elementary Particles, 2nd Ed., Wiley-VCH.
13. Pal, P.B. (2014). An Introductory Course of Particle Physics, 1st Ed., CRC Press.
14. Perkins, D. H. (2014). An Introduction to High Energy Physics, 2nd Ed., Cambridge University Press.
15. Ghoshal, S.N. (2015). Nuclear Physics, Reprint 1st ed., S. Chand & Company Pvt. Ltd., India.
16. Tayal, D.C. (2015) Nuclear Physics, Reprint 5th ed., Himalaya Publishing House, India.
17. Srivastava, B.N. (2019). Basic Nuclear Physics and Cosmic Rays, 18th ed., Pragati Prakashan, India.

COURSE OUTCOME:

Students will be able to:

1. Understand the basic properties of nuclei and their classifications
2. Learn about the nuclear magnetic moment determination method
3. Understand the three radioactive decay phenomena
4. Understand the interactions of radiations with matter and radiation-energy loss in matter
5. Understand different nuclear spectroscopy
6. Understand the nuclear forces and two-nucleon problem
7. Know the nuclear reactions and their classification
8. Obtain the knowledge on various nuclear models
9. Understand the neutron physics and neutron optics
10. Understand the use of nuclear reactions in various fields of science and technology.
11. Know relativistic kinematics of different elementary particles reaction
12. Learn about the quark model and electroweak interaction between elementary particles
13. Learn about standard model (SM) for elementary particles

Course No: PHSC504X0
Course Name: Electronics-II

Marks: 50

Classes: 40 Hours

Group A : Analog Electronics-II

1. (i) Network analysis : Network theorems, equivalent circuits, two-port parameters hybrid parameters, Driving point impedance and admittance, Foster's reactance theorems, properties of poles and zeros of reactance function, Topological descriptions of different commonly used networks, π to T and T to π conversions, reduction of a complicated network into its equivalent T and π form.

(ii) Filter Circuit : L filter, π filter, iterative impedance, image impedance of a network, symmetrical network, characteristic impedance and propagation constant of a network. Methods of development of different constant-k filters like high pass, low pass, band pass and band stop filter circuits.
2. Transmission Lines: Line parameters, characteristic impedance and propagation constant of a transmission line, voltage and current equations of transmission line : Telegraphers' equations and their complete solutions, attenuation constant, phase constant, line of finite length behaving as a line of infinite length, reflection co-efficient in a line, velocity of signal in a line, voltage standing wave ratio, Input impedance of Lossless line, line at radio frequency, Origin of distortions in a transmission line, distortion less line, cable fault location telephone cable.
3. Thyristors: SCR, Triac, Diac, characteristics parameters, Thyristor rectifier & control circuits, DC Power control by SCR and AC power control by Triac.

Group B: Digital Electronics-II

1. Combinational circuits: MUX, DeMUX, Encoder, Decoder, 4 bit comparator. ADC and DAC circuits. Code conversions : BCD to Binary converter, Binary to BCD converter.
2. Memory Unit: Construction of memory, Expansion of memory, Memory classification, Bipolar and MOS storage cells. Organization of RAM, address decoding, Registers and

stack, ROM, PROM, EPROM, EEPROM, SRAM, DRAM, and FPLA. Organization and erasing schemes, Magnetic memories, Optical Memories, Semiconductor Memories.

3. The ALU: ALU organization, Integer representation, Serial and Parallel Adders, 1's and 2's complement arithmetic, Multiplication of signed binary numbers, Floating point representation, Overflow detection, Status flags.
4. Review of 8085 Microprocessor, Internal structure, Different register system, organization and assembly language. Instructions of 8085 Microprocessor, Microprocessor Programming.

Books Recommended:

1. Ryder, J. D. (2015) Networks, Lines and Fields, 2nd ed., Pearson Education, India.
2. Van Valkenburg, M.E. (2019) Network Analysis, 3rd ed., Pearson Education, India.
3. Sze, S.M. (2008) Physics of Semiconductor Devices, 3rd ed., Wiley, India.
4. Millman, J. and Halkias, C.C. (2017) Integrated Electronics, Tata McGraw Hill, India.
5. Jain, R. P. (2010) Modern digital electronics, 4th ed., Tata McGraw Hill, India
6. Anand Kumar, A (2016) Fundamentals of Digital Circuits, 4th ed, PHI, India
7. Kothari, D. P. and Dhillon, J. S. (2015) Digital Circuits and Design 1st ed., Pearson Education, India.
8. Mano, M. (2016) Digital Logic and Computer Design, 1st ed., Pearson Education India, India
9. Tocci, R. J. and Widmer, N. S. (2005) Digital Systems : Principles and Applications, 8th ed., Pearson New Int. Edition.
10. Gaonkar, R. (2013) Microprocessor Architecture, Programming and Applications with 8085, 6th ed., Penram International Publishing, India
11. Kharate, G.K. (2010) Digital Electronics, Oxford University Press, India

COURSE OUTCOME:

After completion of this course, students will be able

1. to achieve the detailed knowledge of network analysis.
2. to understand the operation and design of different kinds of passive filters.
3. to gain knowledge on transmission lines: its theory and applications.
4. to achieve the detailed knowledge of operation and application of different kinds of thyristors like SCR, Triac, Diac etc.
5. to understand the basic structure of 8085 microprocessor.
6. to learn the structure and use of different memory units.
7. to gain basic idea of digital communication.

Course No: PHSC505X9

Course Name: General Lab II

Marks: 50

Classes: 80 Hours

1. Study of differential amplifier circuit using OP-amp and find out its transfer characteristics and differential mode gain.
2. Design of a window comparator using Op-amps and study its characteristics.
3. Astable and Monostable multivibrator with timer IC 555.
4. Determination of the Slew Rate (SR) of an Op-amp.
5. To design a Colpitt oscillator using a transistor.
6. To design one bit BCD adder.
7. To design and develop a FET amplifier and to find out its linearity and frequency response characteristics.
8. Determination of Crystal Structure by X-Ray Diffraction Method
9. Determination of the Excitation Potential of Atoms by the Franck–Hertz Experiment.
10. Determination of the Curie Temperature of a Ferrimagnetic Material
11. Measurement of electronic charge using Millikan's oil drop experiment (Balancing method).
12. Determination of refractive index of a glass plate using Michelson Interferometer.
13. Determination of the gamma and beta ray absorption coefficients by using a G.M. counter.
14. Study of nuclear counting statistics using a G.M. counter.
15. Determination of nuclear g-factor using NMR spectrometry method.

COURSE OUTCOME:

This course will help the students to design and fabricate various digital and analog electronic circuits, e.g. counters, multivibrators, oscillator circuits. The practical course structure is designed to impart the students to provide strong hands-on laboratory training on various apparatus, devices or instruments utilizing in modern and currently active areas of Physics particularly in optics, X-rays, radiation, electric, magnetic, semiconductor-physics and nuclear-physics.

Course No: PHSO506X9

Course Name: Social Service / Community Engagement

Marks: 25

Classes: 20 Hours

SEMESTER- IV

Course No: PHSE551A0

Course Name: Applied Electronics

Marks: 50

Classes: 40 Hours

Group A : Applied Analog Electronics :

1. Special OP- AMP Circuits & applications: Bridge amplifier circuit : advantages over single stage amplifier, instrumentation amplifiers, logarithmic amplifiers, anti-log amplifier, analog multiplier, summing integrator, chopper modulator, chopper stabilized amplifier, pulse width modulator, Regenerative comparators and their uses, pulse generator, ramp generator, square and triangular wave generator, crystal oscillator, voltage controlled oscillator (VCO). Active filters, Butterworth characteristics, first, second and higher order low pass and high pass active filters, band pass and band stop active filters.
2. Voltage regulators : Series Op-amp regulator, Current limiting, Foldback current limiter, IC regulator, precision current and voltage sources, Switching Regulators.
3. Phase Lock Loop (PLL) & applications: Operation of PLL, characteristics and parameters, Application of PLL: Frequency multiplication, tracking, FM demodulation, Order of PLL.
4. Detectors: Peak detectors, zero-crossing detectors, phase-sensitive detectors, precision rectifier.
5. B/W Television: Working principle, TV camera- Image Orthicon, Vidicon, Plumbicon; B/W TV Picture tube, scanning and deflection, synchronization, Details of composite video signal, Transmitting and Receiving systems, Vestigial Side Band (VSB) transmission, Television standards, Advantages of Negative modulation, Different kinds of TV antenna, Block diagram of B/W TV receiver and Transmitter.

Colour TV standards : NTSC, PAL SECAM, colour television principles, Colour subcarrier, transmission format of intensity and colour signal. Colour difference signals, Reproduction of colour signals at the receiver, Colour TV picture tubes: Delta Gun, PIL and Trinitron,

6. Instrumentations: Digital voltmeter: different types, Digital ammeter and ohmmeters.

Group B: Applied Digital Electronics :

1. Digital Logic families: DTL, TTL, ECL, MOS, CMOS logic circuits, their advantages, disadvantages and comparison : Speed of operation, Power dissipation, Figure of merit, Fan-in and Fan-out.
2. Different memory systems : Memory organization and addressing, Sequential Memory : Charge coupled devices (CCD), Unit cell of SRAM and DRAM, Ratioed and Ratio-less shift registers, Special Memory units: MRAM, RRAM, PAL, FPLA. .
3. Specialized Communication Systems: Mobile Communication – Concepts of cell and frequency reuse, Hands-off technique, Description of cellular communication standards; Computer communication: LAN, WAN, Computer topology, TCP/IP Protocol, Circuit message and packet switched networks; Design and examples of ARPANET, ISDN, Medium access techniques – TDMA, FDMA, CDMA, ALOHA, Slotted ALOHA, CSMA/CD; Basics of protocol.
4. Digital communication: Signal sampling, Sampling Theorem, Nyquist rate, aliasing effect, sample and hold systems, Quantization process and error calculation.
5. Pulse modulation and demodulation techniques: PAM, TDM-PAM, PWM, PPM, Pulse code modulation (PCM) - modulation and demodulation, Differential PCM, Delta Modulation.
6. Digital modulation techniques : ASK, FSK, PSK, DPSK, QPSK, MSK principle, modulation and demodulation techniques.
7. Microprocessor and their applications: Architecture of 8 bit (8085) and 16 bit (8086) microprocessors; addressing modes and assembly language programming of 8085 and 8086. Interfacing concepts memory and I/O interfacing; Interrupts and interrupt controllers; microprocessor based data acquisition (DAS) system, comparison of different microprocessors. Microprocessor programming.

Books Recommended:

1. Gayakwad , R.A. (2015) Op- Amps and Linear Integrated Circuits, 4th ed., Pearson Education, India.
2. Millman, J. and Halkias, C.C. (2017) Integrated Electronics, Tata McGraw Hill, India.
3. Gray and Meyer (2009) Analysis and Design of Analog Integrated Circuits, 5th ed., Wiley, India.
4. Soclof, S. (2004) Design and Applications of Analog Integrated Circuits, PHI, India.
5. Jain, R. P. (2010) Modern digital electronics, 4th ed., Tata McGraw Hill, India
6. Anand Kumar, A. (2016) Fundamentals of Digital Circuits, 4th ed, PHI, India
7. Kothari, D. P. and Dhillon, J. S. (2015) Digital Circuits and Design 1st ed., Pearson Education India, India
8. Tocci, R. J. and Widmer, N. S. (2005) Digital Systems : Principles and Applications, 8th ed., Pearson New Int. Edition.
9. Roddy, D. and Coolen, J. (2000) Electronic Communications, 4th ed., Prentice Hall of India, India
10. Taub, H. and Schilling, D. (2017) Digital Integrated Electronics, McGraw Hill Education, India
11. Gulati, R.R. (2014) Monochrome and Color Television, 3rd ed., New Age International Publishers, India
12. Dhake, A. M. (2017) Television and Video Engineering, 2nd ed., McGraw Hill Education, India.
13. Roddy, D. and Coolen, J. (2008) Electronic Communications, 4th ed., Pearson Education, India.
14. Helfrick, A.D. and Cooper, W.D. (2015) - Modern Electronic Instrumentation & Measurement Techniques, 1st ed., Pearson Education, India.
15. Carlson, A. B., Crilly, P.B., and Rutledge, J.C. (2001) Communication Systems, 4th ed., McGraw Hill Higher Education, India
16. Kennedy, G., Davis, B., and Prasanna, S.R.M. (2011) Electronic Communication

Systems, 5th ed., McGraw Hill Education, India.

17. Roddy, D. and Coolen, J. (2000) Electronic Communications, 4th ed., Prentice Hall of India, India

18. Taub, H., Schilling, D. and Saha, S. (2017) Principles of Communication System, 4th ed., McGraw Hill Education, India

COURSE OUTCOME:

To develop the relevant knowledge of electronics in order to deepen the understanding of modern electronic communication devices those are associated with our social life.

After completion of this course, students will be able to

1. gain in-depth knowledge of monochrome and colour television principle.
2. know the details of signal propagation through wave guide.
3. understand the principle behind instrumentation for different measurements.
4. to get details of digital communication including different digital modulation techniques.
5. to develop knowledge on 8085 and 8086 microprocessors with programming
6. achieve detail knowledge of application oriented Op-Amp circuits.
7. understand details inside the linear and switched mode regulated power supplies.
8. know the components, operation and use of phase locked loop.
9. to get details of different logic families like DTL, TTL, ECL, MOS, CMOS, etc.
10. to understand the in-depth knowledge of different memory units.
11. to gain basic knowledge of advanced communication systems like mobile & computer communication

Course No: PHSE551B0

Course Name: Advanced Condensed Matter Physics

Marks: 50

Classes: 40 Hours

1. Lattice defects: Point Defects, Line Defect, Ionic Conductivity and Diffusion, Color Center, Lattice energy of ionic crystal, Calculation of repulsive exponent from experimental data.
2. Plasmon, Electrostatic Screening, Mott's metal to insulator Transition, Polaritron, LST relation, Polaron, Luminescence, Exciton, Raman Effect in Crystal, Kramers Kronig Relation.
3. Quantization of orbit in a strong magnetic field, De Haas Van Alphen Effect, Boltzmann Transport Equation, Conductivity in metal, Ferroelectric materials, Thermodynamics of Ferroelectric Transition,
4. Nearly Free Electron Model, Empty Lattice approximation, Tight Binding Approximation, Surface States, 2D materials.
5. Superconductivity: Energy Gap in Superconductor, Isotope Effect, Persistence of Current, Flux Quantization, Coherence Length, Electron -Phonon- Electron Interaction, Cooper Pairs. BCS Ground State, Macroscopic Quantum Interference
6. Ferromagnetic Material: Exchange Interaction, Antiferromagnetic and Ferrimagnetic materials and their applications. Magnetic Resonance

Books recommended:

1. Michael M. Woolfson, An Introduction to X-ray Crystallography, Cambridge University Press Publisher
2. C. Kittel, Introduction to Solid State Physics, John Wiley & Sons Inc (Sea) Pte Ltd (Publisher)
3. A. J. Dekker, Solid State Physics, Macmillan Student ed., Pan Macmillan, India (Publisher)
4. J. Richard Christman, Fundamentals of Solid State Physics, John Wiley & Sons (Publisher)
5. B. E. Warren, X-ray Diffraction, Dover Publications Inc. (Publisher)

6. A. C. Rose-Innes and E. H. Rhoderick, Introduction to Superconductivity, 1st ed., Paragon Press, UK (Publisher).
7. M. A. Omar, Elementary Solid State Physics- Principles & Applications, 1st ed. Pearson India (Publisher).
8. N. David, C. University, and N. W. Ashcroft, Solid State Physics, 1st ed., Cengage, India (Publisher)
9. F. Annett, Superconductivity, Superfluids, and Condensates: 5 (Oxford Master Series in Physics,), 1st ed. OUP Oxford, UK (Publisher).
10. H. Ibach, and H. Lüth, Solid-State Physics: An Introduction to Principles of Materials Science, 4th ed. Springer, Germany (Publisher)
11. P.S. Kireev (Author), M. Samokhvalov (Translator), Semiconductor Physics, Central Books Ltd (Publisher) or P.S. Kireev, Semiconductor Physics, Mir (Publishers)
12. B. G. Streetman, and S. K. Banerjee, Solid State Electronic Devices, 7th Edition, Pearson Education Asia (Publisher)
13. Robert Allan Smith, Semiconductors, 2 Ed, Cambridge University Press (Publisher)
14. N. W. Ashcroft, and N. D. Mermin, Solid State Physics, Thomson Learning (Publisher)
15. O. Madelung, Introduction to solid-state theory, Spinger (Publisher)
16. J. M. Ziman, Principles of the Theory of Solids, Cambridge University Press (Publisher)
17. S. Blundell, Magnetism in Condensed Matter, OUP Oxford (Publisher)
18. J. R. Schrieffer, Theory of Superconductivity, CRC Press (Publisher)
19. Michael Tinkham, Introduction to Superconductivity, Medtech (Publisher)
20. James F. Annett, Superconductivity, Superfluids and Condensates, OUP Oxford (Publisher)

COURSE OUTCOME:

After this course the students will be able to :

1. Analyze Lattice Defects: Evaluate how point/line defects and lattice energy dictate ionic conductivity and the optical properties of color centers.
2. Model Band Structure: Apply models (Nearly Free, Tight Binding) to determine electronic energy gaps and the properties of 2D materials.

3. Explain Quasiparticles: Quantify collective excitations (Plasmons, Excitons, Polarons) and their impact on a crystal's optical and dielectric response.
4. Evaluate Quantum Phases: Describe the microscopic origins of Superconductivity (BCS theory/Cooper pairs) and Magnetism (Exchange interactions).

Course No: PHSE551C0

Course Name: Astrophysics

Marks: 50

Classes: 40 Hours

Astronomical Methods

1. **Introduction:** Mass, length and time scale in Astrophysics. Apparent and absolute magnitude.
2. **Units and Measurements:** Electromagnetic Spectrum - Measuring stellar characteristics (temperature, distance, luminosity, mass, size).
3. **Sky Coordinates and Motions:** Earth Rotation - Sky coordinates – seasons - phases of the Moon - the Moon's orbit and eclipses – time keeping (sidereal vs synodic period); Planetary motions - Kepler's Laws.
4. **Telescopes and Detectors:** Principle of Optical, Infrared, Radio, X-rays, Gamma-rays, Neutrinos and Cosmic Ray Astronomy; Gravitational Radiation; Detection of Dark Matter and Dark Energy - Astronomy from Space; Imaging – Focal Plane Imagers, PSF and Deconvolution, Interferometry- Photometry, Spectroscopy, Polarimetry, Astrometry; Solar Telescopes; Surveys, Astronomical Databases, Virtual Observatory. Names of most Popular Telescopes in different Wave Bands – TMT, Giant Meter Wave Radio Telescope (GMRT) - Square Kilometer Array (SKA), Astrosat.

Stellar Structure and Evolution

1. **Sun as a star :** Solar Parameters, Solar Photosphere, Solar Cycle, Solar Atmosphere, Chromosphere. Corona, Solar Activity, Basics of Solar Magnetohydrodynamics. Helioseismology, Solar Nucleosynthesis.
2. **Equations of stellar structure :** Fundamental equations – Hydrostatic equilibrium – Mass distribution – Luminosity distribution – Radiation transport - Convective transport – Condition for convection – Adiabatic temperature gradient – Secondary equations
3. **Modeling and evolution :** Approach to solutions - Sun - Main-sequence stars – Spectral types – Convective regions - Hertzsprung–Russell diagram – Color-magnitude diagram – Effective temperature and radius - Giants and supergiants - Evolution of single stars – Solar

evolution – Massive stars – Gamma-ray bursts – Globular clusters – Open clusters – Variable stars - Scaling laws – Matter density – Pressure – Temperature Luminosity – Mass dependence – H-R diagram comparison – Homology transformations

4. **Compact stars :** White dwarfs – Mass-radius relation – Stability – Sirius B – Chandrasekhar mass limit - Neutron stars – Radius of a neutron star – Equations of state and structure – Evidence for neutron stars – Maximum mass - Black holes – Event horizon (Schwarzschild radius) – Angular momentum – -Static Black Holes (Schwarzschild)
5. **Galaxies:** Hubble’s Classification of Galaxies, Galaxy Morphology, Contents and Dimensions – Collisionless Stellar Dynamics – Relaxation Time, Dynamical Friction, Violent Relaxation – Galactic Potential and Orbits – Spiral Density Wave and Lindblad Resonance – Rotation Curves – Tully-Fisher Relation – Central Black Holes and Fundamental Plane Relationship– Mass and Luminosity Function – Press Schechter Formalism – Star Formation History and Chemical evolution – Active Galaxies and Activity Duty Cycle – Galaxies at High Redshift - Evidence of Dark matter. Elliptical Galaxies (The Intrinsic Shapes of Elliptical, de Vaucouleurs Law, Stars and Gas). Spiral and Lenticular Galaxies (Bulges, Disks, Galactic Halo), Gas and Dust in the Galaxy, Spiral Arms.

Books Recommended:

1. Carroll, B.W. and Ostlie, D.A. (2006) An Introduction to Modern Astrophysics, 2nd ed., Cambridge University Press, England.
2. Shu, F. (1981) The Physical Universe: An Introduction to Astronomy, 1st ed., University Science Books, USA.
3. Harwit, M. (2000) Astrophysical Concepts, 3rd ed., Springer, New York, United States.
4. Padmanabhan, T. (2006) Invitation to Astrophysics, Latest Edition, 3rd ed., World Scientific Publishing Co. Pvt. Ltd., India.
5. Padmanabhan, T. (2000) Theoretical Astrophysics (Volume I-III), 1st ed., Cambridge University Press, England.
6. Longair, M.S. (1992) High Energy Astrophysics (Volume 1-2), 2nd ed., Cambridge University Press, England.
7. Sparke, L.S. and Gallagher, J.S. (2015) Galaxies in the Universe: An Introduction, 2nd ed., Cambridge University Press, England.

8. Prialnik, D. (2013) *An Introduction to the Theory of Stellar Structure and Evolution*, Latest Edition, 2nd ed., Cambridge University Press, England.
9. Schneider, S. and Arny, T.T. (2021) *Pathways to Astronomy*, 6th ed., McGraw-Hill Science Engineering, United States.
10. Chandrasekhar, S. (1989) *Stellar Structure and Stellar Atmospheres (Volume 1)*, 1st ed., The University of Chicago Press, United States.
11. Abhyankar, K.D. (2001) *Astrophysics: Stars and Galaxies*, 1st ed., Universities press (India) Limited., India.
12. Menzel, D.H., Bhatnagar, P.L. and Sen, H.K. (1963) *Stellar Interiors*, Chapman & Hall, 1st ed., United Kingdom.

COURSE OUTCOME:

The students will:

1. Be introduced to the basics of astrophysics
2. Know the astronomical units and measurements
3. Understand the radiation emission processes in astrophysics
4. Understand the solar system and solar energy generation
5. Be acquainted with the modeling and evolution of stars including Sun
6. Be familiar with different stars and their motion
7. Know about the black holes

Course No: PHSE551D0

Course Name: Quantum Field Theory

Marks: 50

Classes: 40 Hours

1. **Classical field theory:** From discrete to continuous systems. Natural units, Four-Vectors and Minkowski Space, Lorentz Transformations. Lagrangian and Hamiltonian formulation. Euler-Lagrange equations, Symmetries and Noether's theorem.
2. **Canonical Quantization:** Klein-Gordon (scalar) field, Dirac field and electromagnetic field. Two point correlation functions, causality and propagators. N-point correlation functions and Wick's theorem.
3. **Discrete symmetries:** Parity, charge conjugation, time reversal, CPT theorem.
4. **Interacting fields:** Examples of interacting field theories. Perturbation theory, Correlation functions in interacting theories, Feynman rules and Feynman diagrams in various interacting field theories.
5. **S-Matrix:** LSZ reduction, computation of S-Matrix and cross-section, optical theorem. tree-level processes in QED.
6. **Renormalization:** Computation of one-loop Feynman diagrams, ultraviolet divergences, regularization and renormalization.

Books Recommended:

1. Peskin, M. E. & Schroeder, D. V. (1995) An Introduction to Quantum Field Theory, 1st Ed., Westview Press Inc.
2. Srednicki, M. (2007) Quantum Field Theory 1st Ed., Cambridge University Press
3. Ryder, L. H. (1996) Quantum Field Theory, 2nd Ed., Cambridge University Press
4. Ramond, P. (1997) Field Theory, 2nd Ed., Westview Press Inc.
5. F. Mandl & Shaw G. (2010) Quantum Field Theory, 2nd Ed., John Wiley & Sons Inc.
6. Das, A. (2020) Lectures on Quantum Field Theory, 2nd Ed., World Scientific

7. Pal, P & Lahiri A. (2005) A First book of Quantum Field Theory, 2nd Ed., Alpha Science International Ltd.
8. Roman, P. (1969) Introduction to Quantum Field Theory, 1st Ed., John Wiley
9. Weinberg, S. (2005) The Quantum Theory of Fields, Volume 1: Foundations, 2nd Ed., Oxford University Press, India
10. Weinberg, S. (2005) The Quantum Theory of Fields, Volume 2: Applications, 2nd Ed., Oxford University Press, India

COURSE OUTCOME:

At the end of the course, students will be able to understand Quantum field theory so that he/she can use these in various branches of physics as per his/her requirement. He/she can understand relativistic effects in quantum mechanics and the need for quantum field theory. The course will discuss the Lorentz covariant form of Lagrangian and Hamiltonian for scalar, vector fields, electromagnetic fields and their second quantisation. Students can understand the symmetries and the implications of Noether's Theorem in conserved currents and charges. He/she can understand the interaction picture, Wick's Theorem and S-matrix. The origin of Feynman diagrams and application of Feynman rules to derive the amplitudes for elementary processes in QED, one-loop amplitudes, ultraviolet divergences and renormalization to extract finite results will also be discussed in detail. After the course the students will be equipped with the theoretical tools to appreciate and understand processes in elementary particle physics.

Course No: PHSE551E0

Course Name: General Theory of Relativity

Marks: 50

Classes: 40 Hours

1. **Revision of special theory of relativity and general covariance :** Lorentz transformation, space-time diagrams. Vectors, dual vectors and tensors. Classical theory of fields, scalar and Maxwell theory, energy momentum tensor. Equality of gravitational and inertial masses, non-inertial frames. Principle of equivalence and general covariance.
2. **Geometry of curved spaces :** covariant and contravariant tensors. Tensors of arbitrary rank. Metric tensor. Parallel transport and covariant differentiation, affine connection and its relation to the metric tensor. The Geodesic equation. Riemann curvature tensor and its properties, Bianchi identities. Symmetries and Killing vectors.
3. **Gravitation:** Einstein's equation, Lagrangian formulation, Einstein-Hilbert action, Weak fields, cosmological constant. Newtonian approximation. -
4. **Schwarzschild solution:** exterior geometry, singularities, event horizon and black holes, Kruskal co-ordinates. Trajectories in the Schwarzschild spacetime. Gravitational red and blue shifts, deflection of light, precession of perihelion and radar echo.
5. **Action principle and other solutions:** Action principle for field equations. Conservation laws in curved space. Energy momentum tensor for a perfect fluid, equation of motion from field equation for equation for dust.

Recommended Books:

1. Introducing Einstein's Relativity by Ray D'Inverno (Clarendon Press, 1992)
2. Principles of Gravitation and Cosmology, by M. Berry (Cambridge University Press, 1976)
3. Introduction to General Relativity & Cosmology, by Steven Weinberg (John Wiley &

Sons, 1972)

4. The Classical Theory of Fields by L.D. Landau and E. M. Lifshitz (Pergamon, 1975)

5. Classical Fields: General Relativity and Gauge Theory by Moshe Carmeli (World Scientific, 2001)

6. General Theory of Relativity by P.A. M. Dirac (John Wiley, 1975)

7. Gravity, Black Holes and the Very Early Universe: An Introduction to General Relativity and Cosmology by Tai L. Chow (Springer, 2008)

COURSE OUTCOME:

1. Students will be trained in tensor analysis and tensor calculus
2. This course will teach the formalism of general relativity (GR)
3. Students will learn how to obtain an exact solution of GR, namely, the Schwarzschild Solution.

Course No: PHSE552A9

Course Name: Applied Electronics Laboratory

Marks: 50

Classes: 80 Hours

Experiments:

1. Design, Construction and performance testing of a Logarithmic amplifier using μA 741, diode and matched transistors.
2. Design, Construction and performance testing of an antilog amplifier using μA 741 and matched transistors.
3. Design of an IC Power Amplifier and its linearity, frequency response, efficiency, and distortion calculation.
4. Design of a Precision adjustable voltage regulator using μA 741 and series pass transistor and a transistor as current limiter and its performance comparison with LM78XX series fixed regulators.
5. Design and study of Multiplexer: formation, cascading and equation solving.
6. Design and study of De-multiplexer: formation, cascading and equation solving.
7. Design of an Active high pass/Low pass second order Butterworth filter.
8. Design an active band pass filter using single stage μA 741 Op-amp.
9. Design and study of an active phase shifter.
10. Frequency to Voltage converter circuit design.
11. Design and study of a Voltage Controlled Oscillator (VCO)/Voltage to Frequency converter.
12. Design of BCD addition and subtraction using Full Adder IC
13. Shift registers: PISO, SISO, PIPO, SIPO.
14. Design of a Schmitt trigger circuit using μA 741.
15. DSB-TC and DSB-SC generation using analog multiplier IC MC 1495 or MC1496.

16. Design and performance study of a VCO IC (NE 566).
17. Design and performance study of a PLL IC (NE 565).
18. Study of Pulse Amplitude Modulation transmission and reception.
19. 8085 Microprocessor programming.
20. Study of Pulse Width Modulation using 555 Timer IC.
21. Study of Pulse Code Modulation transmission and reception.
22. Study of D.A.C & A.D.C.

COURSE OUTCOME:

This course will help the students to

1. design and fabricate various advanced digital and analog electronic circuits, e.g. modulator circuits, PLL circuits, Microprocessor programming, etc.
2. design and conduct various electronics experiments.
3. the experiments will help the students to understand the application of the theories in practical field.
4. design and fabricate various advanced digital and analog electronic circuits, e.g. Mux, DeMUX, registers, voltage regulators, active filters etc.
5. design and conduct various electronics experiments.

Course No: PHSE552B9

Course Name: Advanced Condensed Matter Physics Laboratory

Marks: 50

Classes: 80 Hours

1. Determine the susceptibility of a paramagnetic material by Gouy method. Explain the Principle of Gouy Method and describe the experimental arrangement. How do you determine experimentally P_{eff} for $\text{MnSO}_4 \cdot \text{H}_2\text{O}$ and compare with the theoretical value.
2. Determine the photoconductivity of a semiconducting material to find the relaxation time. Explain the principle of Photoconductivity and show the experimental arrangement. Show the necessary plots and find the relaxation time?
3. Determine the Saturation Magnetisation, Coercivity and Retentivity of a ferromagnetic material from Hysteresis Loop. Show the block diagram and related plots to find the magnetic parameters.
4. Determine Lande g factor of a paramagnetic material using ESR. Explain the principle of ESR and describe the experimental arrangement through a block diagram.
5. Determine dielectric constant of a ferroelectric crystal with variation of temperature? Show the Block diagram and the necessary plots to find Curie Temperature?
6. Determine the solar panel characteristics in dark and under illumination and find the fill factor. Explain the principle of operation of a solar cell.
7. Determine junction capacitance of a power transistor in BE and BC modes. Draw the circuit diagram. Find the Barrier potential, doping parameter and doping profile with related plots.
8. Describe the experimental procedure of measuring optical absorption coefficient of a given semiconductor using a spectrophotometer. How will you determine the band gap of such material.
9. Determine the Hall Coefficient of a p-type semiconductor with variation of temperature. Show the related plots and explain the nature of variation.
10. Determine conductivity of an Ionic crystal with variation of temperature. Explain the principle of measuring Ionic Conductivity and show the experimental arrangement. Determine the activation of energy of ionic crystal.

11. Determine the Magnetoresistance of a semiconducting material. Show the related plots and hence find the mobility of the carrier.

12. Determine the photodetectivity of a panel and hence find the detectivity and responsivity. Explain the principle of photodetection with related plots.

COURSE OUTCOME:

This course will help the students to :

1. Characterize Magnetic & Dielectric Properties: Quantify susceptibility, hysteresis parameters (Coercivity/Retentivity), and the Lande g-factor using Gouy, ESR, and tracer techniques.
2. Analyze Semiconductor Transport: Determine Hall coefficients, carrier mobility via Magnetoresistance, and junction capacitance to map doping profiles and barrier potentials.
3. Evaluate Photonic & Ionic Response: Measure photoconductivity relaxation times, solar cell fill factors, and optical band gaps using spectrophotometry and illumination plots.
4. Investigate Temperature-Dependent Transitions: Calculate activation energy for ionic crystals and identify Curie temperatures in ferroelectrics through thermal variation of conductivity and dielectric constants.

Course No: PHSE552C9

Course Name: Astrophysics Laboratory

Marks: 50

Classes: 80 Hours

1. Identification of following objects with naked eyes or a binocular.
 - a) Mercury, b) Venus, c) Mars, d) Jupiter e) Saturn, f) North Star, f) The Big Dipper (Ursa Major) g) The Little Dipper (Ursa Minor), h) Betelgeuse and i) Cassiopeia.
2. Study of movement of Moon between rise to set time.
3. Study of movement of a planet in the sky between the rise to set of the planet .
4. Identify Sun spots with a solar-filter or a mirror.
5. Different Fitting techniques (linear and non-linear, fits to data with experimental errors, evaluating goodness of fit, etc.) and error analysis.
6. Study of Light curve of astronomical sources in different energy band.
7. Study of the power spectrum of different astronomical sources.
8. Correlation, anti-correlation and time-delay between signals from two different wavelengths.
9. RGB image from an astronomical source.
10. With a small telescope, identify following objects :
 - a) Moons of Mars, b) storm in Jupiter, c) rings and moons of Saturn, d) Orion nebula, e) Andromeda galaxy
11. Radio Astronomy with AIPS: Load of a image in AIPS, Measurement of rms of a given image.
12. Radio Astronomy with AIPS: Measurement of flux density of a point and extended source.
13. Polar alignment of an optical telescope.
14. Detection of variation of solar radiation using two component radio interferometer.
15. Study of solar flares on Very Low Frequency signals using a standard transmitter signal.
16. Deflection of radio signal from Sun using a small radio antenna.

17. Variation of radio signal towards Galactic plane using a small radio antenna.
18. CCD characterization.
19. Estimation of atmospheric extinction in different colours (filters)
20. Measurement of period of a binary star system
21. Distance determination to Cepheid variables based on their light curves
22. Classification of stars based on their spectra
23. Use of spectral classification in deriving distances to stars.

COURSE OUTCOME:

Practical experiments are aimed to give students a good idea about the night sky and various hands-on experiments using instruments, such as binocular, astronomical telescope, radio antenna, radio interferometer. The students will be able to identify astrophysical objects, analyze light curve & power spectrum of astronomical sources in different energy bands, measure the period of a binary star system and classify various stars.

Course No: PHSE552D9

Course Name: Advanced Computer Lab

Marks: 50

Classes: 80 Hours

The aim of this Lab is to learn and develop computer programs (in C/C++/Python) for implementing various numerical methods.

1. Integration – Quadrature formulas; Matrices – determinant, multiplication, inversion, eigenvalues, etc.
2. Interpolation – Lagrange interpolating polynomial.
3. Solution of algebraic equations using Gauss elimination with back substitution.
4. Applying pivoting strategies in solving linear algebraic equations.
5. Implementing Tridiagonal systems of equations for linear algebraic equations.
6. Cubic spline interpolation.
7. Random number generation and tests of randomness.
8. Implementing random walk problems in 1-, 2- and 3- dimensions.
9. Implementing Inverse Transform and Acceptance Rejection algorithms.
10. Modeling of data – chi square fitting and least square fit for linear and general equations.

Books recommended

1. Numerical Recipes 3rd Edition: The Art of Scientific Computing, William H. Press, Saul A. Teukolsky, William T. Vetterling , Brian P. Flannery (3 rd Ed., Cambridge University Press, 2007)
2. Numerical Analysis, Richard L. Burden, J. Douglas Faires, Annette M. Burden (10 th Ed., Cengage Learning, 2016)
3. Numerical Recipes in C++: The Art of Scientific Computing, William H. Press , Saul A. Teukolsky, William T. Vetterling , Brian P. Flannery (2 nd Ed., Cambridge

University Press, 2002)

4. Numerical Recipes in C: The Art of Scientific Computing, William H. Press , Brian P. Flannery, Saul A. Teukolsky, William T. Vetterling (2 nd Ed., Cambridge University Press, 2002)

COURSE OUTCOMES:

Through this course, students shall be able to develop and implement C/C++/Python routines and programs for solving advanced numerical methods, which are applicable in various fields in Physics.

Course No: PHSC553X0

Course Name: Research Project/Dissertation

Marks: 100

Classes: 80 Hours

GUIDE LINE FOR THE COURSE :

Students have to perform the following duties :

1. Identify an area for research where the knowledge base can be potentially augmented.
2. Understand the shortcomings in the state of existing knowledge through literature review.
3. Propose / design a possible solution to the problem.
4. Collaborate with other researchers and institutes around to facilitate the proposed solution.
5. Present the entire work in the form of a dissertation.
6. Defend the work through a presentation and a viva exam to a panel of evaluators.

COURSE OUTCOME:

Students are expected to come up with a comprehensive project work in subjects of physics. The students have to perform a research project during their last two semesters on a wide range of modern-day topics under the guidance of any of the faculty members of the Physics department and the exam will be held at the end of fourth semester. This gives an ideal atmosphere for converting class room learning to cutting-edge research applications. The project topics should be chosen so as to inculcate a culture of independent research. At the end of the course each student has to present a thesis.

Each student has to present a seminar on a topic of their own choice in the final semester. There is a good interactive session in the seminar. Thus the seminar gives a good training to students and gives encouragement to be a participant of National and International Seminar.

Course No: PHSO554X9

Course Name: Internship / Industry Project/ Innovation

Marks: 50

Classes: 120 Hours

Course No: PHSO555X9

**Course Name: Intellectual Property Right (IPR) / Skill Enhancement
Course**

Marks: 25

Classes: 20 Hours