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 into 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	PHS 101	DSC 1	Mathematical Physics	50	40	4(3-1-0)
	PHS 102	DSC 2	Classical Mechanics	50	40	4(3-1-0)
	PHS 103	DSC 3	Research Methodology and Ethics	50	40	4(1-0-3)
	PHS 104	DSC 4	Quantum Mechanics I	50	40	4(3-1-0)
	PHS 105	DSC 5	Electronics I	50	40	4(3-1-0)
	PHS 106	IKS	Indian Knowledge System	25	20	2(2-0-0)
			Life and Philosophy of Vidyasagar	25		Compulsory Non-credit
	TOTAL			275		22
II	PHS 201	DSC 6	Quantum Mechanics II	50	40	4(3-1-0)
	PHS 202	DSC 7	Statistical Mechanics	50	40	4(3-1-0)
	PHS 203	DSC 8	Classical Electrodynamics	50	40	4(3-1-0)
	PHS 204	DSC 9	Electronics II	50	40	4(3-1-0)
	PHS 205	DSC 10	General Lab I	50	80	4(0-0-4)
	PHS 206		Field Visit / Industry Visit /Case Study /Hands- on Practical/ Skill Enhanced Course	25		2(0-0-2)
	TOTAL			275		22
III	PHS 301	DSC 11	Condensed Matter Physics	50	40	4(3-1-0)
	PHS 302	DSC 12	Nuclear and Particle Physics	50	40	4(3-1-0)
	PHS 303	DSE 1	Special Paper: Any one from Group I or Group II*	50	40	4(3-1-0)
	PHS 304	DSC 13	General Lab II	50	80	4(0-0-4)
	PHS 305	MOOC	MOOCs from SWAYAM	50		4(3-1-0)
	PHS306		Social Service / Community Engagement	25		2(0-0-2)
	TOTAL			275		22
IV	PHS 401	DSC 14	Molecular Spectroscopy and Applied Optics	50	40	4(3-1-0)
	PHS 402	DSE 2	Special Paper: Any one from Group I or Group II*	50	80	4(0-0-4)
	PHS 403		Research Project/Dissertation	100		8
	PHS 404		Internship / Industry Project/ Innovation	50		4
	PHS 405		Intellectual Property Right (IPR) / Skill Enhanced Course	25		2(0-0-2)
	TOTAL			275		22

*Students must select only one course either from Group I or Group II in special paper options given below. If a course is chosen in Semester III, the corresponding course in the same row must be chosen for Semester IV.

Special paper options

	Semester III	Semester IV
Group I: Theory + Lab Papers	Applied Electronics	Applied Electronics Lab
	Advanced Condensed Matter Physics	Advanced Condensed Matter Physics Lab
	Astrophysics	Astrophysics Lab.
Group II : Theory+Theory Papers	Quantum Field Theory	Particle Physics
	General Theory of Relativity I	General Theory of Relativity II

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

SEMESTER- I

Course No: PHS 101

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: PHS 102

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 electro-magnetic field. Small Oscillations

2. Variational Principles, Hamilton's Principle from Newton's equation & D'Alemberts 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: PHS 103

Course Name : Research Methodology and Ethics

Marks: 50 **Classes: 40 Hours**

Theory

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

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

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

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

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

Practical

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 ($I_{D\ sat}$ 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:

(a) 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.

(b) 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.

(c) 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: PHS 104

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: PHS 105

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 4and 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 1^{st} ed., Pearson Education India, India

6. Mano M. (2016) Digital Logic and Computer Design, 1^{st} ed., Pearson Education India, India

7. Tocci, R. J. and Widmer, N. S. (2005) Digital Systems : Principles and Applications, 8^{th} 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: PHS 106

Course Name : Indian Knowledge System

Marks: 25 **Classes: 20 Hours**

Common syllabus for all students of the science faculty

COURSE OUTCOMES

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.