SYLLABUS

for

Semester III & IV

Program: M. Sc.

Name of the Course: Physics

Effective from

Academic Year

2025-26

Board of Studies in Physics

Undergraduate and Post graduate

	Name	Designation	Institute/Industry
Head of the Department			
1	Prof. Sadanand Sutar	Chairperson	Sir P. T. Sarvajanik College of Science
All Faculty Members of the Department			
1	Prof. Vireshkumar Thakkar	Associate Professor	Sir P. T. Sarvajanik College of Science
2	Dr. Nisha Patel	Assistant Professor	Sir P. T. Sarvajanik College of Science
3	Dr. Dhiraj Shah	Assistant Professor	Sir P. T. Sarvajanik College of Science
4	Prof. Bhupeshkumar Lad	Associate Professor	Sir P. T. Sarvajanik College of Science
5	Dr. Naveen Kumar Singh	Adhyapak Sahayak	Sir P. T. Sarvajanik College of Science
6	Dr. Jenishkumar Patel	Adhyapak Sahayak	Sir P. T. Sarvajanik College of Science
7	Prof. Pradipkumar Dholakia	Assistant Professor	Sir P. T. Sarvajanik College of Science
Subject Expert nominated by Vice-Chancellor			
1	Dr. Arvind Bajaj	Nominated Member	V. S. Patel College of Arts & Science, College Campus, Morarji Desai Marg, Bilimora
Subject Experts			
1	Prof. Smita L. Survase	Nominated Member	Sant Rawool Maharaj Mahavidyalay, Tal-Kudal, Dist.-Sindhudurg, Maharashtra.
2	Prof. Mahesh Shetti	Nominated Member	Wilson College (Autonomous), Mumbai
3	Dr. Debesh R. Roy	Nominated Member	Sardar Vallabhbhai National Institute of Technology, Surat
Representative from Industry/corporate sector/allied area			

1	Mr. Gopal Singh Panwar	Nominated Member	Officer, Human Resources, L & T Defence IC, Hazira, Surat
Meritorious Alumnus			
1	Mr. Darshankumar Jagdishbhai Gabani	Nominated Member	R & D Division, Lucan Techno, Katargam, Surat
Expert from other than the parent University			
1	Prof. Chetan Limbachia	Nominated Member	Head, Department of Applied Physics, M. S. University, Vadodara

Acknowledgement

Graduate Attributes:

After the successful completion of units in different courses of M. Sc. PHYSICS, the learner will be able to:

GA 1: Capacity to conduct the experiments and evaluate the findings based on the knowledge gained in the scientific domain.

GA 2: Ability to organize, carry out and document theoretical and/or experimental Physics problems using scientific methods in their future endeavours.

GA 3: Ability to generate, process, analyse, model and visualise data by using a variety of tools such as programming, sophisticated instrumentation and other resources.

GA 4: Exhibiting creativity and problem-solving skills through appropriate planning and organizational skills to work as a team.

GA 5: Honouring and adhering to professional ethics and standards.

GA 6: Capacity to engage in the technical domain via written and oral communication effectively.

Programme Specific Outcomes:

PSO 1: Apply knowledge of Physics to analyze problems; evaluate and validate experimental results and draw logical conclusions thereof.

PSO 2: Utilize technical and analytical skills through experiential learning.

PSO 3: Recognize the need for continuous learning and knowledge updation throughout their professional career.

PSO 4: Demonstrate and maintain the highest standard on ethical issues in the professional career.

PSO 5: Exhibit the ability to work both, as an individual and as a team member in a variety of situations and disciplines.

PSO 6: Communicate effectively with the scientific community and the general public using written and spoken language as well as the electronic media.

Content

Sr. No	Course number	Course Code	Course title
Semester III			
1	CC VII	PHYMSC-S3P1-4CR25	Quantum Mechanics - II
2	CC VIII	PHYMSC-S3P2-4CR25	Atomic and Molecular Physics
3	CC IX	PHYMSC-S3P3-4CR25	Solid State Physics
4	EC IX	PHYMSC-S3E9-4CR25	Laser Fundamentals and Applications
5	EC X	PHYMSC-S3E10-4CR25	Python Programming and Computational Physics
6	EC XI	PHYMSC-S3E11-4CR25	Nuclear Physics
7	EC XII	PHYMSC-S3E12-4CR25	Foundation of Quantum Information
8	SEC III	PHYMSC-S3SEC3-2CR25	Microprocessor
9	PRACTICAL III	PHYMSC-S3PR3-6CR25	Physics Practical
Semester IV			
1	CC X	PHYMSC-S4DP1-24CR25	Dissertation Project

Semester III

M. Sc. (Physics) SEMESTER III
COURSE TITLE: Quantum Mechanics-II
COURSE CODE: PHYMSC-S3P1-4CR25 [CREDITS - 04]

CC VII	Course Code: PHYMSC-S3P1-4CR25
	Course Learning Outcomes

At the end of this course, learners will be able to
- use the properties of Delta function in calculations in quantum mechanics
- apply the concept of addition of two angular momenta
- relate the bases used in general formalism of addition of two angular momenta
- describe the time independent perturbation theory
- implement time independent perturbation theory in real life physics problems
- apply the variational method and WKB approximation method in various quantum physics problems
- classify different pictures in quantum mechanics
- apply the time dependent perturbation theory to the processes of absorption and emission of radiation by atoms
- connect the differential cross-sections in lab frame and centre of mass frame
- apply Born approximation and partial wave analysis in determining the differential cross-section.

Unit I	The Delta Function and Addition of Angular Momenta	[15L]

Learning Objectives:

This unit is intended to make the learners
- familiarize with the Delta functions and its properties
- study the concept of addition of two angular momenta
- learn the knowledge of Clebsch-Gordan coefficients.

Learning Outcomes:

At the end of this unit, the learner will be able to
- use the properties of Delta function in calculations in quantum mechanics
- apply the concept of addition of two angular momenta
- relate the bases used in general formalism of addition of two angular momenta.

1.1	The Delta Function: One dimensional Delta function, Various definitions of the Delta function, Properties of Delta function, Derivative of Delta function, Three-Dimensional Delta function	[7L]
1.2	Addition of Two Angular Momenta: General Formalism, Transformation between Bases: Clebsch–Gordan Coefficients, Eigenvalues of J^2 and J_z, Calculation of the Clebsch–Gordan Coefficients.	[8L]

Unit II	Approximation Methods for Stationary States	[15L]

Learning Objectives:

This unit is intended to make the learners
- study the concepts of time independent perturbation theory
- apply the time independent perturbation theory to fine structure splitting, Zeeman (normal and anomalous) effect and Stark effect

- get the knowledge of variational method and WKB approximation method.

Learning Outcomes:

At the end of this unit, the learner will be able to
- describe the time independent perturbation theory
- implement time independent perturbation theory in real life physics problems
- apply the variational method and WKB method in various quantum physics problems.

2.1	Time independent perturbation theory, non-degenerate and degenerate case, applications to fine structure splitting, Zeeman (normal and anomalous) effect, Stark effect.	**[9L]**
2.2	Variational method and its applications. WKB method and its applications.	**[6L]**
Unit III	**Time dependent Perturbation Theory**	**[15L]**

Learning Objectives:

This unit is intended to
- develop the theoretical background of different pictures in quantum mechanics
- provide the concepts of time dependent perturbation theory.

Learning Outcomes:

At the end of this unit, the learner will be able to
- classify different pictures in quantum mechanics
- apply the time dependent perturbation theory to the processes of absorption and emission of radiation by atoms.

3.1	The Schrodinger picture, Heisenberg picture, interaction picture, Time dependent perturbation theory, transition probability, first and second order transitions, constant perturbation, Harmonic perturbation, Fermi's golden rule.	**[7L]**
3.2	Adiabatic and sudden approximations, Interaction of Atoms with Radiation: Classical Treatment of the Incident Radiation, Quantization of the Electromagnetic Field, Transition Rates for Absorption and Emission of Radiation, Transition Rates within the Dipole Approximation, The Electric Dipole Selection Rules, Spontaneous Emission.	**[8L]**
Unit IV	**Scattering Theory**	**[15L]**

Learning Objectives:

This unit is intended to make the learners
- study the concepts of scattering theory
- get the knowledge of Born approximation and partial wave analysis.

Learning Outcomes:

At the end of this unit, the learner will be able to
- connect the differential cross-sections in lab frame and centre of mass frame
- apply Born approximation and partial wave analysis in determining the differential cross-section.

4.1	**Scattering and Cross-section**; Connecting the angle in the Lab and CM frames, Connecting the Lab and CM cross section.	**[15L]**

	Scattering amplitude of spinless particles; Scattering amplitude and differential cross section, scattering amplitude. **The Born approximation**; The First-Born approximation, Validity of the First-Born approximation. **Partial wave analysis**; Partial wave analysis for elastic scattering, Partial wave analysis for inelastic scattering.	

Reference Books:

- Quantum Mechanics: Concepts and Applications: Nouredine Zettili, 2nd Ed., John Wiley and Sons Ltd., 2004.
- A Text Book of Quantum Mechanics: P. M. Mathews and K. Venkatesan, 2nd Ed., Tata McGraw Hill Education Private Limited, 2011.
- Introduction to Quantum Mechanics: David Griffiths, 2nd Ed., Pearson Education; 2015.
- Quantum Mechanics: Claude Cohen-Tannoudji, Bernard Diu, Franck Laloe Vol. I & II, 2nd Ed., Wiley-CH, 2019.

Online Learning Resources:

- https://archive.nptel.ac.in/courses/115/103/115103104/
- https://archive.nptel.ac.in/courses/115/101/115101107/

Sir P. T. Sarvajanik College of Science (Autonomous)
Athwalines, Surat-395001

Question Paper Template

Unit	Remembering/ Knowledge (1)	Understanding (2)	Applying (3)	Analysing (4)	Evaluating (5)	Creating (6)	Total marks
I	20%	30%	20%	20%	10%	-	100%
II	20%	30%	20%	20%	10%	-	100%
III	20%	30%	20%	20%	10%	-	100%
IV	20%	30%	20%	20%	10%	-	100%

Mapping of CLOs and PSOs

Course Learning Outcomes	Programme Specific Outcomes					
	1	2	3	4	5	6
● use the properties of Delta function in calculations in quantum mechanics	√	√			√	√
● apply the concept of addition of two angular momenta	√	√	√			√
● relate the bases used in general formalism of addition of two angular momenta	√	√	√		√	√
● describe the time independent perturbation theory	√	√	√		√	
● implement time independent perturbation theory in real life physics problem	√	√	√			
● apply the variational method and WKB approximation method in various quantum physics problems	√	√				√
● classify different pictures in quantum mechanics	√	√	√			
● apply the time dependent perturbation theory to the processes of absorption and emission of radiation by atoms	√	√				√
● connect the differential cross sections in lab frame and centre of mass frame	√	√	√		√	
● apply Born approximation and Partial wave analysis in determining the differential cross section	√	√	√			√

M. Sc. (Physics) SEMESTER III
COURSE TITLE: Atomic and Molecular Physics
COURSE CODE: PHYMSC-S3P2-4CR25 [CREDITS - 04]

CC VIII	Course Code: PHYMSC-S3P2-4CR25	
	Course Learning Outcomes	

After the successful completion of the course, the learner will be able to
- interpret atomic structure and spectroscopic phenomena
- analyze the Quantum Mechanical Model of one-electron atoms
- examine spectral characteristics and atomic structure of multi-electron atoms
- evaluate coupling mechanisms and atomic effects
- analyze molecular spectra and energy states
- apply models to understand molecular rotations
- analyze vibrational and rotational behaviours of molecules
- interpret the spectroscopic techniques and phenomena.

Unit I	One Electron Atoms	[15L]

Learning Objectives:

This unit is intended to make the learners
- familiarize with the quantum mechanical treatment of one-electron atom
- study the fine structure of the hydrogen atom spectrum.

Learning Outcomes:

At the end of this unit, the learner will be able to
- interpret atomic structure and spectroscopic phenomena
- analyze the quantum mechanical model of one-electron atoms.

1.1	Review of Atomic models – Rutherford model, Bohr model, Sommerfeld model.	[1L]
1.2	Quantum mechanical treatment of one-electron atom, Vector Atom model, shapes of the orbits, parity of eigen functions, determination of selection rules, orbital magnetic dipole moment, Larmor precession, space quantization, electron spin, L-S coupling, spectroscopic terms and their notations, Stern-Gerlach experiment.	[8L]
1.3	Spin-Orbit interaction, quantum mechanical relativistic correction, Hydrogen fine structure, Lamb shift, Lamb-Retherford experiment, Exchange symmetry, Pauli's exclusion principle, Slater determinant.	[6L]

Unit II	Multi-electron Atoms	[15L]

Learning Objective

This unit is intended to make the learners
- study the characteristics of spectral lines and atomic structure of multi-electron atoms
- infer the concepts of splitting of spectral lines in the presence of magnetic and electric fields.

Learning Outcomes:

At the end of this unit, the learner will be able to

- examine spectral characteristics and atomic structure of multi-electron atoms
- evaluate coupling mechanisms and atomic effects.

2.1	Helium atoms and its spectrum, exchange force, singlet and triplet in He spectrum, ortho-helium and para-helium, quantum mechanical splitting, ground state energy of He atom, multi-electron atoms, central field approximation, Hartree's self-consistent field, results of Hartree theory, atomic orbitals and Hund's rule, Aufbau principle, L-S and j-j coupling.	**[11L]**
2.2	Normal and Anomalous Zeeman effects, Paschen-Back effect, Stark effect, hyperfine structure, isotope effects.	**[04L]**

Unit III	Molecular Physics-I	[15L]

Learning Objectives:

This unit is intended to make the learners

- study the concepts associated with molecular spectra.

Learning Outcomes:

At the end of this unit, the learner will be able to

- analyse molecular spectra and energy states
- apply models to understand molecular rotations.

3.1	Types of molecular spectra, separation of electronic and nuclear motion, Born-Oppenheimer approximation, electronic spectra, vibrational-rotational spectra, pure rotational spectra, types of molecular energy states and associated spectra, molecular requirement for rotational spectra, molecule as a rigid rotator, non-rigid rotator.	**[15L]**

Unit IV	Molecular Physics-II	[15L]

Learning Objectives:

This unit is intended to make the learners

- familiarize with vibrational and rotational behaviours of molecules
- infer the spectroscopic phenomena associated with Raman and electronic spectra.

Learning Outcomes:

At the end of this unit, the learners will be able to

- analyze vibrational and rotational behaviours of molecules
- interpret the spectroscopic techniques and phenomena.

4.1	Molecule as a harmonic oscillator, molecule as an anharmonic oscillator, fine structure of infra-red bands, molecule as vibrating rotator, diatomic molecule as a symmetric top.	**[06L]**
4.2	Raman spectra, classical and quantum theory of Raman effect, pure rotational Raman spectrum, formation of electronic spectra, electronic band spectra in absorption, electronic band spectra in emission, fine structure of electronic bands, Franck-Condon principle, intensity distribution in band-systems, electron spin resonance, nuclear magnetic resonance.	**[09L]**

References:

1. Physics of Atoms and Molecules: B. H. Bransden and C. J. Joachain, 2nd Ed., Pearson, 2003.
2. Fundamentals of Molecular Spectroscopy by C. N. Banwell 4th Ed., McGraw Hill Education 2017.
3. Atomic and Molecular Physics by Raj Kumar, Campus Books International 2003.
4. Atomic Physics by C. J. Foot, Oxford University Press 2005.
5. Introduction to Atomic Spectra by White Harvey Elliott, McGraw-Hill, Kogakusha Ltd., London.

Online Learning Resources:
- https://onlinecourses.nptel.ac.in/noc23_ph16/preview

Question Paper Template

Unit	Remembering/ Knowledge (1)	Understanding (2)	Applying (3)	Analysing (4)	Evaluating (5)	Creating (6)	Total marks
I	10%	40%	10%	30%	10%	-	100%
II	10%	10%	10%	40%	30%	-	100%
III	10%	10%	40%	40%	-	-	100%
IV	10%	30%	20%	30%	10%	-	100%

Mapping of CLOs and PSOs

Course Learning Outcomes	Programme Specific Outcomes					
	1	2	3	4	5	6
• interpret atomic structure and spectroscopic phenomena	√		√			√
• analyze the quantum mechanical model of one-electron atoms	√		√	√		
• examine spectral characteristics and atomic structure of multi-electron atoms	√		√		√	
• evaluate coupling mechanisms and atomic effects	√		√			
• analyze molecular spectra and energy states	√		√			
• apply models to understand molecular rotations	√					√
• analyze vibrational and rotational behaviours of molecules	√	√				
• interpret the spectroscopic techniques and phenomena	√		√			

M. Sc. (Physics) SEMESTER III
COURSE TITLE: Solid State Physics
COURSE CODE: PHYMSC-S3P3-4CR25 [CREDITS - 04]

CC IX	Course Code: PHYMSC-S3P3-4CR25
	Course Learning Outcomes

At the end of this course, learners will be able to
- elaborate crystal vibrations, phonon behaviour and thermal properties using models like Debye model and Einstein model.
- apply quantum theories of diamagnetism, paramagnetism and ferromagnetism.
- analyze dislocations, crystal defects and material strength, focusing on alloys and single crystals.
- apply concepts of diffusion, color centers and lattice defects to evaluate material properties and performance.

Unit I	Phonons	[15L]

Learning Objectives:

This unit is intended to make the learners
- interpret the fundamentals of crystal vibrations, including phonon behaviour
- analyze the quantization of elastic waves in solids and the relationship between phonon momentum and crystal properties
- explore phonon interactions and scattering processes
- calculate and interpret the heat capacity contributions from phonons using various models
- apply theoretical models to real-world materials and exploring how these concepts help describe thermal and vibrational properties in solids.

Learning Outcomes:

At the end of this unit, the learner will be able to
- explain the behaviour of crystal vibrations, including phonon dispersion relations and the role of the Brillouin zone
- describe the quantization of elastic waves and relate phonon momentum to crystal structure
- analyze inelastic scattering by phonons and its effect on material properties like thermal conductivity
- calculate heat capacity contributions from phonons using models such as Debye model and Einstein model and interpret temperature dependence through the density of states
- apply theoretical models to real-world materials, deriving force constants and understanding phonon interactions.

| 1.1 | Vibrations of Crystals with Monatomic Basis-First Brillouin Zone, Group Velocity, Long Wavelength Limit, Derivation of Force Constants from Experiment, Two Atoms per Primitive Basis, Quantization of Elastic Waves , Phonon Momentum, Inelastic Scattering by Phonons. | [07L] |

1.2	Phonon Heat Capacity - Planck Distribution, Normal Mode Enumeration, Density of States in One Dimension, Density of States in Three Dimensions, Debye Model for Density of States, Debye T^3 Law, Einstein Model of the Density of States, General Result for $D(\omega)$.	[08L]
Unit II	**Diamagnetism and Paramagnetism**	**[15L]**

Learning Objectives:

This unit is intended to make the learners

- enable to derive and apply the Langevin Diamagnetism equation to understand the behaviour of diamagnetic materials in the presence of an external magnetic field
- understand the quantum theory of diamagnetism in mononuclear systems, helping them explain the mechanisms that contribute to diamagnetic behaviour
- have a clear understanding of paramagnetism, its quantum mechanical foundation
- analyze the quenching of orbital angular momentum, calculate spectroscopic splitting factors
- equip with the knowledge to apply cooling techniques like isentropic demagnetization and nuclear demagnetization.

Learning Outcomes:

At the end of this unit, the learner will be able to

- apply the Langevin Diamagnetism equation to explain the behaviour of diamagnetic materials
- explain the quantum theory of diamagnetism for mononuclear systems and identify its key principles
- describe paramagnetism, its underlying quantum principles and the role of rare earth ions, Hund's rules and crystal field splitting
- analyze the quenching of orbital angular momentum, spectroscopic splitting factors and Van Vleck temperature-independent paramagnetism
- apply the concept of cooling by isentropic demagnetization, understand nuclear demagnetization and explore the paramagnetic susceptibility of conduction electrons.

2.1	Langevin Diamagnetism Equation, Quantum Theory of Diamagnetism of Mononuclear Systems, Paramagnetism, Quantum Theory of Paramagnetism – Rare Earth Ions, Hund Rules, Iron Group Ions, Crystal Field Splitting, Quenching of the Orbital Angular Momentum, Spectroscopic Splitting Factor, Van Vleck Temperature-Independent Paramagnetism, Cooling by Isentropic Demagnetization – Nuclear Demagnetization, Paramagnetic Susceptibility of Conduction Electrons.	[15L]
Unit III	**Ferromagnetism**	**[15L]**

Learning Objectives:

This unit is intended to make the learners

- understand ferromagnetic order, including the Curie point, exchange integral and temperature dependence of saturation magnetization
- understand of magnons, including the quantization of spin waves and explore thermal excitation of magnons in ferromagnetic and antiferromagnetic materials

- explain how neutron magnetic scattering is used to probe the magnetic properties of materials and interpret experimental results
- explain ferrimagnetic order, Curie temperature and susceptibility in ferrimagnets
- explore the concept of ferromagnetic domains and the characteristics of single-domain particles, with applications in geomagnetism and biomagnetism.

Learning Outcomes:

At the end of this unit, the learner will be able to

- explain the principles of ferromagnetic order and the temperature dependence of saturation magnetization
- describe the quantization of spin waves, understand magnons and analyze the thermal excitation of magnons
- explain the process of neutron magnetic scattering and its application in studying magnetic materials
- extract the knowledge of ferrimagnetic order, including the Curie temperature and susceptibility of ferrimagnets
- discuss antiferromagnetic order, analyze susceptibility and understand the properties of antiferromagnetic magnons and ferromagnetic domains.

3.1	Ferromagnetic Order - Curie Point and the Exchange Integral, Temperature Dependence of the Saturation Magnetization, Saturation Magnetization at Absolute Zero, Magnons – Quantization of Spin Waves, Thermal Excitation of Magnons, Neutron Magnetic Scattering, Ferrimagnetic Order Curie Temperature and Susceptibility of Ferrimagnets, Iron Garnets, Antiferromagnetic Order – Susceptibility Below the Néel Temperature, Antiferromagnetic Magnons, Ferromagnetic Domains – Anisotropy Energy, Transition Region between Domains, Origin of Domains, Coercivity and Hysteresis, Single Domain Particles-Geomagnetism and Biomagnetism, Magnetic Force Microscopy.	**[15L]**
Unit IV	**Point Defects and Dislocations**	**[15L]**

Learning Objective:

This unit is intended to make the learners

- understand lattice vacancies, their formation and how they influence diffusion in materials
- explain diffusion mechanisms in metals, exploring their impact on material properties and the behaviour of grain boundaries
- understand about color centers, specifically F centers and how these centers affect the optical properties of materials
- explore the shear strength of single crystals, the concept of slip and the behaviour of dislocations, including stress fields and dislocation densities
- explain dislocations and crystal growth, including whiskers and provide a framework for understanding the hardness and strength of materials, particularly alloys.

Learning Outcomes:

At the end of this unit, the learner will be able to

- interpret the concept of lattice vacancies and their role in diffusion and material properties.
- explain the process of diffusion in metals and its impact on material behaviour, particularly in the context of grain growth and phase transitions.
- describe color centers in alkali halides, with a focus on F centers and other defect structures.
- relate the shear strength of single crystals and the role of slip and dislocations in material deformation.
- explain the concept of dislocations, including Burgers vectors, dislocation densities, and the factors influencing the strength of alloys and hardness of materials.

4.1	Lattice Vacancies, Diffusion – Metals, Color Centers - F Centers, Other Centers in Alkali Halides.	[07L]
4.2	Shear Strength of Single Crystals – Slip, Dislocations - Burgers Vectors, Stress Fields of Dislocations, Low-angle Grain Boundaries, Dislocation Densities, Dislocation Multiplication and Slip, Strength of Alloys, Dislocations and Crystal Growth – Whiskers, Hardness of Materials.	[08L]

Reference Books:

- Introduction to Solid State Physics by C. Kittel, John Wiley and Sons, 8th Ed., 2005.
- The Oxford Solid State Basics by Steven H. Simon, Oxford University Press, 2013.
- Solid State Physics by Neil W. Ashcroft and N. David Mermin, Cengage India, 2009.
- Solid State Physics by S. O. Pillai, New Age International Publishers, 8th Ed., 2011.
- Solid State Physics: Structure and Properties of Materials by M.A. Wahab, Alpha Science Intl Ltd, 2nd Ed., 2005.
- Elementary Solid State Physics: Principles and Applications by M. Ali Omar, Addison-Wesley, 1994.

Online Learning Resources:

- https://archive.nptel.ac.in/courses/115/104/115104109/
- https://onlinecourses.nptel.ac.in/noc21_ph30/preview

Question Paper Template

Unit	Remembering/ Knowledge (1)	Understanding (2)	Applying (3)	Analysing (4)	Evaluating (5)	Creating (6)	Total marks
I	20%	40%	20%	20%	-	-	100%
II	-	20%	40%	20%	20%	-	100%
III	-	20%	40%	20%	20%	-	100%
IV	20%	20%	40%	20%	-	-	100%

Mapping of CLOs and PSOs

Course Learning Outcomes	Programme Specific Outcomes					
	1	2	3	4	5	6
• elaborate crystal vibrations, phonon behaviour, and thermal properties using models like Debye and Einstein	√	√	√		√	√
• understand and apply quantum theories of diamagnetism, paramagnetism, and ferromagnetism	√	√			√	√
• analyze dislocations, crystal defects, and material strength, focusing on alloys and single crystals	√	√				√
• apply concepts of diffusion, color centers, and lattice defects to evaluate material properties and performance.	√				√	

M. Sc. (Physics) SEMESTER III
COURSE TITLE: Laser Fundamentals and Applications
COURSE CODE: PHYMSC-S3E9-4CR25 [CREDITS - 04]

EC IX	Course Code: PHYMSC-S3E9-4CR25
	Course Learning Outcomes

At the end of this course, learners will be able to
- interpret laser operation principles, including Einstein coefficients, threshold conditions and laser rate equations for different level systems
- analyze the working mechanisms and applications of Nd:YAG, gas, dye and semiconductor lasers
- interpret optical resonator modes, quality factor and mode selection techniques in laser systems
- interpret Q-switching and mode-locking techniques, including mechanical, electro-optic, acousto-optic and saturable absorber method
- analyze harmonic generation, optical mixing, parametric processes, laser spectroscopy techniques and their applications in light manipulation
- apply ray model to analyze fiber propagation, numerical aperture and dispersion effects in step and graded index fibers
- analyze material and multipath dispersion, pulse broadening, and frequency response in optical fiber communication systems.

Unit I	LASER I	[15L]

Learning Objective:
This unit is intended to make the learners
- explain laser principles, rate equations, threshold conditions, and the operation of Nd:YAG, gas, dye and semiconductor lasers.

Learning Outcomes:
At the end of this unit, the learner will be able to
- interpret laser operation principles, including Einstein coefficients, threshold conditions, and laser rate equations for different level systems
- analyze the working mechanisms and applications of Nd:YAG, gas, dye, and semiconductor lasers.

1.1	Introduction, Einstein coefficients, Light amplification, Threshold conditions, Laser rate equations: Two level system, three level system and four level system, Variation of Laser power around threshold, Optimum output coupling. Neodymium lasers (Nd:YAG and Nd: Glass), Gas Lasers: Neutral Atom Gas Lasers: Helium-Neon Laser, CO_2 laser, Argon ion laser, Dye laser, Semiconductor lasers.	[15L]

Unit II	LASER II	[15L]

Learning Objective:
This unit is intended to make the learners

	• aware of the optical resonator modes, mode selection, Q-switching and mode-locking techniques in laser systems.	
Learning Outcomes:		
At the end of this unit, the learner will be able to		
	• relate optical resonator modes, quality factor and mode selection techniques in laser systems	
	• interpret Q-switching and mode-locking techniques, including mechanical, electro-optic, acousto-optic and saturable absorber method.	
2.1	Introduction, Optical Resonators: Modes of a rectangular cavity and the open planar resonator, Quality factor, Ultimate line width of the laser, Mode selection: Transverse mode selection and longitudinal mode selection, Q-switching, Techniques for Q-switching, Mechanical Shutter, Electro-optic effect, Acousto-optic effect, Shutters using saturable absorber, Mode locking in lasers, Techniques for mode locking.	**[15L]**
Unit III	**Non-linear Optics**	**[15L]**
Learning Objectives:		
This unit is intended to make the learners		
	• explain harmonic generation, optical mixing, parametric processes and self-focusing of light	
	• describe laser spectroscopy techniques, including Raman scattering, Brillouin scattering and Doppler-free two-photon spectroscopy.	
Learning Outcome:		
At the end of this unit, the learner will be able to		
	• analyze harmonic generation, optical mixing, parametric processes, laser spectroscopy techniques and their applications in light manipulation.	
3.1	Harmonic generation, Second harmonic generation, Phase matching, Third harmonic generation, Optical mixing, Parametric generation light, Self-focusing of light, Multiphoton process: Multi-quantum Photoelectric effect, Two photon processes, Experiments in two photon processes, Three photon processes, Parametric generation of light, Parametric light oscillator, Frequency up conversion, Phase conjugate optics, Laser Spectroscopy: Rayleigh and Raman scattering, Stimulated Raman effect, Hyper- Raman effect : Classical treatment, Coherent anti stokes Raman Scattering, Spin Flip Raman laser, Free-electron laser, Photo-acoustic Raman spectroscopy, Brillouin Scattering, Saturation Absorption spectroscopy, Doppler free two Photon spectroscopy.	**[15L]**
Unit IV	**Light Wave Communications**	**[15L]**
Learning Objective:		
This unit is intended to make the learners		
	• explain fiber propagation, dispersion effects, numerical aperture, pulse broadening and frequency response in step and graded index fibers.	

Learning Outcomes:		
At the end of this unit, the learner will be able to		
• apply ray model to analyze fiber propagation, numerical aperture and dispersion effects in step and graded index fibers		
• analyze material and multipath dispersion, pulse broadening and frequency response in optical fiber communication systems.		
4.1	Light information carrying-capacity of light waves, Introduction to fiber propagation using a ray model: Step index fiber: numerical aperture and multipath dispersion, Propagation and multipath dispersion in graded index fiber, Material dispersion, Refractive index of the bulk media: theory and experimental values, Time dispersion in Bulk media. The combined effect of Material dispersion and Multipath dispersion, Root- mean- square Pulse widths and Frequency response: RMS pulse widths, Frequency response, Total RMS pulse width.	**[15L]**

Reference Books:

- Optical Electronics by A. K. Ghatak and K. Thyagarajan, Cambridge University press, (1990).
- Lasers and Non – linear Optics by B. B. Laud, Wiley Eastern Limited, (1993).
- Lasers Theory and Applications by K. Thyagarajan and A. K. Ghatak, McMillan India Limited, (1981).
- Lasers Fundamentals by William T. Silfvast, Cambridge University Press, 2nd Ed., (2004).
- Solid State Laser Engineering by Walter Koechner, Springer, 6th Ed., (2020).
- Optical Communication Systems by John Gowar, Prentice-Hall of India (1984).

Online Learning Resources:

- https://onlinecourses.nptel.ac.in/noc20_cy17/preview
- https://onlinecourses.nptel.ac.in/noc21_ph01/preview

Question Paper Template

Unit	Remembering/ Knowledge (1)	Understanding (2)	Applying (3)	Analysing (4)	Evaluating (5)	Creating (6)	Total marks
I	20%	20%	20%	40%	-	-	100%
II	20%	30%	10%	40%	-	-	100%
III	20%	30%	10%	40%	-	-	100%
IV	20%	20%	10%	50%	-	-	100%

Mapping of CLOs and PSOs

Course Learning Outcomes	Programme Specific Outcomes					
	1	2	3	4	5	6
• interpret laser operation principles, including Einstein coefficients, threshold conditions, and laser rate equations for different level systems	√	√			√	√
• analyze the working mechanisms and applications of Nd:YAG, gas, dye, and semiconductor lasers	√					
• interpret optical resonator modes, quality factor, and mode selection techniques in laser systems	√	√	√		√	√
• interpret Q-switching and mode-locking techniques, including mechanical, electro-optic, acousto-optic, and saturable absorber method	√	√	√		√	
• analyze harmonic generation, optical mixing, parametric processes, laser spectroscopy techniques, and their applications in light manipulation	√	√	√		√	
• apply ray model to analyze fiber propagation, numerical aperture, and dispersion effects in step and graded index fibers	√		√			√
• analyze material and multipath dispersion, pulse broadening, and frequency response in optical fiber communication systems.	√	√			√	√

M. Sc. (Physics) SEMESTER III
COURSE TITLE: Python Programming and Computational Physics
COURSE CODE: PHYMSC-S3E10-4CR25 [CREDITS - 04]

EC X	Course Code: PHYMSC-S3E10-4CR25
	Course Learning Outcomes

At the end of this course, learners will be able to

- recall Python basics, including variables, data types, modules and key commands for scientific programming
- interpret Python data structures, input-output operations and module usage for scientific and engineering applications
- apply Python conditionals, loops, plotting techniques and user-defined functions to solve scientific and engineering problems
- analyze nonlinear oscillators, bifurcation, chaos and predator-prey models using mapping, visualization, and phase-space analysis techniques
- apply finite-difference algorithms to solve and visualize quantum wave packets and electromagnetic wave propagation
- analyze the behaviour of quantum wave packets and electromagnetic waves using Schrödinger and Maxwell's equations.

Unit I	PYTHON Language - I	[15L]

Learning Objective:

This unit is intended to

- explain Python basics, data structures, and input-output operations for scientific and engineering applications.

Learning Outcomes:

At the end of this unit, the learner will be able to

- remember Python basics, including variables, data types, modules and key commands for scientific programming
- understand Python data structures, input-output operations and module usage for scientific and engineering applications.

1.1	Introduction to Python for Science and Engineering, Interacting with Python, Installing Python on Your Computer, The Spyder Window, **The IPython Pane:** Magic commands, System shell commands, Tab completion, Recap of commands, **Interactive Python as a Calculator:** Binary arithmetic operations in Python, Types of numbers, Important note on integer division in Python, **Variables:** Names and the assignment operator, Legal and recommended variable names, Reserved words in Python, Script Files and Programs, **Python Modules:** Python modules and functions: A first look, Some NumPy functions, Different ways of importing modules, Getting Help: Documentation in IPython, Stand-alone IPython, Programming Errors. **Strings, Lists, Arrays, and Dictionaries** Strings, **Lists:** Slicing lists, the range function: Sequences of numbers, Tuples, Multidimensional lists and tuples, **NumPy Arrays:** Creating	[15L]

arrays (1-d), Mathematical operations with arrays, Slicing and addressing arrays, Fancy indexing: Boolean masks, multi-dimensional arrays and matrices, Differences between lists and arrays, Dictionaries, Objects.

Input and Output

Keyboard Input, **Screen Output:** Formatting output with *str.format(),* Printing arrays, **File Input:** Reading data from a text file, Reading data from an Excel file: CSV files, **File Output:** Writing data to a text file, Writing data to a CSV file.

Unit II	PYTHON Language - II	[15L]

Learning Objectives:

This unit is intended to

- explain conditionals, loops and list comprehensions for efficient data handling and control flow in Python

- describe plotting techniques, user-defined functions, and object attributes for effective data visualization and manipulation in Python.

Learning Outcome:

At the end of this unit, the learner will be able to

- apply Python conditionals, loops, plotting techniques and user-defined functions to solve scientific and engineering problems.

| 2.1 | **Conditionals and Loops**
 Conditionals: if, elif, and else statements, Logical operators, Loops: for loops, while loops, Loops and array operations, List Comprehensions.
 Plotting
 An Interactive Session with PyPlot, Basic Plotting, Specifying line and symbol types and colours, Error bars, Setting plotting limits and excluding data, Subplots.
 Logarithmic Plots: Semi-log plots, Log-log plots, **More Advanced Graphical Output:** An alternative syntax for a grid of plots, Plots with multiple axes, Mathematics and Greek symbols, **The Structure of matplotlib: OOP and All That:** The backend layer, The artist layer, The PyPlot (scripting) layer, **Contour and Vector Field Plots:** Making a 2D grid of points, Contour plots, Streamline plots, Three-Dimensional Plots.
 Functions
 User-Defined Functions: Looping over arrays in user-defined functions, Fast array processing for user-defined functions, Functions with more than one input or output, Positional and keyword arguments, Variable number of arguments, Passing function names and parameters as arguments, **Passing data (objects) to and from functions:** Variables and arrays created entirely within a function, Passing lists and arrays to functions: Mutable and immutable objects, Anonymous Functions: lambda Expressions, NumPy Object Attributes: Methods and Instance Variables. | [15L] |

Unit III	Oscillatory Motion and Chaos	[15L]

Learning Objective:

This unit is intended to

- explain nonlinear oscillators, bifurcation, chaos, predator-prey models and phase-space analysis using mathematical models and visualization techniques.

Learning Outcomes:

At the end of this unit, the learner will be able to

- analyze nonlinear oscillators, bifurcation, chaos and predator-prey models using mapping, visualization, and phase-space analysis techniques.

3.1	Free nonlinear oscillation, Nonlinear Oscillators, Bug Population Dynamics, The Logistic Map (Model), Properties of Nonlinear Maps (Theory and Exercise), Fixed Points, Period Doubling, Attractors, Mapping Implementation, Bifurcation Diagram (Assessment), Bifurcation Diagram Implementation, Visualization Algorithm: Binning, Feigenbaum Constants (Exploration), Logistic Map Random Numbers (Exploration), Other Maps (Exploration), Signals of Chaos: Lyapunov Coefficient and Shannon Entropy, Coupled Predator–Prey Models, Lotka–Volterra Model, Lotka–Volterra Assessment, Predator–Prey Chaos, Exercises, LVM with Prey Limit, LVM with Predation Efficiency, LVM Implementation and Assessment, Two Predators, One Prey (Exploration), Chaotic Pendulum, Free Pendulum Oscillations, Solution as Elliptic Integrals, Implementation and Test: Free Pendulum, Visualization: Phase-Space Orbits, Chaos in Phase Space, Assessment in Phase Space, Exploration: Bifurcations of Chaotic Pendulums, Alternate Problem: The Double Pendulum, Assessment: Fourier/Wavelet Analysis of Chaos, Exploration: Alternate Phase-Space Plots, Further Explorations.	**[15L]**
Unit IV	**Quantum Packets and Electromagnetic Waves**	**[15L]**

Learning Objective:

This unit is intended to

- learn quantum wave packets, Schrödinger equation, FDTD algorithm, and Maxwell's equations through implementation, visualization, and assessment.

Learning Outcomes:

At the end of this unit, the learner will be able to

- apply finite-difference algorithms to solve and visualize quantum wave packets and electromagnetic wave propagation
- analyze the behaviour of quantum wave packets and electromagnetic waves using Schrödinger and Maxwell's equations.

4.1	Quantum Wave Packets, Time-Dependent Schrödinger Equation (Theory), Finite- Difference Algorithm, Wave Packet Implementation, Animation, Wave Packets in Other Wells (Exploration), Algorithm for the 2D Schrödinger Equation, Exploration: Bound and Diffracted 2D Packet, Wave Packet–Wave Packet Scattering, Algorithm, Implementation, Results and Visualization, E&M Waves via Finite-Difference Time Domain, Maxwell's Equations, FDTD Algorithm, Implementation,	**[15L]**

	Assessment, Extension: Circularly Polarized Waves, Application: Wave Plates, Algorithm, FDTD Exercise and Assessment.	

Reference Books:

- Introduction to Python for Science and Engineering: David J. Pine. CRC Press Taylor and Francis Group. (2019)
- Computational Physics with Python: Dr. Eric Ayars, California State University. (2013).
- Computational Physics Problem solving with Python: R. H. Landau, Manuel J. Páze and Cristian C. Bordeianu, 3rd Ed., Wiley-VCH, (2015).
- Computational Physics: Nicholas Giordano, Hisao Nakanishi, 2nd Ed., Pearson Prentice Hall. (2006).
- An Introduction to Computational Physics: T. Pang, 2nd Ed., Cambridge University Press (2006).

Online Learning Resources:

- https://archive.nptel.ac.in/courses/115/104/115104095/
- https://ocw.mit.edu/courses/6-0001-introduction-to-computer-science-and-programming-in-python-fall-2016/
- https://onlinecourses.swayam2.ac.in/cec22_cs20/preview

Question Paper Template

Unit	Remembering/ Knowledge (1)	Understanding (2)	Applying (3)	Analysing (4)	Evaluating (5)	Creating (6)	Total marks
I	40%	40%	20%	-	-	-	100 %
II	20%	30%	50%	-	-	-	100 %
III	10%	30%	20%	40%	-	-	100 %
IV	10%	20%	30%	40%	-	-	100 %

Mapping of CLOs and PSOs

Course Learning Outcomes	Programme Specific Outcomes					
	1	2	3	4	5	6
• recall Python basics, including variables, data types, modules, and key commands for scientific programming	√	√				√
• interpret Python data structures, input-output operations, and module usage for scientific and engineering applications	√	√	√			√
• apply Python conditionals, loops, plotting techniques, and user-defined functions to solve scientific and engineering problems	√	√				
• analyze nonlinear oscillators, bifurcation, chaos, and predator-prey models using mapping, visualization, and phase-space analysis techniques	√	√	√			√
• apply finite-difference algorithms to solve and visualize quantum wave packets and electromagnetic wave propagation	√	√	√		√	
• analyze the behavior of quantum wave packets and electromagnetic waves using Schrödinger and Maxwell's equations.	√	√	√			√

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M. Sc. (Physics) SEMESTER III
COURSE TITLE: Nuclear Physics
COURSE CODE: PHYMSC-S3E11-4CR25 [CREDITS - 04]

EC XI	Course Code: PHYMSC-S3E11-4CR25
	Course Learning Outcomes

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

- demonstrate knowledge of ion optics, ion production, detection in mass spectrometry and compare different mass spectrometers for nuclear mass measurement
- interpret hyperfine splitting principles, its role in nuclear spin and magnetic moment and apply magnetic resonance techniques for accurate measurement
- explain nuclear composition, neutron-proton hypothesis and discuss nuclear forces and stability based on the inventory of stable nuclides
- apply the Bethe-Weizsäcker and semi-empirical mass formulas to predict nuclear stability and analyze different nuclear models and their applications
- analyze artificial transmutation and nuclear reactions, apply conservation laws, calculate Q-values and analyze reaction cross-sections and induced radioactivity in nuclear science
- explain the discovery and properties of neutrons and compare different neutron sources based on energy levels and production methods.

Unit I	**Determination of Some Nuclear Properties**	[15L]

Learning objectives:

This unit is intended to make the learners

- understand the principles and techniques involved in nuclear mass measurement using different mass spectrometers
- analyze the working and significance of various high-resolution mass spectrometers used in Nuclear Physics
- explore methods of measuring nuclear spin and magnetic moment through hyperfine splitting and resonance techniques
- examine the applications of Zeeman Effect, molecular spectra and magnetic resonance absorption methods in determining nuclear properties.

Learning outcomes:

At the end of this unit, learners will be able to

- demonstrate knowledge of ion optics, ion production and detection in mass spectrometry for nuclear mass measurement.
- compare and contrast different mass spectrometers.
- explain the principles behind hyperfine splitting and its role in determining nuclear spin and magnetic moment.
- apply magnetic resonance techniques and accurately measure nuclear magnetic moments.

1	Nuclear Mass Measurement: Introduction, ion Optics, Production and Detection of Positive loins, Dempster's Semi-circular Focusing Mass Spectrometer, Aston's Mass Spectrograph, Bainbridge's First Mass Spectrograph, Double Focusing Mass Spectroscopes, Special Types of High Resolution Mass Spectrometers, Measurement of Nuclear Spin and Magnetic Moment: Hyperfine Splitting of the Atomic Energy Levels, Nuclear Spin from Zeeman Effect of Hyperfine Lines, Nuclear Spin and Statistics from Molecular Spectra, Magnetic Resonance Method of Rabi, Magnetic Resonance Absorption Method of Measuring Nuclear Magnetic Moment.	**[15L]**
Unit II	**Nuclear Models**	**[15L]**

Learning objectives:

This unit is intended to make the learners

- understand the fundamental concepts of nuclear structure and the neutron-proton hypothesis
- learn the nature of nuclear forces
- explore various nuclear models
- learn Bethe-Weizsäcker formula and its applications
- investigate the nuclear shell model, including single-particle states and its applications in understanding nuclear properties.

Learning outcome:

At the end of this unit, learners will be able to

- explain the composition of the nucleus and describe the neutron-proton hypothesis.
- discuss the characteristics of nuclear forces and apply concepts of nuclear stability to interpret the inventory of stable nuclides.
- apply the Bethe-Weizsäcker formula and the semi-empirical mass formula to calculate nuclear binding energy and predict nuclear stability.
- compare different nuclear models, including the single particle shell model and collective model, and analyze their applications in nuclear structure research.

2	Constitution of the Nucleus Neutron-proton Hypothesis, Nature of Nuclear Force, inventory of Stable Nuclides, Nuclear Models, Liquid Drop Model, Bethe-Weizsacker Formula, Applications of the Semi-empirical Binding Energy Formula, Fermi Gas Model of the Nucleus, Nuclear Shell Structure, Single Particle States in Nuclei, Applications of Extreme Single Particle Shell Model, Single Particle Shell Model, Individual Particle Model, Collective Model.	**[15L]**
Unit III	**Nuclear Reactions**	**[15L]**

Learning objectives:

This unit is intended to make the learners

- understand the concept of artificial transmutation of elements and the significance of Rutherford's experiment in nuclear reactions
- analyze different types of nuclear reactions and the role of conservation laws in governing these reactions
- explore the energetics of nuclear reactions, including the determination of reaction Q-value and cross-sections
- investigate reaction mechanisms such as α-particle-induced reactions and the discovery of induced radioactivity.

Learning outcome:

At the end of this unit, learners will be able to

- explain the principles behind artificial transmutation of elements and describe Rutherford's contribution to Nuclear Physics
- classify various types of nuclear reactions and apply conservation laws (energy, momentum, charge and nucleon number) to nuclear interactions
- calculate the Q-value of nuclear reactions experimentally and analyze the significance of reaction cross-sections in Nuclear Physics
- describe the process of reaction yield, partial cross-sections and the discovery of induced radioactivity with practical applications in nuclear science.

3.1	Discovery of Artificial Transmutation of Elements Rutherford's Experiment, Types of Nuclear Reactions, Conservation Laws in Nuclear Reactions, Collision between subatomic particles, Energetics of Nuclear Reactions, Experimental Determination ion of Q, Cross Section of Nuclear Reaction, Partial Cross Sections, Reaction Yield, Reaction Induced by $\alpha -$ particles, Discovery of induced Radioactivity.	**[05L]**
Unit IV	**Neutron Physics**	**[15L]**

Learning objectives:

This unit is intended to make the learners

- understand the fundamental properties of neutrons and their classification based on their energy
- explore different sources of neutrons
- analyze various neutron detection techniques
- investigate the interaction of neutrons in matter, including their slowing down, diffusion, and the use of neutron monochromators.

Learning Outcomes:

At the end of this unit, learners will be able to

- explain the historical discovery of the neutron and describe its physical properties and classification based on energy levels
- identify and compare different neutron sources, including ultrafast neutrons, neutrons from uranium fission and slow neutron sources
- describe various neutron detection methods, such as slow neutron detection through charged particle production and fast neutron detection via slowing down processes
- analyze the principles governing neutron interactions in matter, including neutron moderation, diffusion of thermal neutrons and the role of neutron monochromators.

4	Discovery of neutron, properties of the neutron, classification of neutrons according to their energy, sources of neutrons, radioactive (α, n) sources, photo-neutron sources, accelerated charged particle sources, ultrafast neutrons, neutrons from uranium fission, slow neutrons sources, neutron detectors, slow neutron detection though charged particle production in nuclear reactions, slow neutron detection through induced radioactivity measurement, fast neutron detection, neutron detection through slowing down of fast neutrons, neutron monochromators, slowing down of neutrons in matter, diffusion of thermal neutrons.	**[15L]**

Reference Books:

- Introductory Nuclear Physics by Krane, John Wiley & Sons, 3rd Ed., 1991.
- Nuclear Physics by Ghoshal, S. Chand & Co. 1997.
- Introduction to Nuclear and Particle Physics by V. K. Mittal, R. C. Verma, S. C. Gupta, PHI Learning, 2018.

Online Learning Resources:

- https://archive.nptel.ac.in/courses/115/104/115104043/
- https://archive.nptel.ac.in/courses/115/102/115102017/
- https://ocw.mit.edu/courses/22-02-introduction-to-applied-nuclear-physics-spring-2012/
- https://ocw.mit.edu/courses/8-701-introduction-to-nuclear-and-particle-physics-fall-2020/

Question Paper Template

Unit	Remembering/ Knowledge (1)	Understanding (2)	Applying (3)	Analyzing (4)	Evaluating (5)	Creating (6)	Total marks
I	20%	30%	25%	25%	-	-	100%
II	20%	30%	25%	25%	-	-	100%
III	20%	30%	25%	25%	-	-	100%
IV	20%	30%	25%	25%	-	-	100%

Mapping of CLOs and PSOs

Course Learning Outcomes	Programme Specific Outcomes					
	1	2	3	4	5	6
• demonstrate knowledge of ion optics, ion production, detection in mass spectrometry, and compare different mass spectrometers for nuclear mass measurement	√	√	√		√	
• interpret hyperfine splitting principles, its role in nuclear spin and magnetic moment, and apply magnetic resonance techniques for accurate measurement	√	√				
• explain nuclear composition, neutron-proton hypothesis, and discuss nuclear forces and stability based on the inventory of stable nuclides	√	√	√			
• apply the Bethe-Weizsäcker and semi-empirical mass formulas to predict nuclear stability and analyze different nuclear models and their applications	√	√	√		√	√
• analyze artificial transmutation and nuclear reactions, apply conservation laws, calculate Q-values, and analyze reaction cross-sections and induced radioactivity in nuclear science	√	√			√	√
• explain the discovery and properties of neutrons and compare different neutron sources based on energy levels and production methods.	√	√				

M. Sc. (Physics) SEMESTER III
COURSE TITLE: Introduction to Quantum Computation
COURSE CODE: PHYMSC-S3E12-4CR25 [CREDITS - 04]

EC XII	Course Code: PHYMSC-S3E12-4CR25
	Course Learning Outcomes

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

- apply the linear algebra in quantum mechanics problems
- explain the postulates of quantum mechanics
- apply the concept of quantum mechanics in superdense coding
- describe the density operator formulation of quantum mechanics
- describe the Schmidt decomposition, EPR and Bell inequality
- describe quantum bits
- describe quantum circuits
- explain the Deutsch–Jozsa algorithm
- describe single qubit operations, controlled operations and universal quantum gates
- apply the method of quantum simulation for quantum physics problems.

Unit I	**Mathematical Methods for Quantum Computation**	[15L]

Learning objectives:

This unit is intended to make the learners

- introduce students about linear algebra
- introduce linear operators and matrices
- provide the knowledge of commutator and anti-commutator
- provide the knowledge of the polar and singular value decomposition.

Learning outcomes:

At the end of this unit, learners will be able to

- apply the linear algebra in quantum mechanics problems
- verify the identities of commutator and anti-commutator
- use the polar and singular value decompositions.

1	Linear Algebra ; Bases and linear independence, Linear operators and matrices, The Pauli matrices, Inner Products, Eigen vectors and Eigenvalues, Adjoints and Hermitian operators, Tensor products, Operator functions, The Commutator and anti-commutator, The polar and singular value decompositions.	[15L]

Unit II	**Quantum Mechanical Measurements**	[15L]

Learning objectives:

This unit is intended to make the learners

- introduce the postulates of quantum mechanics
- provide the knowledge of superdense coding
- provide the knowledge of Schmidt decomposition, EPR and Bell inequality.

Learning Outcome:	
At the end of this unit, learners will be able to	
• explain the postulates of quantum mechanics	
• apply the concept of quantum mechanics in superdense coding	
• describe the density operator formulation of quantum mechanics	
• describe the Schmidt decomposition, EPR and Bell inequality.	

2	The postulates of quantum mechanics ; State Space, Evolution, Quantum measurement, Distinguishing quantum state, Projective measurements, POVM measurements, Phase, Composite system, Application: superdense coding, The density operator; Ensembles of quantum states, General properties of the density operator, The reduced density operator, The Schmidt decomposition and purifications, EPR and the Bell inequality.	**[15L]**
Unit III	**Fundamental concepts of Quantum Computations**	**[15L]**

Learning objectives:	
This unit is intended to make the learners	
• introduce quantum bits	
• introduce quantum circuits and quantum algorithm	

Learning outcome:	
At the end of this unit, learners will be able to	
• describe quantum bits	
• describe quantum circuits	
• explain the Deutsch–Jozsa algorithm	

3.1	Quantum bits, Multiple qubits, Quantum computation; Single qubit gates, Multiple qubit gates, Measurements in bases other than the computational basis, Quantum Circuits, Qubit copying circuits?, Example: Bell States, Example: quantum teleportation, Quantum algorithms; Classical computations on a quantum computer, Quantum parallelism, Deutsch's algorithm, The Deutsch-Jozsa algorithm, Quantum algorithms summarized.	**[15L]**
Unit IV	**Quantum Algorithms and Applications**	**[15L]**

Learning objectives:	
This unit is intended to make the learners	
• provide the knowledge of basic elements of quantum computation	
• develop the foundation for quantum simulation.	

Learning Outcomes:		
At the end of this unit, learners will be able to • describe single qubit operations, controlled operations and universal quantum gates • apply the method of quantum simulation for quantum physics problems.		
4	Quantum circuits ; Quantum algorithms, Single qubit operations, Controlled operations, Measurement, Universal quantum gates; Two-level unitary gates are universal, Single qubit and CNOT gates are universal, A discrete set of universal operations, Approximating arbitrary unitary gates in generically hard, Quantum computational complexity, Summary of the quantum circuit model of computation, Simulation of quantum systems, Simulation in action; The quantum simulation algorithm, An illustrative example, Perspectives on quantum simulation.	**[15L]**

Reference Books:
- Quantum Computation and Quantum Information, Michael A. Nielsen and Isaac L. Chuang, Cambridge University Press, 2010.
- Introduction to Quantum Mechanics, D. J. Griffiths, Cambridge University Press 2nd Ed., 2016.

Online Learning Resources:
- https://ocw.mit.edu/courses/18-435j-quantum-computation-fall-2003/
- https://openlearninglibrary.mit.edu/courses/course-v1:MITx+8.370.1x+1T2018/about
- https://onlinecourses.nptel.ac.in/noc21_cs103/preview
- https://archive.nptel.ac.in/courses/115/101/115101092/

Question Paper Template

Unit	Remembering/ Knowledge (1)	Understanding (2)	Applying (3)	Analyzing (4)	Evaluating (5)	Creating (6)	Total marks
I	20%	30%	25%	25%	-	-	100%
II	20%	30%	25%	25%	-	-	100%
III	20%	30%	25%	25%	-	-	100%
IV	20%	30%	25%	25%	-	-	100%

Mapping of CLOs and PSOs

Course Learning Outcomes	Programme Specific Outcomes					
	1	2	3	4	5	6
• apply the linear algebra in quantum mechanics problems	√	√	√		√	
• explain the postulates of quantum mechanics	√	√				
• apply the concept of quantum mechanics in superdense coding	√	√	√			
• describe the density operator formulation of quantum mechanics	√	√	√		√	√
• describe the Schmidt decomposition, EPR and Bell inequality	√	√			√	√
• describe quantum bits	√	√				
• describe quantum circuits	√	√	√		√	
• explain the Deutsch–Jozsa algorithm	√	√	√		√	
• describe single qubit operations, controlled operations and universal quantum gates	√	√				
• apply the method of quantum simulation for quantum physics problems	√	√	√		√	

M. Sc. (Physics) SEMESTER III
COURSE TITLE: Microprocessor
COURSE CODE: PHYMSC-S3SEC3-2CR25 [CREDITS - 02]

SEC III	Course Code: PHYMSC-S3SEC3-2CR25
	Course Learning Outcomes

At the end of this course, learners will be able to
- interpret the conversion of number system and will acquire basic understanding and concept of Microprocessors.
- relate the usage of Intel 8085 instruction set and to learn writing of assembly language programs for beginners.
- design microprocessor-based project.
- use combination of input and output devices to work in programmed manner

Unit I	Assembly Language Programming	[60L]

Learning Objectives:

This unit is intended to make the learners
- study programming using assembly language on 8085 IC.
- aware of the connection of the real world with machine.

Learning Outcomes:

At the end of this unit, the learner will be able to
- acquire basic understanding and concept of Microprocessors
- interpret the usage of Intel 8085 instruction set
- learn writing of assembly language programs
- design microprocessor-based projects.

| 1.1 | 1. Data transfer program:
 A) To load register A, B, C, D with same content.
 B) From four memory location [X] to [X + 3] load l the register E, D, C, A respectively.
 2. Two bites of data are stored at location X and Y interchange them.
 3. Two bytes of data are stored at consecutive location in memory at [x]. Write a program to move the data from [X], [X + 1] to [Y], [Y + 1].
 4. Data test program:
 All zero conditions of byte at memory location [x] B) all 1's conditions of byte at memory location [x]. If condition is true right '01' or else '00' at location [X + 1].
 5. Mask off least significant 4- bits of 8-bit number,
 6. Mask off most significant 4- bits of 8-bit number.
 7. Shifting of a 16-bit number left by two bits,
 8. Arithmetic Program:
     A. Addition of two 8-bit
     B. Subtraction of two 8-bit
     C. addition of two 16-bit numbers,
     D. Subtraction of two 16-bit numbers
     E. 1's Complement of 16-bit number, | |

F. 2's Complement of 16-bit number,
9. A) 4 bits of data are stored at 4 consecutive location starting at X.
    Write a program which increment the values of all the four data.
   B) 2 bits of data stored at X and X + 1 compute the sum of the two and
     store the result at Y location ignore the possible overflow.
10. A) 4 bits of data are stored at 4 consecutive locations starting at X.
     Write a program which increment the values of all the four data.
   B) 2 bits of data stored at X and X + 1 compute the sum of the two and
      store the result at Y location ignore the possible overflow.
   C) four unsigned numbers are stored at consecutive data memory
      location starting at Memory location X. Compute the summation
      and ignore the possible overflow.
11. Perform binary additional subtraction in 2's complement between two
     bytes
12. Perform BCD addition and subtraction in 10's compliments between
     two bytes.
13. A) Find the largest and smallest from array of data.
     B) Computer number of ones in one byte of data

Reference Books:
- Microprocessor Architecture, programming and application with 8085, McGraw-Hill in New Jersey and Ohio. Ramesh Gaonkar, 5th Ed., 2000.
- Fundamentals of Microprocessors and Microcomputers: B. Ram, Dhanpat Rai Publications (1992).

Online Learning Resources:
- https://onlinecourses.nptel.ac.in/noc22_ee12/preview
- https://onlinecourses.nptel.ac.in/noc25_ee48/preview

NOTE:
➢ The candidates will have to appear for a viva voce while submitting the project.
➢ The examiner will mark the candidates based on their performance. The suggested marking scheme is given below.

Question Paper Template

Evaluation Criterion	Examination	% of Marks
Attendance	CIE	10%
Performance during hands on sessions	CIE	20%
Project	SEE	40%
Viva Voce	SEE	30%
	Total	**100%**

Mapping of CLOs and PSOs

Course Learning Outcomes	Programme Specific Outcomes					
	1	**2**	**3**	**4**	**5**	**6**
• interpret the conversion of number system and will acquire basic understanding and concept of Microprocessors.	√	√	√		√	√
• relate the usage of Intel 8085 instruction set and to learn writing of assembly language programs for beginners.	√	√			√	
• design microprocessor-based project.	√	√	√			√
• use combination of input and output devices to work in programmed manner	√	√	√		√	

M. Sc. (Physics) SEMESTER III
COURSE TITLE: Physics Practical
COURSE CODE: PHYMSC-S3PR3-6CR25 [CREDITS - 06]

Practical III	Course Code: PHYMSC-S3PR3-6CR25
	Course Learning Outcomes

After the successful completion of the course, learners will be able to
- demonstrate practical skills
- utilize Physics theory concepts through practical

	Group-A Practicals
1	To generate square wave using Fourier expansion.
2	To construct a wave-packet for the region x = [-L,L].
3	To convert the time independent Schrodinger equation in matrix form using central divided formula; for 1D infinite well potential.
4	To generate plots for the probability functions $\psi_1^2, \psi_2^2, \psi_3^2$ and ψ_4^2; for 1D infinite well potential.
5	To generate the Hamiltonian matrix and determine the eigen values and eigen vectors for finite square well potential and plot $x \rightarrow V$.

	Group-B Practicals
1	To determine the dissociation energy of diatomic molecule using a spectrophotometer.
2	To determine the optical band gap energy (E_g) of a semiconductor using UV-Visible spectroscopy by analysing its absorption spectrum and by applying Tauc'c plot.
3	To study fluorescence emission spectra of fluorescent molecules.
4	To study the absorption spectrum of iodine molecules.
5	To write code to calculate and plot the energy levels and wavefunctions of the hydrogen atom using the Schrödinger equation (e.g., using numerical methods like finite difference or finite element methods).
6	To simulate the emission spectrum of hydrogen, considering transitions between different energy levels and calculate the wavelengths of emitted photons.
7	To simulate the motion of atoms in a molecule (e.g., water, diatomic molecules) using classical mechanics and interatomic potentials (e.g., Lennard-Jones potential).
8	To simulate the vibrational spectra of molecules using the harmonic oscillator model and calculate the vibrational frequencies.
9	To simulate the rotational spectra of molecules using the rigid rotor model and calculate the rotational constants

Group-C Practicals

1	To study the current vs voltage characteristics of CdS photoresistor at constant irradiance.
2	To measure the photo-current as a function of the irradiance at constant voltage.
3	To determine the heat capacity of the calorimeter.
4	To study the thermal conductivity of copper and aluminium at a constant temperature gradient.
5	To determine the electrical conductivity of aluminium and copper by plotting a current-voltage characteristic curve.
6	To verify the Wiedmann-Franz law and find out the Lorenz number.
7	To determine the particle size of lycopodium powder.

Reference Books:
- Advanced Practical Physics by B. L. Worsnop and H. T. Flint, 3rd Ed., Asia Publishing House, New Delhi, 2021
- University Practical Physics by D. C. Tayal, Edited by Ila Agarwal, 1st Ed., Himalayan Publishing House, 2000.
- Experimental Physics: Modern Methods by R. A. Dunlap, Oxford University Press, New Delhi 1988.
- Methods of Experimental Physics: Series of Volumes by D. Malacara, Academic Press Inc. 1988.

Online Learning resources:
- https://phet.colorado.edu/
- https://www.olabs.edu.in/
- https://vlab.amrita.edu/index.php?sub=1

Note:
➢ Group-A practical shall be performed by computation.
➢ The duration of each experiment is of 4 hours. Three such experiments are to be performed by each student per week.
➢ In the external exam, a student will have to perform three experiments, one from each group. The experiment will be of 4-hour duration.
➢ There should be three examiners, one for each group, in the external examination.

Mapping of CLOs and PSOs

Course Learning Outcomes	Programme Specific Outcomes					
	1	2	3	4	5	6
• demonstrate practical skills	√	√	√		√	√
• utilize Physics theory concepts with appropriate practical	√	√			√	