SIKKIM UNIVERSITY

(A Central University Established by an Act of Parliament of India, 2007)

LEARNING OUTCOME - BASED CURRICULUM

M.Sc. PHYSICS (POSTGRADUATE PROGRAMME)

(With effect from Academic Session 2023-24)

DEPARTMENT OF PHYSICS

SIKKIM UNIVERISTY

6TH MILE, TADONG - 737102

GANGTOK, SIKKIM, INDIA

VICE-CHANCELLOR'S MESSAGE

Sikkim University stands at the forefront of embracing the transformative National Education Policy (NEP) 2020. In alignment with NEP 2020's vision and the guidelines of the Learning Outcomes-based Curriculum Framework (LOCF) mandated by the UGC, we have undertaken a comprehensive revision of our curriculum across all departments. This initiative ensures a holistic educational experience that transcends traditional knowledge delivery, emphasizing the practical application of knowledge in real-world scenarios.The shift towards LOCF marks a pivotal change from teacher-centric to learner-centric education, fostering a more active and participatory approach to learning. Our updated curriculum clearly defines Graduate Attributes, Programme Learning Outcomes (PLOs), and Course Learning Outcomes (CLOs), setting clear objectives for our students to achieve. This revision is designed to enable a teaching-learning environment that supports the attainment of these outcomes, with integrated assessment methods to monitor and encourage student progress comprehensively.

A key innovation in our curriculum is the mandatory integration of Massive Open Online Courses (MOOCs) through the SWAYAM platform, enhancing accessibility and the breadth of learning opportunities for students. Our approach encourages multidisciplinary studies through the curriculum while allowing for specialization. The curriculum embodies the policy's core principle of flexibility by enabling mobility for students, thereby allowing the exit and entry of students in the program.

I extend my heartfelt gratitude to our faculty, the Head of the Department, the Curriculum Development Committee members, the NEP coordinators, and the dedicated NEP Committee of Sikkim University for their relentless dedication to updating our curriculum. I appreciate Prof. Yodida Bhutia, the Chairperson, and all dedicated NEP Committee members for their thorough review and integration of LOCF and NEP components into our curriculum.

To our students, I convey my best wishes as we embark on this journey with our updated and inclusive curriculum, aiming not only to enrich their academic knowledge but also to nurture their personal growth, critical thinking, and ability to adapt and innovate in an ever-changing world.

Best wishes,

Prof. Avinash Khare
Vice Chancellor
Sikkim University

1. Preamble

Master of Science (M.Sc.) in Physics at Sikkim University is a two-year degree program which is designed for young, bright and enthusiastic students to acquire the knowledge of fundamental laws and principles of physics along with their applications in diverse areas. The courses will cover fundamental and advanced topics in Physics, interdisciplinary fields, Ability & Skill Enhancement courses to be learnt through lectures, tutorials, laboratory experiments, project works, seminars etc. Students will have the option to choose the courses from other departments and online courses through SWAYAM platform. The overall aim of this program is to train students to be efficiently capable of working in academics, research and other frontiers in science and technology exhibiting good scientific knowledge and temperament.

2. Post Graduate Attributes

Graduates will:

- have in-depth knowledge and understanding on theoretical principles and experimental findings in different sub-areas in Physics as well as related interdisciplinary fields.
- have the ability to use and demonstrate the analytical concepts, critical thinking, problem solving techniques in basic and advanced areas of physics.
- have the ability of handling/using different modern tools and techniques relevant for the areas in physical sciences.
- have the ability of team work as well as working in interdisciplinary topics.
- have a strong sense of intellectual integrity and the ethics of scholarship.
- reach a high level of achievement in writing, research or project activities, problem-solving and communication.
- be critical and creative thinkers, with an aptitude for continued self-directed learning.
- be able to examine critically, synthesise and evaluate knowledge across a broad range of disciplines.
- have a set of flexible and transferable skills for different types of employment.
- be able to initiate and implement constructive change in their communities, including professions and workplaces.

3. Programme Learning Outcomes (PLOs)

After completing the programme, the students will have

PLO1	Subject Knowledge	understanding of fundamental aspects in all core areas of physics
PLO2	Problem Solving	the capability to formulate and solve relevant scientific problems using the knowledge of physics learned
PLO3	Research skills	the ability to select research problems and find out the solutions
PLO4	Communication Skills	the capability to communicate effectively about scientific/technical understanding both verbally and in writing
PLO5	Science and Society	the ability to apply logical reasoning to evaluate the different societal problems and suggest scientific measures

PLO6	Life-Long Learning	the ability of self-learning to enhance the personal skills and knowledge throughout life
PLO7	Application of modern tools and techniques	the ability of handling/using different scientific tools and techniques to solve physical problems
PLO8	Moral and ethical awareness	the understanding and practice to refrain from unethical academic behaviour like plagiarism, falsification, misrepresentation, manipulation etc
PLO9	Mutual and multidisciplinary competence	the ability to work in a team as well as working in interdisciplinary fields.
PLO10	Social responsibility	the ability to be a law abiding and responsible citizen

3. Course Structure of Two years M.Sc. Physics Programme

Table 1: Courses Category

Course Category	Course Type	No of courses	Credits per course	Total Credits
Compulsory	Discipline Specific (Theory)	09	04	36
	Discipline Specific (Practical)	04	04	16
	Discipline Specific (Project)	01	04	04
	Value Added Course	02	04/02	06
Elective	Discipline Specific	05	04	20
	Skill Enhancement	04	02	08
Open	Interdisciplinary	02	04	08
Audit	National Service	01	00	00
Total Credits				**98**

SWAYAM (MOOC available on SWAYAM portal)

Students may earn up to 40 percent of the total credits of the programme from MOOCs (Massive Open Online Courses) Courses offered on SWAYAM (Study Webs of Active–Learning for Young Aspiring Minds). The selection of the course(s) from SWAYAM is subject to the availability, no. of credit and the 75 percent similarity of content with the existing courses in the department. The credits and the grade earned by the students in the particular course will be transferred and added in their mark statement. SWAYAM coordinator of the department will display the list of MOOCs before the commencement of the semester. Students will have the option to choose more than one course to fulfil the 4 credit course requirement in the syllabus. They will have to submit their choice of the MOOCs to the coordinator of the department for approval.

‘National Service’ – compulsory audit Course

The “National Service” shall be one compulsory audit Course for all Masters Students of our university. It is exempted only for NSS volunteers who have completed 120 hours of service. The students shall complete the requirements of “National Service” by doing some service in their own villages, towns, etc. for a period of 30 days during the winter vacation between semesters I and II. The report of such service shall be evaluated by the department. If the report is “Not Satisfactory”, they will not be eligible for the degree.

Table 2: Courses and Credit Scheme

Semester	Course Code	Course Title	Lecture Hrs	Tutorial Hrs	Practical Hrs	Credits	IA Maarks	ES Marks	Total Marks
I	PHY-C-501	Classical Mechanics	3	1	0	4	50	50	100
	PHY-C-502	Quantum Mechanics	3	1	0	4	50	50	100
	PHY-C-503	Mathematical Physics	3	1	0	4	50	50	100
	PHY-V-504	Indian Contribution to Physics	3	1	0	4	50	50	100
	PHY-P-505	Practical I	0	0	8	4	50	50	100
	Skill Enhancement Course I (Choose any one from PHY-S-506/507/508)		2	0	0	2	25	25	50
	PHY-S-506	Physics Teaching							
	PHY-S-507	Disaster Management							
	PHY-S-508	ICT in Physics							
Semester I Total						**22**	**275**	**275**	**550**
II	PHY-C-551	Electromagnetic Theory	3	1	0	4	50	50	100
	PHY-C-552	Statistical Physics	3	1	0	4	50	50	100
	PHY-C-553	Electronics	3	1	0	4	50	50	100
	PHY-P-554	Practical II	0	0	8	4	50	50	100
	PHY-V-555	Cyber Security	2	0	0	2	25	25	50
	Open I (Choose any one from PHY-O-556/557/558)		3	1	0	4	50	50	100
	PHY-O-556	Nano & Soft Materials							
	PHY-O-557	Renewable Energies							

Semester	Course Code	Course Title	Lecture Hrs	Tutorial Hrs	Practical Hrs	Credits	IA Maarks	ES Marks	Total Marks
	PHY-O-558	Nonlinear Dynamics & Turbulence							
	Skill Enhancement Course II (Choose any one from PHY-S-559/560/561)		2	0	0	2	25	25	50
	PHY-S-559	Laser Technology & Applications							
	PHY-S-560	Microscopy Techniques							
	PHY-S-561	Plasma Technology							
	Semester II Total					**24**	**300**	**300**	**600**
III	PHY-C-601	Solid State Physics	3	1	0	4	50	50	100
	PHY-C-602	Advanced Quantum Mechanics & Electrodynamics	3	1	0	4	50	50	100
	PHY-P-603	Practical III	0	0	8	4	50	50	100
	Open II (Choose any one from PHY-O-604/605/606/607/608)		3	1	0	4	50	50	100
	PHY-O-604	Biophysical Techniques							
	PHY-O-605	Group Theory & Applications							
	PHY-O-606	Econophysics							
	PHY-O-607	Density Functional Theory							
	PHY-O-608	Computational Techniques							
	Elective I (Choose any one from PHY-E-609/610/611)		3	1	0	4	50	50	100
	PHY-E-609	Introduction to Space Physics and Astrophysics							
	PHY-E-610	Plasma Physics							
	PHY-E-611	Advanced Statistical, Atomic, Molecular & Optical Physics							
	Elective II (Choose any one from PHY-E-612/613/614)		3	1	0	4	50	50	100
	PHY-E-612	Solid state Spectroscopy							

Semester	Course Code	Course Title	Lecture Hrs	Tutorial Hrs	Practical Hrs	Credits	IA Maarks	ES Marks	Total Marks
	PHY-E-613	Quantum Optics & Quantum Information Processing							
	PHY-E-614	Semiconductor Physics and Devices							
	Skill Enhancement Course III (Choose any one from PHY-S-615/616/617)		2	0	0	2	25	25	50
	PHY-S-615	Spectroscopic Techniques							
	PHY-S-616	Medical Physics							
	PHY-S-617	Parallel Computing							
	Semester III Total					**26**	**325**	**325**	**650**
	PHY-C-651	Nuclear & Particle Physics	3	1	0	4	50	50	100
	PHY-P-652	Practical IV	0	0	8	4	50	50	100
	PHY-R-653	Project Work	0	0	8	4	50	50	100
	Elective III (Choose any one from PHY-E-654/655/656)		3	1	0	4	50	50	100
IV	PHY-E-654	Gravitation and Cosmology							
	PHY-E-655	Conformal Field Theory							
	PHY-E-656	Physics in Nanoscale							
	Elective IV (Choose any one from PHY-E-657/658/659/660)		3	1	0	4	50	50	100
	PHY-E-657	Quantum Field Theory							
	PHY-E-658	X-ray Crystallography & Molecular Biophysics							
	PHY-E-659	General Relativity							
	PHY-E-660	Advanced Electronics							
	Elective V (Choose any one from PHY-E-661/662/663/664)		3	1	0	4	50	50	100
	PHY-E-661	Thin Film Technology							
	PHY-E-662	Nonlinear Science: Solitons and Chaos							
	PHY-E-663	High Energy Physics							

Semester	Course Code	Course Title	Lecture Hrs	Tutorial Hrs	Practical Hrs	Credits	IA Maarks	ES Marks	Total Marks
	PHY-E-664	Magnetism and Superconductivity							
	Ability & Skill Enhancement Course IV (Choose any one from PHY-S-665/666/667)		2	0	0	2	25	25	50
	PHY-S-665	Scientific Methods & Writing							
	PHY-S-666	Physics of Defense Application							
	PHY-S-667	Machine Learning & Artificial Intelligence							
	Semester IV Total					**26**	**325**	**325**	**650**
	Aggregate Total					**98**	**1225**	**1225**	**2450**

Notes:

1. For one credit of theory, one hour of lecture/tutorial will be delivered while for one credit of practical; two hours of laboratory work will be conducted, per week.
2. For Open Elective Courses, students can choose the courses offered by the parent department or other departments of the university or from MOOCs available on SWAYAM portal.
3. Experiments in the Practical Courses may be added/removed subject to the requirement and availability of the programme.
4. For a 4-credit theory course, there will be internal evaluation of 50 marks (best two tests out of three tests carrying 25 marks each) and an End term examination of 50 marks.
5. For a 2-credit theory course, there will be internal evaluation of 25 marks and End term examination of 25 marks.
6. The practical courses will be evaluated in continuous mode internally by the course instructor. The internal evaluation will carry 50% of the total marks. The other 50% will be evaluated as End term examination.
7. The project work should be a guided study of an advanced topic not covered in the curriculum. It is expected that the student learns and applies some of the techniques and knowledge taught in the class in this Project Work. The main objective of the Project Work is to provide students with skill and knowledge in conducting research in fundamental and applied aspects of physics/allied fields. Proper acknowledgement and permission of unavoidable earlier published work must be given in the thesis. If any kind of plagiarism is practised by the student, his/her dissertation or project work shall be liable to be rejected.
8. Project Work will be evaluated at the end of the semester by an evaluation committee consisting of four members: Head of the Department, Supervisor, an Internal Examiner and an External Examiner.
9. The relevant Ordinance or rules of PG programme of the university shall be followed by the department.

Core Papers (Semester I)

PHY-C-501: CLASSICAL MECHANICS

Course Learning Outcomes: On completion of the course, the students will be able to

- understand the concepts of generalized coordinates, cyclic coordinates, constraints, D'Alembert's principle and basic formalism of Lagrangian dynamics.
- understand Hamiltonian formalism to solve the dynamics of some mechanical systems.
- understand the Poisson's brackets and Lagrange brackets.
- learn the methods of problem solving related to central force, rigid body dynamics and canonical transformation.
- apply the nonlinear dynamical equations to understand the chaos and fractals.

Course Content:

Unit I: Lagrangian Formulism

Constraints and their classifications, Generalized coordinates, virtual displacement, D'Alembert's principle and Lagrangian equations, Hamilton's principle, Lagrangian equations from Hamilton's principle, symmetry properties and conversation laws, Noether's theorem, Central force problem, Kepler's problem, scattering problem, Virial theorem

Unit II: Hamiltonian Formulism

Generalized momenta, Hamilton's equations of motion, Cyclic coordinates, physical significance of the Hamiltonian function, Hamilton's equations from variational principle, Routh's procedure, Canonical transformations, generating functions (four basic types), examples of canonical transformations, infinitesimal contact transformation, preservation of phase volume under Hamilton flow (Liouville theorem, Poisson brackets, applications to simple problems , equations of motion in the Poisson bracket notation, Hamilton-Jacobi equation, action-angle variable, Solving Kepler's problem by HJ method.

Unit III: Rigid Bodies

Degrees of freedom of a free rigid body, Angular momentum and kinetic energy of a rigid body Moment of inertia tensor, principal moments of inertia, products of inertia, The kinematics of rigid body motion, Euler angles, infinitesimal rotations, the Coriolis force, rigid body equations of motion.

Unit IV: Small Oscillations & Chaos

Theory of small oscillations, normal modes of oscillation and examples

Non-linear equation of motions; phase diagram, simple examples like Duffing and van der Pol oscillators

Basic idea of chaotic solutions; fixed points and attractors; bifurcations; strange attractors; logistic maps, fractal dimensions and Lyapunov exponent.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation
- Use of audio-visual aids to show the 3D motions, Euler angles, Coriolis force, oscillations, phase diagrams, chaos attracters, bifurcations, fractals etc.

Assessment Framework
Out of three internal assessments, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25marks)	Internal Assessment 3 (25marks)	End Semester Examination (50 marks)
Written examination with questions of objective, short and long types.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentatio ns	Written examination of 2 hours with questions of objective, short and long questions.

Suggested Readings:

1. H. Goldstein, C. Poole and J. Safko: *Classical Mechanics*, 3rd Ed, Pearson Education (2002).
2. Rana and Joag: *Classical Mechanics*, Tata Mcgraw Hill, (1991)
3. J. B. Marion: *Classical Mechanics of Particles and Systems*, Academic Press, (1999)
4. A.K. Raychaudhuri: Classical Mechanics: A Course of Lectures, OUP, India 1983
5. MG Calkin, Lagrangian and Hamiltonian Mechanics; World Scientific Publishing Co Pte Ltd (18 March 1999)

PHY-C-502: Quantum Mechanics

Course Learning Outcomes: On completion of the course, the students will be able to
- understand the basic concepts and principles of quantum mechanics and its applications to simple systems like simple harmonic oscillator and hydrogen atom.
- have an understanding of the perturbation theory and other approximation methods.
- understand the interaction of light and matter, selection rules, identical particles
- understand the scattering processes in quantum systems using partial wave methods and Born approximation

Course Content:

Unit I: Exactly Solvable Problems
One dimension: Postulates of Quantum Mechanics. Free particle, position space and momentum space wave function, Heisenberg uncertainty relation, expectation values. Schrodinger equation, equation of continuity. Particle in a box, simple harmonic oscillator (ladder operator and wave functions), Ehrenfest theorem. classical limit.
Three dimension: Rotational Invariance and angular momentum, eigenstates and eigenvalues of angular momentum operators. Separation of variables, spherical harmonics. Particle in central force, free particle in spherical polar coordinate, hydrogen atom.

Unit II: Approximation Methods
Time independent perturbation theory, non-degenerate and degenerate cases, fine structure and Zeeman Effect (without spin), Stark effect, Fine structure, hyperfine structure, Lamb shift.
Approximation methods: WKB approximation, validity of WKB approximation, alpha emission. Variational method, ground state of helium atom.

Unit III: Interaction with radiation and identical particle

Time dependent Perturbation Theory: Heisenberg and Interaction pictures. Two state problem. First order perturbation, constant and periodic perturbation, sudden and adiabatic perturbation. Higher order perturbation. Transition rate, Fermi's Golden rule.

Dipole approximation, photoelectric effect, Absorption and stimulated emission, spontaneous emission, Einstein's A and B coefficient.

Identical Particles and Spins: Indistinguishability, symmetric and anti-symmetric wave functions, Pauli exclusion principle, electron spin functions, the helium atom, Spin angular momentum, Addition of angular momenta, Clebsch-Gordon coefficients, LS and JJ couplings.

Unit IV: Scattering Theory

One dimensional scattering by barrier, reflection and transmission coefficient. Three dimensional scattering, Lippman-Schwinger equation, Born approximation, optical theorem. Higher order Born approximation. Plane wave vs. spherical wave, method of partial wave analysis, scattering by hard sphere, attractive well and repulsive barrier potential. Low energy scattering and bound states, resonances. Coulomb scattering.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation
- Use of audio-visual aids to show three dimensional motions, Euler angles, oscillations, phase diagrams, chaos attracters, bifurcations, fractals etc.

Assessment Framework

Out of three internal assessments, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination with questions of objective, short and long types.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination of 2 hours with questions of objective, short and long questions.

Suggested Readings:

1. E. Merzbacher: *Quantum Mechanics*, 3rd Edition, John Wiley & Sons (2003)
2. J. J. Sakurai: Modern *Quantum Mechanics*, Pearson Education, Reprint(1967)
3. R. Shankar: Principles of Quantum Mechanics, Springer, 2nd edn. (1994).
4. P. T. Mathews and S. Venkatesan: *Textbook on Quantum Mechanics*, McGraw Hill (2002)
5. David J Griffiths, Introduction to Quantum Mechanics, Pearson Education, second edition, 2015
6. L. I. Schiff: *Quantum Mechanics*, 3rd Edition, Mc Graw Hill Intl. Edition (1988)
7. J. M. Ziman: *Elements of Advanced Quantum Theory*, Cambridge University Press.(1975).
8. J. Powell and B. Crasemann: *Quantum Mechanics*, Narosa Publishing House, (1998).
9. R. Eisberg and R. Rensick: *Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles* (2nd Ed), John Wiley & Sons, (2003).
10. A. Ghatak and S. Lokanathan: *Quantum Mechanics (Theory and Application*) (4th Ed), Macmillan (2003).

11. L. D. Landau and L. M. Lifshitz: *Quantum Mechanics*: *Non-relativistic Theory*, Butterworth-Heinemann, 3rd Edn. (1981)..
12. K. Thankappan: *Quantum Mechanics*, New Age Intl. Pub (1996)
13. S. Gasiorowiz: *Quantum Mechanics*, Wiley (1995)
14. P. A. M. Dirac: Principles of Quantum Mechanics, Dover Publications
15. R. P. Feynman,: Feynman lectures on physics - volume III, Pearson

PHY-C-503: MATHEMATICAL PHYSICS

Course Learning Outcomes: On completion of the course, the students will be able to

- develop the mathematical skills necessary to understand problems in advanced physics through theory of complex analysis and applications to special functions, ordinary and partial differential equations, integral transform, Green's function and group theory.
- evaluate integrals involving complex variables arising in different physical problems.
- use linear algebra in quantum mechanics, tensor analysis in electrodynamics, general relativity.
- use integral transform in continuum mechanical systems.
- use group theory in explaining symmetry in condensed matter and particle physics.

Course Content:

Unit I: Complex Analysis
Geometrical representation of complex numbers. Functions of complex variables, differentiation. Properties of analytical functions, Cauchy-Riemann conditions. Contours and contour Integration in complex plane, Cauchy theorem, Cauchy integral Formula. Taylor and Laurent series representation, Features of singular points, poles. Residues, Cauchy residue theorem. Applications of the residue theorem.

Unit II: Linear Algebra
Vector Spaces, linear independence, spanning set and basis, Linear operators, representations of vectors and linear operators with respect to bases and change of basis, Inner Product space, Hermitian operators. Eigen values and eigenvectors and their determination, diagonalization of linear operators and matrices.

Unit III: Integral Transforms & Special Functions
Fourier transforms, Laplace transforms. Fuch's theorem, Frobenius method of series solution.
Bessel's, Legendre's, Hermite's and Laguerre's differential equations and solutions: Generating function, Rodrigue's formula, orthogonality, recurrence relations, Associated Legendre and Laguerre polynomials, Green's function

Unit IV: Group Theory
Definitions and examples of physically important finite groups. Multiplication table, Homomorphism and Isomorphism. Subgroups, Cyclic groups, Center, Classes, Cosets, Factor groups. Representation, reducible and irreducible representations, Character table. Simple applications. Introduction to Lie groups and some examples

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.

- Use of smart board for power point presentation.
- Use of audio-visual aids to show integral transforms, special functions etc.

Assessment Framework

Out of three internal assessments, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination with questions of objective, short and long types.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination of 2 hours duration with questions of objective, short and long questions.

Suggested Readings:

1. H.J. Weber and G. B. Arfken: *Mathematical Methods for Physicists*,Academic Press6th Ed. (2005). ISBN-10: 0120598760 ISBN-13: 978-0120598762
2. Murray R. Spiegel: *Complex Variables*, Mc Graw Hill (1964). ASIN: B000LC6GMS
3. R. V. Churchill: *Complex Variables & Applications*, Mc Graw Hill Inc. 2nd Edn. (1960). ISBN-10: 0070108536 ISBN-13: 978-0070108530 1.
4. Lipschutz-Lipson: Schaum's outline of theory and problems of linear algebra: Tata McGraw Hill
5. S. Sternberg: Group Theory and Physics, Cambridge Univ. Press, (1994).
6. P. Dennery and A. Kryzywicki: *Mathematics for Physicists,* Dover Publications, (1996).
7. K. F. Riley: Mathematical Methods for Physics and Engineering, CUP, New York (2002)
8. *B. D. Gupta: Mathematical Physics, Vikas Pub. House, New Delhi (2004).*
9. C. Harper : Introduction to Mathematical Physics, Prentice Hall Text Books:
10. J Mathews and R L Walker, Mathematical Methods for Physics, Addison-Wesley publishing company Inc. 1973
11. C. Birkhoff and G.C. Rota, Ordinary Differential Equations (4th Ed), John Wiley & Sons, 2003.
12. Forsythe : A Treatise on Differential Equations, CBS(1995)
13. R. L. Rabenstein: Ordinary differential equations, Cambridge University Press, (2004)
14. M. Hamermesh: Group Theory and its Application to Physical Problems, Addison-Wesley Publishing Company, (1962).

PHY-P-505: PRACTICAL I

Course Learning Outcomes: On completion of the course, the students will be able to

- design experimental setups related to measurement of some physical quantities.
- measure data, analyse and interpret.
- check the reliability of the results using error analysis

Course Content:
[Minimum 10 experiments to be performed from the following list]

1. Fibre Optics
2. Fresnel Diffraction
3. Photoconductivity
4. Stefan's Law
5. Dielectric Constant
6. Ultrasonic Diffraction
7. Hall Effect
8. Planck's Constant
9. Michelson Interferometer
10. Susceptibility of Paramagnetic Solution
11. Hydrogen Spectrum and Rydberg Constant
12. Single Slit, Double Slit, Grating and Thin Wire Diffraction
13. Foaming and Foam Stability

Suggested Teaching Learning Strategies

- Theoretical backgrounds and purpose of the experiments should be clearly explained.
- Two students can perform the experiments together.
- Error analysis should be incorporated.

Assessment Framework

Internal Assessment (50 marks)	End Semester Examination (50 marks)
Continuous evaluation through individual viva for each experiments performed, Lab note book reports and overall performance in the lab.	Students will perform one experiment. They will write the working theory and note the readings, interpret it and find the results.

Suggested Readings:

1. Laboratory Manuals available to the department
2. Any other open sources

Core Papers (Semester II)

PHY-C-551: ELECTROMAGNETIC THEORY

Course Learning Outcomes: On completion of the course, the students will be able to

- handle problems based on potentials and electric fields involving various boundary conditions.
- build analogy between electrostatics and magnetostatics.
- have fair knowledge of Maxwell's equations and their importance, conservation laws and gauges used in electrodynamics.
- have sound knowledge of electromagnetic waves in various bounded and unbounded media.
- understand the radiation in antennas and its propagation.

Course Contents:

Unit I: Electrostatics

Equations of electrostatics in differential and integral forms. Potentials and fields due to point charges and continuous charge distributions. Boundary value problems and their solutions by separation of variables, method of images. Multipole expansion: Electric dipole and quadrupole moments. Electrostatics and dielectrics: Polarization and bound charge, displacement field, Poisson's equation in a uniform linear dielectric. Boundary value problems with dielectrics.

Unit II: Magnetostatics

Electric Current as a source of magnetic field, Equations of magnetostatics in differential and integral forms, Vector potential, magnetic dipole, multipole expansion of vector potential Magnetic fields and matter: magnetization and bound currents, Amperes law for free currents and H field, Boundary Conditions, magnetic scalar potential.

Unit III: Time varying fields & Maxwell's equations

Electromotive force, Faraday's Law of induction. Maxwell's equations, displacement current, covariant formulation of Maxwell's equations, Boundary conditions, Electromagnetic field energy, vector and scalar potentials, Wave equations, Gauge transformations, Poynting's theorem, Conservation laws.

Unit IV: Electromagnetic wave propagation and radiation

Properties of the electromagnetic wave equations in different media (vacuum, conductor, plasma and waveguides). Rectangular waveguides and resonant cavities. Reflection and refraction of electromagnetic waves at the interface of non-conducting media. Radiation from a moving point charge, Retarded potentials, oscillating electric and magnetic dipoles. Radiation from antennas, Radiation power and Larmor formula.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation.
- Use of audio-visual aids to show the electric and magnetic field patterns, propagation and radiation of waves etc.

Assessment Framework

Out of three internal assessments, the best two will be chosen.

Internal Assesment1 (25marks)	Internal Assesment2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination with questions of objective, short and long types.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentatio ns.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentatio ns.	Written examination of 2 hours with questions of objective, short and long questions.

Suggested Readings:

1. D. J. Griffiths: *Introduction to Electrodynamics* (3rd Ed.), Pearson Edn., (2002)
2. J. D. Jackson: *Classical Electrodynamics*, Wiley Eastern, (2003)
3. G. L. Pollack, D. Stump and D. R. Stump: Electromagnetism, Addison-Wesley (2001).
4. W. H. Hayt, Jr. J. A. Buck: Engineering Electromagnetics, The McGraw-Hill (2001).
5. M.N.O. Sadiku: *Elements of Electromagnetics*, Oxford University Press (2018).

PHY-C-552: STATISTICAL PHYSICS

Course Learning Outcomes: On completion of the course, the students will be able to

- relate between statistics and physical systems.
- understand the laws of thermodynamics on the basis of collective behaviour of systems.
- understand microcanonical, canonical and grand canonical ensembles and their partition functions to derive the established laws of thermodynamics.
- acquire sound knowledge of M.B., B.E. and F.D. statistics, the behaviour of particles using distribution functions.
- understand the thermodynamic behaviour of quantum systems and phenomena arising in degenerate gases, such as, Bose-Einstein condensation.

Course Content:

Unit I: Thermodynamic laws and functions

Entropy, Free energy, Internal Energy, Enthalpy, Chemical Potential, Systems with large number of degrees of freedom, Micro and macro states, Phase space of a classical system, Density of states, Liouville's Theorem.

Unit II: Basic principles of ensembles

Micro-canonical, Canonical and Grand canonical ensembles, Concept of ensemble average, Equation of state, specific heat and entropy of a classical ideal gas, Gibb's paradox and its resolution, Energy and Density fluctuations, Virial and equipartition theorems, Partition function, General expression for probability, the most probable distribution, Maxwell-Boltzmann distribution, partition function of system of particles, Translational, vibrational and rotational partition functions, Electronic partition function- Boltzmann theorem of equipartition of energy, application to heat capacities of gases and solids

Unit III: Quantum Statistics
Inadequacy of classical theory, Quantum mechanical ensemble theory, density matrix, Ensembles in quantum statistical mechanics, Ensembles of ideal Boltzman, Bose-Einstein and Fermi gases, Identical particles, quantum distribution functions, Bose-Einstein and Fermi-Dirac statistics, Grand partition function for ideal Bose and Fermi gas.

Unit IV: Ideal Bose & Fermi Systems
Thermodynamics of Black body radiation, Stefan-Boltzman law, Wien's Displacement Law, Ideal Bose System: Thermodynamic behaviour of ideal Bose gas, Bose-Einstein condensation
Thermodynamic behaviour of an ideal Fermi Gas, Degenerate Fermi Gas, Fermi Energy and Mean Energy, Fermi Temperature, Fermi Velocity of a particle of a degenerate gas, Compact stars.

Suggested Teaching Learning Strategies
- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation.
- Use of audio-visual aids to show the behaviour of thermodynamic systems, radiation, distribution functions etc.

Assessment Framework
Out of three internal assessments, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination with questions of objective, short and long types.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination of 2 hours with questions of objective, short and long questions.

Suggested Readings:

1. R. K. Patharia: *Statistical Mechanics* (2^{nd} Ed) Butterworth Heinman, Elsevier (2005)
2. K. Huang: *Statistical Mechanics* (2^{nd} Ed) John Wiley & Sons (2002)
3. K. Huang, *Introduction to Statistical Physics*, Taylor & Francis (2001).
4. F. Reif: *Statistical and Thermal Physics*, McGraw Hill (1985).
5. T. Guenault: *Statistical Physics* (2^{nd} Ed), Kluwer Academic (1995).
6. S. Lokanathan and R.S. Gambhir, *Statistical and Thermal Physics*, Prentice Hall, (2000).
7. B. B. Laud: *Fundamentals of Statistical Mechanics*, New Age Intl. Publishers (1998)
8. L. D. Landau and E. M. Lifshitz: *Statistical Physics*, Part I & II, Butterworth and Heinman (1980).

PHY-C-553: ELECTRONICS

Course Learning Outcomes: On completion of the course, the students will be able to
- understand semiconductor devices, their structure, characteristics and applications.
- understand analog and digital circuits and applications.
- understand electronic control systems and their frequency analysis.

Course Contents:

Unit I: Semiconductor Devices:

Energy bands in intrinsic and extrinsic semiconductors, equilibrium carrier concentration, direct and indirect band-gap semiconductors.

Carrier transport: diffusion current, drift current, mobility and resistivity, generation and recombination of carriers, Poisson, and continuity equations. P-N junction, Zener diode, BJT, MOS capacitor, MOSFET, LED, photodiode, and solar cell.

Unit II: Analog Circuits

Diode circuits: clipping, clamping, and rectifiers. BJT and MOSFET amplifiers: biasing, ac coupling, small-signal analysis, frequency response. Current mirrors and differential amplifiers.

Op-amp circuits: Amplifiers, summers, differentiators, integrators, active filters, Schmitt triggers, and oscillators

Unit II: Digital Circuits:

Boolean operations, simplification of Boolean expression, De Morgans theorem, Adder and subtractor, Multiplexer and Demultiplexer, encoder and Decoder. Flip flops: RS, JK, Master slave, D and T. Counters, registers. A/D and D/A converters. Microprocessor and microcontroller basics.

Unit II: Control Systems:

Basic control system components; Feedback principle; Transfer function; Block Diagram representation; Signal flow graph; Transient and steady-state analysis of LTI systems; Frequency response; Routh-Hurwitz and Nyquist stability criteria; Bode and root-locus plots; Lag, lead and lag-lead compensation; State variable model and solution of state equation of LTI systems.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation.
- Use of audio-visual aids to show the different kinds of electronic devices.
- Simulation of electronic circuits using PSPICE software
- Application of numerical techniques using MATLAB, SciLab, FORTRAN etc.

Assessment Framework

Out of three internal assessments, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination with questions of objective, short and long types.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination of 2 hours duration with questions of objective, short and long questions.

Suggested Readings:

1. R. L. Boylestad and L. Nashelsky, *Electronic Devices and Circuit Theory* (10th Edn), Prentice Hall (2008)
2. D. P. Leach, A. P. Malvino and G. Saha, *Digital Principles and Applications* (6^{th} Edn), Tata McGraw Hill (2007)
3. A. S. Sedra and K. C. Smith, *Electronics Circuits*, (6thEdn), Oxford University Press (2009)

PHY-P-554: PRACTICAL II

Course Learning Outcomes: On completion of the course, the students will be able to

- demonstrate the basic concepts of electronics through standard set of experiments in analog and digital circuits; diodes, Logic Gates, multivibrators, oscillators, Op-Amp and uses of CRO (DSO).
- analyse the characteristics of semiconductor devices, flip-flops, counters, converters and microprocessor.

Course Contents:

[Minimum 10 experiments from Electronics Lab to be performed. Another minimum of 5 problems are to be solved in the computational lab.]

Electronics Lab:

There should be few lectures covering the relevant topics for the working of the following listed experiments.

1. Clipping and Clamping Circuits
2. Wien's Bridge Oscillator
3. F.E.T
4. Op-Amp (741)
5. Multivibrators
6. Semiconductor sensor
7. External effects on semiconductor devices (temperature, magnetic field, radiation etc)
8. Multiplexer and Seven Segment Display
9. J-K flip-flop and Up Down Counters
10. Adder/Substractor and Decoders
11. Converters: (A to D) & (D to A)
12. Microprocessor

Suggested Teaching Learning Strategies

- Theoretical backgrounds and purpose of the experiments should be clearly explained.
- Two students can perform the experiments together.
- Error analysis should be incorporated.

Assessment Framework

Internal Assessment (50 marks)	End Semester Examination (50 marks)
Continuous evaluation through individual viva for each experiments performed and lab note books.	Students will perform one experiment. They will write the working theory and note the readings, interpret it and find the results.

Suggested Readings:

1. A. S. Sedra and K. C. Smith, *Electronics Circuits*, (6thEdn), Oxford University Press (2009)
2. R. Gaekwad, *Op-Amps and Linear Integrated Circuits*, (4^{th} Edn) Prentice Hall of India (2002).
3. Millman & Halkias, *Integrated Electronics: Analog & digital circuits systems,* Mc Graw Hill, 1972.
4. D. P. Leach, A. P. Malvino and G. Saha, *Digital Principles and Applications* (6^{th} Edn), Tata McGraw Hill (2007)
5. H. S. Kalsi, *Electronic Instrumentation*, Tata McGraw Hill Education, 2012.

CORE COURSES (SEMESTER III)

PHY-C-601: SOLID STATE PHYSICS

Course Learning Outcomes: On completion of the course, the students will be able to

- learn fundamentals of crystal structures and crystallographic techniques
- learn crystal defects and their effect on material properties, and also the physics of vibration in solids and the thermal properties.
- learn the origin of band structure in solids, band structure calculations and electrical properties.
- learn magnetism in solids, superconductivity and various theories
- understand both theoretical and experimental aspects of current understanding in solid state physics.

Course Contents:

Unit I: Crystal Structure & Crystallography

Fundamental crystal lattice systems, direct and reciprocal lattice, Brillouin zones, Miller indices, Bragg's law, Laue diffraction, diffraction conditions, Ewald spheres, neutron diffraction, electron diffraction. Symmetry groups (point and space) and representation, influence of symmetry on physical properties,

Crystallographic techniques, Laue, powder and rotating crystal methods, modern diffractometer, intensity of diffracted beam, structure factor, selection rules for diffraction, shape of diffraction peaks, crystallite size, Scherrer formula.

Unit II: Crystal Defects & Lattice Vibrations

Defects in crystalline solids, special point defects, dislocation and Burgers vector, stacking fault, twin and grain boundaries, inclusions, voids and F-centers, effects of crystal defects on material properties. Lattice vibrations, phonons, dispersion relations, acoustic and optical vibrational modes, crystal momentum, phonon momentum, phonon scattering processes (normal and Umklapp), anharmonic lattice vibrations, thermal expansion, thermal conductivity, heat capacity and temperature dependence.

Unit III: Band Structure & Electrical Properties

Periodic crystal potential and Bloch theorem, origin of energy band gap, Kronig-Penney model, Brillouin zone schemes, band structure calculation methods (nearly free electron, tight-binding, augmented plane wave, pseudo potential), direct and indirect band gap, and optical properties.

Linear dielectrics, polarization and relaxation, Debye model for dynamic permittivity, dielectric loss, electrical properties (piezoelectric, ferroelectric and pyroelectric), electrons and holes, effective mass, Fermi surface and material properties, De Hass van Alfen effect, theory of cyclotron resonance.

Unit IV: Magnetism & Superconductivity

Temperature dependence of magnetic susceptibilities, Curie-Weiss Law, exchange interaction between spins, Heisenberg and Ising model, magnetic domain, Weiss molecular field theory, Landau theory of magnetic phase transition, excitations in magnetic states (magnons), spin wave in magnetic chain, dispersion relation, spin Hall effect.

Superconductivity, Meissner effect, type I and type II superconductors, high Tc superconductors, London theory, Ginzburg-Landau theory of phase transition and superconductivity, fundamentals of BCS theory, electron-phonon interaction, Cooper instability, flux quantization in superconducting ring, Josephson junction.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation.
- Use of audio-visual aids to show the different kinds of crystal structures, band structures etc

Assessment Framework

Out of three internal assessments, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination with questions of objective, short and long types.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination of 2 hours with questions of objective, short and long questions.

Suggested Readings:

1. *Introduction to Solid State Physics*, Charles Kittel, John Wiley & Sons, Inc. (2005).
2. *Solid State Physics, Introduction to the Theory*, James D. Patterson and Bernard C. Bailey, Springer-Verlag, Berlin (2007).
3. *Solid State Physics*, Neil W. Ashcroft and N. David Mermin, Cengage Learning (2008).
4. *Solid State Physics, Principles and Modern Applications*, John J. Quinn and Kyung-Soo Yi, Springer-Verlag, Berlin (2009).
5. *Structure Determination by X-ray Crystallography, Analysis by X-rays and Neutrons*, Mark Ladd and Rex Palmer, Springer NY (2013).
6. *Magnetism in Condensed Matter*, Stephen Blundell, Oxford University Press (2001).
7. *Superconductivity, Superfluids and Condensates*, James F. Annett, Oxford University Press (2003).

PHY-C-602: Advanced Quantum Mechanics and Electrodynamics

Course Learning Outcomes: On completion of the course, the students will be able to understand

- the basics of relativistic quantum mechanics.
- Lagrangian and Hamiltonian formulations and quantisation of electromagnetic fields
- scattering and diffraction theory for electromagnetic waves.
- motion of the relativistic charged particles in an electromagnetic field.

Course Content:

Unit I: Relativistic Quantum Mechanics

Klein-Gordon equation, probability density and probability current density, solution of free particle Klein-Gordon equation in momentum representation. Dirac equation, solution of free particle. Interpretation of negative probability density and negative energy solutions. Interaction with electromagnetic field. Inadequacy of Relativistic Quantum Mechanics, requirement of Field theory.

Unit II: Quantisation of Fields

Classical field theory, Lagrangian and Hamiltonian formulations. Real and Complex scalar and Dirac fields. Symmetry and conservation, Noethers theorem. Quantisations of scalar field, creation, annihilation and number operators, Fock space, momentum and Hamiltonian operator, time ordering, Green's functions, Feynman propagator. Quantisation of Dirac field, anti commutation, propagators

Unit III: Scattering and Diffraction

Scattering in long wavelengths, Perturbation theory of scattering, Rayleigh's explanation of the Blue Sky, Scattering by gases and liquids, Attenuation in optical Fibers. Spherical wavelet expansion of a vector plane wave, Scattering of electromagnetic waves by a sphere, Scalar Diffraction theory, Vector equivalents of Kirchhoff integral, Vectorial diffraction theory, Diffraction by a circular aperture, Scattering in the short wavelength limit, Optical theorem and related matters

Unit IV: Dynamics of Relativistic Particles and Electromagnetic fields

Relativistic momentum and energy of a particle, Matrix representation of Lorentz transformation, Infinitesimal generators, Thomas precession, Invariance of electric charge, Covariance of electrodynamics, Transformation of electromagnetic fields, Relativistic equation of motion for spin in a slowly varying external fields. Lagrangian and Hamiltonian for a relativistic charge particle, Motion in a uniform static magnetic field, Motion in combined uniform static electric and magnetic fields, Particle drift in nonuniform static magnetic fields, Adiabatic invariance of flux through orbit of particle, Lagrangian for electromagnetic field, Canonical and Symmetric stress tensors, Conservation laws, Solution of the wave equations in covariant form.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation
- Use of audio-visual aids wherever applicable.

Assessment Framework

Out of three internal assessments, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination with questions of objective, short and long types.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination of 2 hours with questions of objective, short and long questions.

Suggested Readings:

1. R. Shankar: Principles of Quantum Mechanics, Springer, 2nd edn. (1994).
2. J. S. Townsend: Modern Approach to Quantum Mechanics, University Science Books, California (2000)
3. J. J. Sakurai: Advanced *Quantum Mechanics*, Pearson Education, Reprint (1967).
4. M. Peskin and D. V. Schroeder: Introduction to Quantum Field Theory (Frontiers in Physics), Westview Press, (1995).
5. J. D. Jackson: *Classical Electrodynamics*, Wiley Eastern, (2003)
6. G. L. Pollack, D. Stump and D. R. Stump: Electromagnetism, Addison-Wesley (2001).
7. James D. Bjorken and Sidney D. Drell, Relativistic Quantum Mechanics, McGraw Hill Education, Edition 1 (2013).
8. James D. Bjorken and Sidney D. Drell, Relativistic Quantum Fields, Dover Publications Inc., (2013).
9. Steven Weinberg, Quantum Theory of Fields, Cambridge University Press, 2008.
10. T-Y Wu and W-Y P. Hwang: *Relativistic Quantum Mechanics and Quantum Field,*World Scientific Publishing Co., (1991).
11. Claude Itzykson & Jean Bernard Zuber: Quantum Field Theory, Dover publications Inc. (2006).
12. Sylvan S. Schweber, An Introduction to Relativistic Quantum Field Theory, Dover Publications Inc. , (2005).
13. Franz Mandl and Graham Shaw, Quantum Field Theory, Wiley-Blackwell; 2nd Revised edition edition (9 April 2010)
14. Lewis H. Ryder, Quantum Field Theory, Cambridge University Press (2008)

PHY-P-603: PRACTICAL III

Credits: 4 **Max. Marks: 100**
Practical: 120 hrs
Course Learning Outcomes: On completion of the course, the students will be able to

- understand the concepts involved in various numerical methods and apply these to solve physical problems computationally.
- construct the algorithm, implement and generate the results in any of their preferred computational language.

Course Content:
This is a practical oriented course where students can learn and implement the basic computational techniques so that they can independently develop the numerical codes to solve the problems. The course instructor will provide the relevant physics problems (at least 5 in each unit) to be solved using the following topics.

Unit I: Introduction to Programming language

Representing numbers in a computer, machine precision, Errors and approximations. Concept of computer language. Fortran 90, Program structure, Data Types, Arithmatic Operators, Intrinsic functions, I/O, Arrays, Control Statements, Formatted I/O, File processing, Subprograms, Subroutines.
Introduction to Matlab/Python, Mathematical functions, Basic plotting, Matrix generation, Array equations and Linear equations, Programming in Matlab/Python, Script files, Function files, Control flow and operators, Saving output to a file

Unit II: Numerical Solutions of Algebraic Equations
Introduction to numerical Techniques, Roots of Equations: Bisection, Newton-Raphson, secant method. System of Nonlinear equations, Newton's method for Nonlinear systems. Applications in Physics problems.
Solution of linear systems: Gauss, Gauss-Jordan elimination, matrix inversion and LU decomposition. Eigenvalues and Eigenvectors. Applications.

Unit III Numerical Differentiation & Integration:
Approximating the derivative, numerical differentiation formulas, Numerical Integration: Quadrature Formula, trapezoidal and Simpson's rule, Gauss-Legendre integration. Applications.
Initial value and boundary value problems, Euler's and Runge-Kutta methods,.

Unit IV Numerical Solution of Differential Equations:
Finite difference method. Solution of elliptic, parabolic and hyperbolic partial differential equations, finite volume method. Introduction to finite element method, Spectral methods

Suggested Teaching Learning Strategies
- Demonstration of computational techniques using smartboard.
- Performing hands on implementation of the algorithms.
- Each week each student will have to complete and demonstrate one programming assignment.

Assessment Framework

Internal Assessment (50 marks)	End Semester Examination (50 marks)
Continuous evaluation through programming assignments and hands on demonstration.	Students will implement the algorithms allotted to them. They will write the algorithm, implement it in any computational language, generate the output and analyse the results.

Suggested Readings:

1. W. H. Press, B. P. Flannery, S. A. Teukolsky, W. T. Vetterling: *Numerical Recipe in Fortran,* Cambridge University Press India Ltd (2000)
2. G. Lindfield and J. Penny: *Numerical Methods: using Matalab*, Academic Press (2012)
3. R. Pratap: *Getting Started with MATLAB 7*, Oxford University Press, 2006.
4. V. Rajaraman: *Computer based Numerical Methods*, Prentice Hall India, 1980,
5. S. Attaway: *MATLAB: A Practical Approach*, Elseiver, 2009.
6. A. Gilat: *MATLAB: an Introduction with applications*, John Wiley Sons, 2004.
7. S. C. Chapra and R. P. Canale, Numerical Methods for Engineers, Tata McGraw Hill (2002).
8. R.J. Schilling and S.L. Harries, Applied Numerical Methods for Engineers using MATLAB and C, Thomson Brooks/Cole, (2006).
9. J. H. Mathews, Numerical Methods for Mathematics, Science, and Engineering, Prentice Hall of India (1998).
10. S. S. M. Wong, Computational Methods in Physics, World Scientific (1992).

CORE COURSE (SEMESTER IV)

PHY-C-651: NUCLEAR & PARTICLE PHYSICS

Course Learning Outcomes: On completion of the course, the students will be able to

- learn nuclear interactions, nuclear models and radio-activity.
- understand the development of particle physics in a qualitative way, symmetry and conservation laws.
- learn about QED and compute decay rates and scattering cross sections.
- learn the basics of chromodynamics, weak interactions and gauge theory.

Course Content:

Unit I: Nuclear Physics

Properties of nuclear forces, deuteron problem, n-p scattering. Nuclear models, liquid drop model, shell model and collective model.

Radioactivity, Alpha, Beta and Gamma decays, Fermi Theory of beta decay, internal conversion, selection rules.

Unit II: Elementary Particles

Elementary particles, quantum numbers, weak, strong and electromagnetic interactions, quarks and leptons, quark model of hadrons, standard model.

Relativistic kinematics; Symmetries and conservation laws; P,C and T discrete symmetries; CP violation.

Unit III: Quantum Electrodynamics

Klein-Gordon equation, Dirac equation, solution of free particle, Interaction with em field. Inadequacy of Relativistic Quantum Mechanics, requirement of Field theory. Feynman diagrams. Cross sections and S-matrices, Feynman rules for QED, elementary processes, renormalization.

Unit IV: Gauge Theory

Chromodynamics, Feynman rules, asymptotic freedom, weak interactions.

Gauge symmetry, local gauge invariance, Yang-Mills theory, Spontaneous symmetry breaking, Higgs mechanism, neutrino oscillations.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation.
- Use of audio-visual aids to show different kinds of nuclear models, Feynman diagrams etc.

Assessment Framework

Out of three internal assessments, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination with questions of objective, short and long types.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination of 2 hours with questions of objective, short and long questions.

Suggested Readings:

1. S N Ghoshal: Nuclear Physics, S. Chand and Co. Ltd. 2010, ISBN-10: 8121904137ISBN-13: 978-8121904131.
2. R. Roy and B.P. Nigam: Nuclear Physics (Theory & Experiment), New Age Intl., (1967).
3. D. J. Griffiths: Introduction to Elementary Particles, John Wiley & Sons (1987).
4. Francis Halzene & Alan D. Martin: Quarks & Leptons: An introductory course in modern particle physics, Wiley, 2008, ISBN-10: 8126516569; ISBN-13: 978-8126516568
5. Ta Pei Cheng & Ling-Fong: Gauge theory of elementary particle physics, Oxford University Press, 1984, ISBN-10: 0198519567, ISBN-13: 978-0198519560
6. Ian J R Aitchison & Anthony J G Hey: Gauge theories in particle physics: A practical introduction, CRC Press, 2013 ISBN-10: 1466513179ISBN-13: 978-1466513174.
7. M. Peskin and D. V. Schroeder: Introduction to Quantum Field Theory (Frontiers in Physics), Westview Press, (1995).
8. S. Krane: Introductory Nuclear Physics, John Wiley, (1988).
9. Emilio. Segre: Nuclei and Particles: An introduction to nuclear and subnuclear physics, Dover, (2013).
10. W. N. Cottingham and D. A. Greenwood: An Introduction to Nuclear Physics. Cambridge University Press, 2nd Edn. (2001).
11. W. Greiner and A. Schafer, Quantum Chromodynamics, Springer-Verlag, (1994).
12. F. J. Yndurain: The Theory of Quarks & Gluon Interactions, Springer-Verlag, (1999).

PHY-P-652: PRACTICAL IV

Course Learning Outcomes: On completion of the course, the students will be able to

- get acquainted to the experiments in physics at advanced level.
- understand the experiments spread over many fields of physics involved complicated designs and exhaustive analysis.

Course Contents:

[Minimum 10 experiments to be performed]

1. Four Probe
2. Electron Spin Resonance (ESR)
3. Automation
4. Knife edge and Polarisation (QW plate, Half wave plate)
5. Ionization potential
6. Specific heat of solids
7. Zeeman Effect
8. Raman effect
9. Emission and absorption
10. Laser Doppler Anemometry
11. Microprocessor
12. Faraday Rotation

Suggested Teaching Learning Strategies

- Theoretical backgrounds and purpose of the experiments should be clearly explained.
- Two students can perform the experiments together.
- Error analysis should be incorporated.

Assessment Framework

Internal Assessment (50 marks)	End Semester Examination (50 marks)
• Continuous evaluation through individual viva for each experiment performed and lab note books. • Solving relevant problems and presenting them for Computational Lab.	Students will perform one experiment. They will write the working theory and note the readings, interpret it and find the results.

Suggested Readings:

1. Lab Manuals available in the department
2. Any other open source materials

PHY-R-653: PROJECT WORK

Course Learning Outcomes: On completion of the course, the students will be able to

- critically examine the background literature relevant to their specific research area.
- have a comprehensive understanding of scientific methods and techniques applicable in their field of the project.
- demonstrate originality in the application of knowledge, together with a practical understanding of how research and enquiry are used to create and interpret knowledge in their field.
- have originality in tackling and solving problems and developed the ability to critically evaluate research techniques and methodologies.
- develop communication skills through oral presentation and writing.

Course Contents:

The project work course should be a guided study of an advanced topic not covered in the curriculum. It is expected that the student learns and applies some of the techniques and knowledge taught in the class through this Project Work. The main objective of the Project Work is to provide students with skill and knowledge in conducting research in fundamental and application aspects of physics/allied fields. Proper acknowledgement and permission of unavoidable earlier published work must be given in the thesis. If any kind of plagiarism is practised by the student, his/her dissertation or project work shall be liable to be rejected.

Suggested Teaching Learning Strategies

The students should regularly meet and discuss with their respective supervisors regarding their doubts and progress of their work.

Assessment Framework

The Project Work will be evaluated at the end of the semester by an evaluation committee consisting of the following four members: Head of the Department, the Supervisor, an Internal Examiner and an External Examiner. Students have to present their work and submit the report to the committee. The presentation and report will have equal weightage of 50 marks each.

Suggested Readings:

As suggested by the respective supervisors.

Open Courses:

PHY-O-556: NANO AND SOFT MATERIALS

Course Learning Outcomes: On completion of the course, the students will be able to understand
- basics of the underlying physics of nanomaterials
- the synthesis methods and techniques of nanomaterials.
- various spectroscopic techniques to characterize the nanomaterials.
- basics of the science of soft materials.

Course Content:

Unit-I Nanomaterials and their properties

Introduction to nanotechnology. Various kinds of Nanostructures-Carbon fullerenes and nanotubes, Metal and metal oxide nanowires, Self-assembly of Nanostructures, Core-shell nanostructures, Nanocomposites. Thermodynamics of Nanomaterials. Physical Properties of nanomaterials - Photocatalytic, Dielectric, Magnetic, Optical, Mechanical.

Unit-II Synthesis of Nanomaterials

Bottom up and top down approaches. Synthetic methodologies including Sol-gel, Micromulsion, CVD, PVD, Molecular beam epitaxy, Vapor (solution)-liquid-solid growth, (VLS or SLS), Spray Pyrolysis, Template based synthesis, Lithography, Laser ablation.

Unit-III Characterization Techniques and Applications

Absorption and PL spectroscopy, Electron Microscopic techniques, X-ray and electron diffraction, AFM, Auger Electron Spectroscopy, X-ray Photoelectron Spectroscopy. Applications of Nanomaterials.

Unit IV: Soft Materials

Introduction to Soft Condensed Materials and their properties: Plastic and Liquid Crystals, Thermotropic (Nematic, Smectic and Discotic) and Lyotropic Liquid Crystals; Surfactants and Polymers; Colloids: Foams, Gels and Microemulsions; Biomaterials; Applications of Soft Materials

Suggested Teaching Learning Strategies
- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation.
- Use of audio-visual aids.

Assessment Framework

Out of three internal assessments, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination with questions of objective, short and long types.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination of 2 hours with questions of objective, short and long questions.

Suggested Readings:

1. Guozhong Cao, Nanostructures and Nanomaterials: Synthesis, Properties and Applications, Imperial College Press 2004.
2. T. Pradeep, Nano: The Essentials Understanding nanoscience and nanotechnology, Tata McGraw- Hill Publishing Company Limited New Delhi, 2007.
3. Nanomaterials Synthesis, Properties and Applications Edited by A S Edelstein and R C Cammarata, IOP Publishing Ltd 1996.
4. Principles of Condensed Matter Physics, Chaikin and Lubensky, Cambridge University Press 1995.
5. The Physics of Liquid Crystals, P-G de Gennes, J Prost, Oxford University Press, 1994.

PHY-O-557: Renewable Energy

Course Learning Outcomes: On completion of the course, the students will be able to

- Learn different aspects of harnessing solar power.
- Learn various physical processes involved in solar power conversion.
- Learn different types of solar cell designs.
- Learn about production of hydrogen, energy conversion, safety and storage.

Course Contents:

Unit I: Harnessing Solar Energy: Various renewable energies, Origin of Solar energy, Modes of solar radiation reaching Earth, Solar spectrum AM0, AM1.5, Albedo values, Extraterrestrial and terrestrial solar irradiance, Diurnal and seasonal variations of solar irradiance, Solar zenith angle, Solar irradiance calculations, Solar concentrators, Solar tracking system, Solar farm and large-scale power production.

Unit II: Physics of solar cell: Evolution of solar cells, Absorption of photons, Density of states, Direct and indirect semiconductors, absorption coefficients, Urbach tail, Generation rate of electron-hole pairs, Radiative and non-radiative recombination of electrons and holes, Migration of electrons and hole, Separation of electrons and holes, I-V characteristics of pn junction solar cell, Fill factor, Solar cell efficiency, Schockley-Queisser limit.

Unit III: Solar cell design: Construction and working principle of a pn junction solar cell, Factors affecting solar performance and efficiency improvement, Solar cell materials and design, Multi-junction solar cell, Thin film solar cell, Organic and polymer solar cells, Status and challenges in the solar cell research.

Unit IV: Hydrogen energy, storage and safety: Hydrogen as world's future energy, Hydrogen production methods, Thermal, Biological and thermochemical, Electrolytic and Photolytic method, Fujishima-Honda experiment, Solar to hydrogen conversion efficiency, Recent development on photocatalytic hydrogen production, Hydrogen storage, Gaseous, Liquid and Solid hydrogen, Rechargeable hydrides, Nanomaterials for hydrogen storage, Transportation, Onboard applications, Hydrogen safety concerns.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation.
- Use of audio-visual aids.

Assessment Framework

Out of three internal assessments, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination with questions of objective, short and long types.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination of 2 hours with objective, short and long questions.

Suggested Readings:

1. Zekai Sen, Solar Energy Fundamentals and Modeling Techniques, Springer-Verlag, London (2008).
2. Solar Energy Perspective, International Energy Agency, France (2011).
3. Peter Wurfel, Physics of Solar Cells, Wiley-VCH, Weinheim, Germany (2005).
4. J. Bisquert, The Physics of Solar Cells, Taylor & Francis Group, Boca Raton, USA (2018).
5. A. Luque and S. Hegedus, Handbook of Photovoltaic Science and Engineering, John Wiley & Sons Ltd., England (2003).
6. Rabindra K. Satpathy and Venkateswarlu Pamuru, Solar PV Power: Design, Manufacturing and Applications from Sand to Systems, Academic Press Inc. Elsevier (2020).
7. Hydrogen Production and Storage, International Energy Agency, France (2006).
8. G. Zini and P. Tartarini, Solar Hydrogen Energy Systems, Springer-Verlag, Italy (2012).
9. E. B. Agyekum, C. Nutakor, A. M. Agwa, and S. Kamel, A Critical Review of Renewable Hydrogen Production Methods: Factors Affecting Their Scale-UP and Its Role in Future Energy Generation, Membranes (Basel), 12, 173 (2022).

PHY-O-558: Nonlinear Dynamics and Turbulence

Course Learning Outcomes: On completion of the course, the students will be able to

- learn stability analysis and bifurcation diagram of different nonlinear maps in both one and two dimensions.
- demonstrate different types of nonlinear attractors using basic computational schemes.
- understand the theory of turbulence phenomena at different length and time scales occurring in nature.
- know about numerical schemes for simulating turbulence phenomena at fluid as well as kinetic scales.

Unit I: Nonlinear Dynamics

Fixed point, Stability, Linear stability analysis, Existence and Uniqueness; Saddle-Node and Pitchfork bifurcation; Flows on the circle, Uniform and Non-uniform oscillators; Linear systems; Phase plane, Existence, Uniqueness and Topological consequences; Limit cycles, Poincare-Bendixson theorem; Bifurcation in two dimensional flows, Hopf bifurcation, Quasi-periodicity and Poincare maps.

Unit II: Chaos

Revision of chaos, Lorenz equations, Chaos on a strange attractor, Lorenz map; One-dimensional maps, Logistic map, Liapunov exponent, implementation using numerical techniques, Universality;

Fractals, Cantor set, Box dimension, Pointwise and Correlation dimension; Strange attractors, Henon map, Rossler system, Forced double well oscillators, Chaos control using mechanical and electrical systems, chaos-synchronization-based secure communications.

Unit III: Turbulence
Hydrodynamic Turbulence: Symmetries and conservation laws; Probabilistic description of turbulence; Survey of probabilistic tools; Experimental laws of fully developed turbulence; Kolmogorov's theory of 1941; Turbulence phenomenology; Intermittency, Hydromagnetic Turbulence: Flux freezing; Motions of lines of forces in a vacuum; Validity of hydromagnetic equations; Goldreich - Sridhar theory; Cowling's theorem; Mean-field dynamo models; Biermann battery; Fluctuation dynamo.

Unit IV: Algorithms for turbulence simulations
Particle-in-Cell Method: Revision of numerical integration; Working knowledge of numerical interpolation; Cloud-in-Cell algorithm; Electromagnetic PIC algorithms,
Algorithms for Continuum Vlasov simulation: Piecewise Parabolic Method, Galerkin Methods, Vlasov Maxwell systems.

Suggested Teaching Learning Strategies
- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation.
- Use of audio-visual aids.

Assessment Framework
Out of three internal assessments, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination with questions of objective, short and long types.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination of 2 hours with objective, short and long questions.

Suggested Readings:

1. Steven H Strogatz, Nonlinear Dynamics and Chaos (2014)
2. Uriel Frisch, Turbulence: The Legacy of A N Kolmogorov, Cambridge University Press. ISBN: 9780521451031
3. Russel Kulsrud, Plasma Physics for Astrophysics, Princeton Series in Astrophysics (2004)
4. Ronald C. Davidson, Methods in Nonlinear Plasma Theory, Academic Press (1972)
5. C K Birdsall, Plasma Physics via Computer Simulation
6. Arber and Vann, A Critical Comparison of Eulerian-Grid-Based Vlasov Solvers, Journal of Computational Physics 180, 339–357 (2002)

PHY-O-604: BIOPHYSICAL TECHNIQUES

Course Learning Outcomes: On completion of the course, the students will be able to understand

- the interaction of light with matter and use of light scattering to understand the properties of different systems.
- the techniques of separating different biochemical compounds and identifying them.
- optical spectroscopy techniques of Infra-red and Raman Spectroscopy to identify different compounds and study them. The rotation and vibration modes of compounds and the ways of studying the modes.
- electronic transitions in electronic states in molecules by UV-visible spectroscopy and other spectroscopy techniques to study different complicated biochemical compounds.

Course Contents

Unit I: Light scattering and Electron Microscopy:

Elastic and inelastic scattering, light scattering by macromolecules, dynamic light scattering, radius of gyration and molecular mass. Transmission and scanning microscopy, negative staining, cryo-electron microscopy.

Unit II: Chromatography and Mass spectrometry:

Electrospray MS, MALDI, applications. Paper Chromatography, TLC, column, gas-liquid, ion-exchange, size-exclusion and affinity chromatographies, HPLC and FPLC, applications to macromolecules.

Unit: III: IR and Raman spectroscopy

Rotational and vibrational spectra, oscillator, molecular symmetry, optical density, investigations of molecular structure, hydrogen bonding. Examples and comparison of IR and Raman spectra, resonance Raman spectroscopy

Unit IV: Absorption, Fluorescence and NMR Spectroscopy

UV and Visible spectra, chromophores, Circular Dichroism and Optical Rotatory Dispersion, cotton effect, applications to proteins and nucleic acids, Frank-condon principle, classical picture, resonance condition, Bloch condition, relaxation phenomenon, Fourier transform technique. NMR, chemical shifts, coupling constraints, Karplus equation, analysis of simple NMR spectra, Nuclear Overhauser Effect, proton magnetic resonance, 13C and 31P spectra.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation.
- Use of audio-visual aids.

Assessment Framework

Out of three internal assessments, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination with questions of objective, short and long types.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentatio ns.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentatio ns.	Written examination of 2 hours with objective, short and long questions.

Suggested Readings:

1. C N Banwell and E M McCash, Fundamentals of Molecular Spectroscopy, 4th Edition, McGraw Hill India.
2. K. Wilson and K. H. Gouldberg: *Principles and Techniques of Bochemistry*, Edward Arnold (Publishers) Ltd, London, UK, (1986).
3. K. E. van Holde: *Physical Biochemistry,* Prentice-Hall Inc., New Jersey, USA, (1971)
4. D. Freifelder: *Physical Biochemistry*, W.H.Freeman and Company, New York, USA, (1982).
5. C. R. Cantor and P. Schimmel: *Biophysicsal Chemistry*, Vol 1, W. H. Freeman and Company, NewYork, USA. (1985).
6. L. Stryer: *Biochemistry*. W.H.Freeman and Company, NewYork, USA, (1995).

PHY-O-605: Group Theory and Applications

Course Learning Outcomes: On completion of the course, the students will be able to

- introduce and study the basic definition(s) and a few simple examples to make it familiar.
- develop representations of finite groups and its applications to the physics problems.
- introduce Lie groups and Lie algebras along with classifications and rich underlying structures.
- apply group theory in diverse topics of physics. They should also be able to demonstrate the effectiveness of group theory to have a clear understanding of physics.

Course Content:

Unit 1: Basics: Introduction:
Definition of a Group, Subgroups, Conjugacy Classes, Examples of Groups; Homomorphism of Groups, Symmetric Group, Direct and Semi-direct Products; Examples: Symmetry Group of a Molecule, Symmetry Point Groups

Unit 2: Representations of Finite Groups:
Vector Spaces, Group Action on Vector Spaces, Reducible and Irreducible Representations, Irreducible Representations of Point Groups, Regular Representation, Tensor Product of Representations, Decomposition of Reducible Representations, Irreducible Representations of Direct Products, Induced Representations.
Elementary Applications, General Considerations, Level Splitting under Perturbation, Selection Rules, Molecular Vibrations

Unit 3: Lie Groups and Lie Algebras:
U(1) group, Generators of the Lie group, Finite Dimensional Lie Algebra, SU(2) algebra; Semi-simple Lie Algebras, Lie Algebra of a Lie Group, Examples of Lie Groups; Compact Simple Lie Algebras, SU(3) algebra, Cartan matrix, Fundamental weights

Unit 4: Applications:
Continuous Symmetry and Constant of Motion, Translational symmetry in three-dimensional space, Tensor Product Rule for SU(2), Young tableau, SU(2) Clebsch–Gordan matrix , Wigner–Eckart theorem , Elementary Particles in Nuclear and Particle Physics, Isospin symmetry, Quark Model, Antiparticles, Symmetry breaking from SU(3) SU(2).
Non-compact Groups, Lorentz group, Poincare group, Conformal group; Dynamical Symmetry in Hydrogen atom.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation.
- Use of audio-visual aids.

Assessment Framework

Out of three internal assessments, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination with questions of objective, short and long types.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination of 2 hours with objective, short and long questions.

Suggested Readings:

1. Georgi, Howard. 1999. Lie Algebras in Particle Physics: From Isospin to Unified Theories (Frontiers in Physics). Boulder, Colorado: Westview Press.
2. Hamermesh, M. 1962. Group Theory and Its Applications to Physical Problems. Reading, MA: Addison-Wesley.
3. Joshi, A. W. 1973. Elements of Group Theory for Physicists. Delhi: New Age International (P) Ltd. Pub.
4. Ma, Zhong-Qi, and Xiao-Yan Gu. 2004. Problems and Solutions in Group Theory for Physicists. Singapore: World Scientific Publishing.
5. O'Raifeartaigh, Lochlainn. 1986. Group Structures of Gauge Theories. N. York: Cambridge University Press.
6. Ramond, Pierre. 2010. Group Theory: A Physicist's Survey. N. York: Cambridge University Press.
7. Schiff, L. I. 1955. Quantum Mechanics. N. York: McGraw-Hill International Editions. (See Chapter 7: Symmetry in Quantum Mechanics.)
8. Tung, Wu-Ki. 1985. Group Theory in Physics. Singapore: World Scientific Publishing.
9. Zee, A. 2106. Group Theory in a Nutshell for Physicists. Princeton: Princeton University Press.
10. Landau, L. D., and E. M. Lifshitz. 1965. Quantum Mechanics: Non-Relativistic Theory. Oxford: Pergamon Press. (See Chapter 13: Polyatomic Molecules, where molecular vibrations are discussed.)
11. Serre, Jean-Pierre. 1977. Linear Representations of Finite Groups. N. York: Springer-Verlag.
12. Sury, B. 2004. Group Theory: Selected Problems. Hyderabad: Universities Press.

PHY-O-606: Econophysics

Course Learning Outcomes: On completion of the course, the students will be able to

- understand the characteristics of financial markets and data
- understand the scaling concepts used in probability theories and apply it to financial time series to gain new insights into the behavior of financial markets
- apply the stochastic model that displays several of the statistical properties observed in empirical financial data
- understand some market pricing models

Course Contents:

Unit 1 Introduction

A brief Introduction to Economics and Financial Markets, Characteristics of financial data, Efficient market hypothesis, Random walk, Central limit theorem, Speed of convergence

Unit 2 Probability Theory and Time correlations

Probability Theory: moments, cumulants, multidimensional distributions, modular, shape-stable distributions, Hierarchical characterization of correlations, portfolio Theory , non-linear and non-stationary modelling of time series , scaling behaviour and fat-tailed distributions

Unit 3: Stochastic Processes

Stochastics in physical context, Brownian motion, Random walk

Stochastic models in price dynamics, Stochastic calculus, Markov chains, Ornstein-Uhlenbeck process

Unit 4: Market Models

Market pricing models for options and other derivatives, Black-Scholes theory, Risk-neutral valuation, Martingale measures, Binomial Model, Levy financial models, Limitations of the models, Financial Models and turbulence

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation.
- Use of audio-visual aids.

Assessment Framework

Out of three internal assessments, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination with questions of objective, short and long types.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination of 2 hours with objective, short and long questions.

Suggested Readings:

1. An Introduction to Econophysics: Correlations and Complexity in Finance, R.N. Mantegna and H.E. Stanley (Cambridge University Press, 1999)
2. The Statistical Mechanics of Financial Markets, J. Voit (Springer, 2005)
3. The Mathematics of Financial Derivatives: A Student Introduction, P. Wilmott, S.Howison and J. Dewynne (Cambridge University Press, 1997)
4. Theory of Financial Risk and Derivative Pricing: From Statistical Physics to Risk Management, J.P. Bouchaud and M. Potters (Cambridge University Press, 2009)
5. A Guided Walk Down Wall Street: an Introduction to Econophysics, G. L. Vasconcelos: arXiv:cond-mat/0408143

PHY-O-607: Density Functional Theory

Course Learning Outcomes: On completion of the course, the students will be able to learn

- wavefunction-based ab initio methods for multi-electron systems.
- electron density-based ab initio methods for multi-electron systems.
- Kohn-Sham formulation of density functional theory.
- various exchange-correlation functionals and handling of available computational packages.

Course Contents:

Unit I: Wavefunction-based ab initio Methods:

Born-Oppenheimer approximation, Orbitals and Basis sets (STOs, GTOs), Hartree product, Antisymmetric nature of many-electron wavefunction, Slater determinants, Hartree-Fock (HF) approximation, Coulomb and Exchange integrals, Derivation of HF equations, Koopmans' theorem, Self-consistent procedure in HF theory.

Unit II: Density-based ab initio Methods:

Electron density vs many-electron wavefunction, Electron correlation, Thomas-Fermi energy functional, Dirac exchange correction, Gradient expansion, Limitations.

Unit III: Khoh-Sham Density Functional Theory:

Hohenberg-Kohn (HK) theorems, HK functional, Levy constrained search formulation, *V*- and *N*-representable densities, Kohn-Sham (KS) formulation of DFT, KS equations, KS orbital energies, Janak's theorem.

Unit IV:

Basic XC Functionals and Computation:

Local density approximation, Generalized gradient approximation, Hybrid XC functionals (B3PW91, B3LYP), Dispersion corrected functionals, Introduction to computational packages (GAUSSIAN/NWChem/VASP), Simple calculations.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation.
- Use of audio-visual aids.

Assessment Framework

Out of three internal assessments, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination with questions of objective, short and long types.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination of 2 hours with objective, short and long questions.

Suggested Readings:

1. Modern Quantum Chemistry, Introduction to Advanced Electronic Structure Theory, Attila Szabo and Neil S. Ostlund, Dover Publications, Inc. NY (1989).
2. Density-Functional Theory of Atoms and Molecules, R. G. Parr, and W. Yang, OUP, Oxford, (1989).
3. Density Functional Theory, An Approach to the Quantum Many-Body Problem, Reiner M. Driezler and Eberhard K. U. Gross, Springer (1990).
4. Density Functional Theory: A Practical Introduction, D. S. Sholl and J. A. Steckel, John Wiley & Sons, New Jersey, USA (2009).
5. Perspective: Fifty Years of Density-Functional Theory in Chemical Physics, Axel D. Becke, J. Chem. Phys. 140, 18A310 (2014).
6. Density Functional Theory: Its Origins, Rise to Prominence and Future, R. O. Jones, Rev. Mod. Phys. 87, 897 (2015).

PHY-O-608: Computational Techniques

Course Learning Outcomes:: The student will get familiarised with Linux operating system, basic data-visualisation softwares, and will learn how to simulate some simple statistical ensembles in computer, for example, Ising models, spatio-temporal dynamics of molecules and fluid systems. At the end of the course, the student will

- learn to use command-line interface to write codes in open-source platforms.
- develop their own scripts for verifying statistics of different ensembles using Monte-Carlo method.
- benchmark phase-transition phenomena using Molecular dynamics algorithms for structureless particles.
- be able to compare growth rates of fluid instabilities using different spatiotemporal discretisation techniques.

Course Contents:

Unit I: Introduction to computer simulation

Setting up Linux environment, compilers, editors etc; Basic Linux commands; Working knowledge of shell-scripting; Revision of some numerical methods and algorithms; Simple user-graphics interface, examples of simulation.

Unit II: Simulation of Statistical Ensembles

Basic idea of random sampling; Importance sampling; Principle of detailed-balance; Metropolis algorithm; Algorithms for grid generation; Solving 2D Ising model; Monte-Carlo algorithm for statistical physics.

Unit III: Algorithms for Ordinary Differential Equations

Introduction to ODE solvers; Error analysis; Comparison between ODE solvers; Symplectic algorithms; Boundary conditions; Minimum image convention and Ewald sum; Thermostats and Barostats; Integrated quantities for statistical analysis.

Unit IV: Numerical Solution of Partial Differential Equations

Solving some partial differential equations; Finite Difference algorithm; Finite Element algorithm; Finite Volume algorithm; Spectral algorithms; Flux limiters; Pseudo-Spectral method; Boundary effects; Comparison of accuracy.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation.
- Use of audio-visual aids.

Assessment Framework

Out of three internal assessments, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination with questions of objective, short and long types.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination of 2 hours with objective, short and long questions.

Suggested Readings:

1. Fundamentals of Engineering Numerical Analysis, by Parviz Moin; Cambridge Univ Press (2010)
2. A Guide to Monte Carlo Simulations in Statistical Physics, by David P Landau and Kurt Binder; Cambridge (2009)
3. The Art of Molecular Dynamics Simulation, by D C Rapaport; Cambridge University Press (2011)
4. Implementing Spectral Methods for Partial Differential Equations: Algorithms for Scientists and Engineers, by David A Kopriva; Springer (2009)

ELECTIVE COURSES:

PHY-E-609: Introduction to Space Physics and Astrophysics

Course Learning Outcomes: On completion of the course, the students will be able to

- understand the basics of the Solar structure, atmosphere and other physical processes happening there.
- understand the magnetohydrodynamic waves excited in space plasmas and heating of the particles.
- understand the basics of telescopes and classification of stars based on magnitude and spectra.
- understand the stellar structure and their evolution.

Course Content

Unit I: Sun and Solar Wind

Structure of the Sun, EM radiations from the Sun, Standard Solar Model, Solar neutrinos, Solar atmosphere, solar corona, solar cycles, sunspots, solar energetic particles, solar wind, solar flares, coronal mass ejections

Unit II: Solar Plasma

Magnetohydrodynamic waves: Alfven waves, magneto-sonic waves, Frozen in field, Energetic particles in the heliosphere, Planetary bow shocks, interaction with magnetized planets, plasma sources in magnetosphere, plasma acceleration, Jovian magnetosphere, plasma flow in magnetosphere, formation of aurora

Unit III: Stellar observations

Celestial coordinate systems, Telescope: Operational principle, different types and mounting. Introduction to large telescopes.

Observational characteristics: Magnitude, mass, luminosity, astrometry, photometry, spectrometry and polarimetry. Various astronomical instruments and detectors.

Stellar Spectra and classifications, Herzsprung-Russel (H-R) diagram.

Unit IV: Stellar structure and evolution

Hydrostatic equilibrium, Stellar structure equations. Energy production in stars: Nuclear reactions, reaction rates, p-p chain and carbon-nitrogen-oxygen (CNO) cycle, Triple alpha process, Stellar atmosphere and Saha equation. Gravitational collapse, degeneracy pressure in stars – structure of white dwarf and neutron star.

Main sequence, pre- and post-main sequence stars. Red giants. Supernova, Black holes and types.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation
- Use of audio-visual aids wherever applicable.

Assessment Framework

Out of three internal assessments, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination with questions of objective, short and long types.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentatio ns.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentatio ns.	Written examination of 2 hours with objective, short and long questions.

Suggested Readings:

1. May-Britt Kallenrode: *Space Physics: An Introduction to plasmas and Particles in the Heliosphere and Magnetospheres* 3rd Ed. Springer, 2004.
2. Tamas I. Gombosi: *Physics of the Space Environment*, Cambridge University Press, 1998.
3. Thomas E. Cravens: Physics of Solar System Plasmas, Cambridge University Press, 2004.
4. Badyanath Basu: *An introduction to Astrophysics,* Prentice Hall of India, (2003).
5. K. D. Abhayankar: *The Physics of Stars and Galaxies*
6. H. L. Duorah and Kalpana Duorah.: *Introduction to Astrophysics*
7. Bradley W. Ostlie and Dale A. Carrol: *An introduction to Modern Astrophysics*, Addision-Wesley, (1996).
8. R. Kippenhahn and A.Weigert: *Stellar structure and evolution (Astronomy and Astrophysics Library),* Springer, (1994).
9. Margaret G. Kivelson Christopher T. Russell: *Introduction to Space Physics*, Cambridge University Press, 1996.
10. 4. George K. Parks: Physics of Space Plasmas: An Introduction, 2nd Ed., Westview Press, 2004.

PHY-E-610: PLASMA PHYSICS

Course Learning Outcomes: On completion of the course, the students will be able to

- learn basics of plasma physics and will understand the motion of charged particles in various electric and magnetic field conditions.
- learn the various theoretical models to study plasma dynamics and its behaviour.
- understand the concept of plasma instabilities and analyse on the basis of dispersion relation.
- understand the physics on nonlinear plasma physics and its applications in astrophysical processes.

Course Content:

Unit I: Introduction

Plasma State: Ionized gas, Saha ionization equation, Collective degrees of freedom, Definition of Plasma, Concept of Plasma temperature, Debye shielding, Quasi-neutrality, Plasma parameters, Plasma approximation, Natural existence of Plasma.

Single-particle motion: Dynamics of charged particles in electro-magnetic fields, Particle drifts, EXB drifts, Grad-B drift, Curvature drift, Polarization drift, Adiabatic invariants and their technological applications.

Unit II: Models to study Plasma
Kinetic theory of Plasma: Vlasov equations, Solution of linearized Vlasov equation, Langmuir waves, Ion sound waves, Wave-particle interaction and Landau damping.
Fluid theory of Plasma: Plasma oscillations, Electron-acoustic waves, Ion-acoustic waves, Electrostatic ion waves perpendicular to magnetic field, Electromagnetic waves perpendicular to magnetic field.

Unit III: Plasma Instabilities:
Equilibrium and stability: Plasma instabilities and classification, Two-stream and gravitational instabilities.
Nonlinear Debye shielding, Evacuation of the Debye sphere, Basics of exotic plasma effects: Plasma as exotic medium, Shielding in three spatial dimensions.

Unit III: Nonlinear Plasma Physics:
Weakly nonlinear processes: Concept of nonlinearity and dispersion, Weakly nonlinear and weakly dispersive waves, Wave energy alteration with dispersion and dissipation mechanisms, Shock & soliton formation, Nonlinear wave equations and asymptotic integrations. Strongly nonlinear processes: Excitation of strongly nonlinear and strongly dispersive waves, Energy integral methods, Non-linear coherent structures in complex plasmas, Astrophysical-cosmic-space applications.

Suggested Teaching Learning Strategies
- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation
- Use of audio-visual aids wherever applicable.

Assessment Framework
Out of three internal assessments, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination with questions of objective, short and long types.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentatio ns.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentatio ns.	Written examination of 2 hours with objective, short and long questions.

Suggested Readings:

1. Francis F Chen: *Introduction to plasma physics and controlled Fusion*, vol. I: plasma physics, 2nd edition, Springer, 1984.
2. Robert J Goldston and Paul H Rutherford: *Introduction to Plasma Physics*, Institute of Physics, London, 1995.
3. U. S. Unan and U Golkowsky: *Principles of Plasma Physics for Engineers and Scientist*, Cambridge University Press, 2011.
4. Nocholas A Krall and Alvin W Trivelpiece: *Principles of plasma physics*, San Francisco Press, 1986.
5. Donald E. Gurnett and A. Battacharjee: *Introduction to Plasma Physics: With Space and Laboratory Applications,* Cambridge University Press, 2005.
6. M. Kono and M. M. Skoric: *Nonlinear Physics of Plasmas*, Springer-Verlag, 2010.

7. Alexander Piel: *Introduction to Plasma Physics: An Introduction to Laboratory, Space and Fusion Plasmas,* Springer-Verlac, 2010.
8. Richard Dendy: *Plasma Physics: An Introductory Course*, Cambridge University Press, 1996.
9. Richard H Huddlestone and Stanly Leonard: *Plasma Diagnostic Techniques*, Academic Press Inc., 1965.
10. R. J. Shul, S. J. Pearton, *Handbook of Advanced Plasma Processing Techniques*, Springer-Verlac, 2000.
11. I. H. Hutchinson: *Principles of Plasma diagnostics*, Cambridge University Press, 2002.
12. Francis F Chen and Jane P Chang: *Lecture Notes on Principles of Plasma Processing,* Kluwer Academic/Plenum Publishers, 2003.

PHY-E-611 : ADVANCED STATISTICAL , ATOMIC, MOLECULAR & OPTICAL PHYSICS

Course Learning Outcomes: On completion of the course, the students will be able to

- learn the principles of many body interacting systems.
- learn the thermodynamics of fluctuations and its analysis.
- learn the response of atoms to electromagnetic field.
- learn about the advanced experiments in the field of laser-matter interaction.

Course Content:

Unit I: Statistical Mechanics of Interacting System

Imperfect gases at low temperature: Method of pseudopotential: two body problem, N-body problem, imperfect Bose gas, Fermi gas. Cluster expansion: classical gas, quantum mechanical system; Virial coefficients.

Phase transitions: Formulation of the problem; Theory of Yang and Lee; Lattice gas, binary alloy, Ising model in one and two dimensions, liquid Helium.

Unit II: Fluctuations

Thermodynamic fluctuations, spatial correlations in fluid; Brownianmotion, Einstein-Smoluchowski theory, Langevin theory; Fokker-Planck equation, Spectral analysis, fluctuation-dissipation theorem, Onsagar relations.

Unit III: Interaction of Atoms with Radiation

Perturbation by an oscillating electric field, The rotating-wave approximation, Interaction with monochromatic radiation, The concepts of π-pulses and $\pi/2$-pulses, The Bloch vector and Bloch sphere, Ramsey fringes, Radiative damping, The damping of a classical dipole, The optical Bloch equations, The optical absorption cross-section, Cross-section for pure radiative broadening, The saturation intensity, Power broadening, The a.c. Stark effect or light shift. Doppler free spectroscopy.

Unit IV: Non-linear Optical Susceptibility

Introduction, Schrödinger calculation of non-linear optical susceptibility, Perturbation solution of the Density matrix equation of motion, density matrix calculation of the Linear and second order susceptibility, Electromagnetic Induced transparency, Intensity dependent refractive Index. Experimental evidences: Optical Cooling and Trapping of Atoms, Magnetic trapping of neutral atoms, quantum information processing of the trapped ions.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation
- Use of audio-visual aids wherever applicable.

Assessment Framework

Out of three internal assessments, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination with questions of objective, short and long types.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination of 2 hours with objective, short and long questions.

Suggested Readings:

1. R. K. Patharia: *Statistical Mechanics* (2^{nd} Ed) Butterworth Heinman, Elsevier (2005)
2. K. Huang: *Statistical Mechanics* (2^{nd} Ed) John Wiley & Sons (2002)
3. B. H. Bransden and C. J. Joachain, Physics of Atoms and Molecules, Longman,1996.
4. C. N. Banwell and E. M. McCash, Fundamentals of Molecular Spectroscopy, Tata McGraw Hill, 1994.
5. Atomic Physics- C J Foot, Oxford master series in Physics
6. Wolfgang Demtröder- Laser Spectroscopy Vol. 1: Basic Principles(4th edition)- Springer (2008)
7. Rober Boyd- Nonlinear Optics – 3rd edn. – Elsevier (2008)
8. H Metcalf and P V der Straton, Laser cooling and Trapping, 1994, Springer)
9. K Thyagarajan and Ajoy Ghatak, Lasers: Fundamentals and Applications, Springer, 2011, 2^{nd} edition.
10. G. K. Woodgate, Elementary Atomic Structure, Clarendon Press, 1989.
11. F. L. Pilar, Elementary Quantum Chemistry, McGraw Hill, 1990.
12. H. E. White, Introduction to Atomic Spectra, Tata McGraw Hill, 1934.
13. J. M. Hollas, Modern Spectroscopy, John Wiley & Sons, 2004.
14. R.J. Abraham and J. Fishe and P. Loftus, Introduction to NMR Spectroscopy, John Wiley & Sons. 1994.
15. J. A. Weil, J.R. Balton & J.E. Wertz, Electron Paramagnetic Resonance: Elementary Theory and Practical Applications. John Wiley and Sons, 1994.

PHY-E-612: Solid state Spectroscopy

Course Learning Outcomes: On completion of the course, the students will be able to

- understand the principles of atomic spectroscopy, ligand theory etc.
- understand group theory and applications.
- understand theory of electron transitions and crystal field.
- understand working principle of laser, common lasers and spectral analysis methods.

Course Content:

Unit I: Atomic Spectroscopy

Free Ion: The Free-ion; free ion terms for d2 and f2 configuration; Spin-orbit Coupling; Energy level states for d2 and f2 configuration; Ground states for fN configuration; Rare earth free-ions; Coulomb and Spin-orbit energies - Intermediate coupling.

Ligand Field: The concept of ligand field; The scope of ligand field theory; The Physical properties affected by ligand fields; Ligand fields and f electron systems; The magnetic properties of actinide element compounds.

Unit II: Group Theory

Sketch of Group theory; Kramer's degeneracy; Crystal field splitting - D3hsymmetry; Product of two representations - Selection rules; Examples of selection rules -D3h symmetry; Applications of theoretical results to the analysis of experimental data.

Unit III: Optical Spectra

Rare Earth Ions: Judd-Ofelt theory for the parametrization of intensities; Radiative properties; Up conversions in rare earths; Luminescent properties of Eu3+ and Tb3+ ions.

Trivalent Rare Earth Ions in Crystal Field: Introduction; Parametrization of crystal field splitting; The spin Hamiltonian; Examples of crystal field parametrization; Model description of the crystal field.

Unit IV: Optical Instruments and Spectral Analyses

Rare Earth Lasers: Introduction; Principles of laser action; Typical rare earth lasers; Nd:YAG and Nd:Glass lasers; Energy level scheme of the Nd in YAG.

Spectral Analyses: Spectrographs and Spectrophotometers for UV, VIS and IR regions; Absorption and Emission spectra; Temperature dependent spectra; Axial, Sigma and Pi polarization spectral measurements.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation.
- Use of audio-visual aids to show the 3D configurations of the models and devices.

Assessment Framework

Out of three internal assessment, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination of 1 hour duration with questions of objective, short and long types.	Students will present their learning and conclusions in a written report. Assessment will evaluate the clarity of writing, organization of content, appropriate use of scientific terminology, and adherence to formatting guidelines.	Written examination of 1 hour duration questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination of 3 hours duration with questions of objective, short and long questions.

Suggested Readings:

1. B.N. Figgis; *Introduction to Ligand Fields*, Wiley Eastern Limited, New Delhi, 1976.
2. S. Hufner, *Optical Spectra of Transparent Rare Earth Compounds*, Academic Press, London, 1978.
3. J. W. Robinson: *Atomic Spectroscopy*, M Dekker, New York, 1990.
4. Joseph Sneddon et al.*: Lasers in analytical atomic spectroscopy*, Wiley VCH, 1997.
5. J. Michael Hollas: *Modern spectroscopy*, John Wiley & Sons, 2004.
6. A. W. Joshi, *Elements of Group Theory for Physicist*, New Age International Publishers, New Delhi, 2005.
7. Michael Tinkham: *Group Theory and Quantum Mechanics*, McGraw Hill, 2003.

PHY-E-613: Quantum Optics & Quantum Information Processing

Course Learning Outcomes: On completion of the course, the students will be able to

- gain an understanding of Fock states, quantum beats, coherent states, quantum distribution theory
- distinguish between first and second order coherence, semiclassical and quantum theory of atom-field interaction
- learn quantum cryptography, EPR paradox, Bell's theorem and allied theories of quantum optics
- acquire a knowledge of quantum computers, its physical realization, algorithms on quantum computers, entanglement, teleportation, quantum key distribution.

Course Content:

Unit I: Quantum theory of radiation

Review of quantum theory of radiation; Quantization of free electromagnetic field; Fock states, Lamb shifts, Quantum beats, coherent & squeezed states of the field, Quantum distribution theory & partially coherent radiation (Q-representation and Wigner-Weyle distribution)

Unit II: Quantum Field Interactions

Field- Field and Photon – Photon interferometry, First & second order Coherence; photon detection & quantum coherence functions. Photon counting & Photon statistics; Classical & Quantum description of TWO source interference, Atom-field interaction- Semiclassical& Quantum theory.

Unit III: Quantum Optics

Laser without inversion & other effects of atomic coherence &interference Resonance florescence Quantum theory of laser- density operator approach and Heisenberg- Langevin approach, Theory of micro-Masers. Atom optics. EPR paradox; hidden variable & Bell's theorem; Quantum calculation of the correlation in Bell's theorem; Bell's theorem without inequalities (GHZ equality). Quantum Cryptography (Bennett-Brossard protocol), Quantum Non demolition measurement.

Unit IV: Quantum Computations

Quantum circuits; Quantum search algorithm, Quantum Computers- Physical realization, Condition for quantum computation, Different implementation schemes for quantum computation; Quantum information theory (Distinguishing Quantum states, Data compression, Classical& Quantum information & noisy Quantum channels), Entanglement as physical resonance, Quantum key distribution and security of quantum key distribution.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation.
- Use of audio-visual aids and ICT tools.
- Provide guidance and mentorship to help students develop research proposals, execute projects, and analyze findings.

Assessment Framework

Out of three internal assessment, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Students will provide a written explanation of their class learning and their interpretation.	Written examination of 1 hour duration with questions of objective, short and long types. Can also be conducted through Assignments/presentations. can also be used.	The students will have to submit assignments delivered in the class. The assignments can be solving exercise problems of a textbook or filling the gaps between analytical steps showed in the class.	Written examination of 3 hours duration with questions of objective, short and long questions.

Suggested Readings:
1. M.O. Scully & M. Suhail Zubairy: *Quantum optics*, Cambridge University Press, 2002.
2. D. F. Walls and G. J. Milburn: *Quantum optics*, Springer, 2008.
3. M A Nielsen & I L Chuang: *Quantum Computation & Quantum Information*, Cambridge University Press, 2010.
4. Rodney Loudon: *The Quantum theory of light*, Oxford University Press, 2003.
5. Ioan Burda: *Introduction to Quantum Computation*, Universal Publishers, Florida, USA, 2005.

PHY-E-614: Semiconductor Physics and Devices

Course Learning Outcomes: On completion of the course, the students will be able to

- understand physics of semiconductors and various properties.
- understand various pn junction devices and their I-V characteristics.
- understand various bi- and tri-junction semiconductor devices and their operation.
- understand various semi-conductor devices and their applications.

Course Content:
Unit I: Characterization of Semiconductors
Review of quantum theory of semiconductors, Semiconductors in equilibrium, Carrier transport in semiconductors, Semiconductor under non-equilibrium. Hall effect: measurement of resistivity, mobility, carrier concentration, diffusivity, Hall coefficient, Haynes-Shockley experiment, mobility, diffusivity and life time of minority carriers.
Unit II: P-N Junctions-Characteristics and Devices
Junction in equilibrium, Continuity of Fermi level across the junction, Junction under forward and reverse bias, zero-bias, built-in potential, Electric field in depletion region, Biased junction, Space charge width under electric field, Junction capacitance, Diffusion capacitance, One sided junction,

Non-uniformly doped junctions, Linearly graded, Hyper abrupt etc., Avalanche and Zener Breakdown. Zener diode, Varactor diode, Tunnel diode, Photovoltaic Cell

Unit III: Junction Diodes and Transistors

Metal-semiconductor Junction Diode: Structure, metal semiconductor contacts, energy band diagram for different cases, barrier formation, Schottky barrier diode, Nonideal effects on barrier heights, Current voltage characteristics, Comparison of barrier diode and PN-junction diode, Metal Semiconductor Ohmic Contact, Ideal non-rectifying barriers, Heterojunction, Two-dimensional electron gas.

Bipolar Junction Transistor: Structure, Basic principle of operation, Modes of operation, Carrier concentration profile in various regions in forward active mode, current gain and current gain factors, Equivalent circuit models: Ebers-Moil model, Dependence of Ebers-Moll parameters on the structure and operating point, Maximum transition current, Voltage and power rating, Transistor as a switch.

Unit IV: Semiconductor Devices

Photodiode and solar cells, Microwave Devices: IMPATT devices: Read diode, principle of operation, applications, other structures. Gunn devices: Two valley semiconductors, transferred electron mechanism, formation and drift of space charge domain, application to resonant circuit. Semiconductor optical amplifiers, LEDs and LDs: device structure and characteristics, DFB, DBR, and quantum well lasers, Laser diode arrays, Semiconductor photodetectors; PINs and APDs, CCDs and OEICs

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation.
- Use of audio-visual aids and ICT tools

Assessment Framework

Out of three internal assessment, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination of 1 hour duration with questions of objective, short and long types.	Students will summarize and present their learning in the class. The evaluation will be on the basis of their quality of presentation.	Written examination of 1 hour duration questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination of 3 hours duration with questions of objective, short and long questions.

Suggested Readings:

1. Adir Bar-lev: *Semiconductor and electronic Devices*, Prentice Hall of India, 1993.
2. Hess, K.: *Advanced Theory of Semiconductor Devices*, Prentice Hall of India, 2000.
3. Roy.D.K. : *Physics of Semiconductor Devices*, University Press, India, 2000.
4. Streetman, B.G.: *Solid State Electronic Devices*, Prentice Hall of India, 2000.
5. Sze, S.M.: *Semiconductor Devices; Physics and Technology*, Wiley Eastern Ltd., 2009.
6. Sze, S. M: *Physics of Semiconductor Devices*, Wiley Eastern Ltd., 2007.
7. Wang, S.: *Fundamentals of Semiconductor Theory and Device Physics*, Prentice Hall of India, 1989.
8. Jasprit Singh*, Semiconductor Devices - Basic Principles*, John Wiley &Sons, Inc., 2002.
9. Zambuto, M.*: Semiconductor Devices*, McGraw Hill, 1989.

PHY-E-654: GRAVITATION AND COSMOLOGY

Course Learning Outcomes: On completion of the course, the students will be able to

- learn the principle of general relativity, Einstein's field equation and experimental tests.
- learn the Robertson-Friedman-Walker model of the universe and the physics of CMBR.
- learn the early phase of universe including the inflation period.
- learn fluctuations in early universe and structure formation.

Course Contents:

Unit I: General Relativity

Basics of tensor algebra, metric tensor, equivalence principle, geodesic equation, affine connection, covariant derivative, parallel transport, energy-momentum tensor, curvature tensor, Bianchi identities, Einstein's field equations, metric for a static isotropic field, Schwarzschild solution, applications and experimental tests of general relativity.

Unit II: Standard Model of Cosmology & CMB Radiation

Cosmological principle, Robertson-Walker metric, Hubble's observation, redshift parameter, dynamics of expansion, Friedmann equations, age of the universe, mass-energy content of the universe, cosmological constant, basics of steady state cosmology.

Discovery of cosmic microwave background (CMB) radiation, equilibrium era, recombination and decoupling era, last scattering, CMB observations (COBE, WMAP, Planck), power spectrum, CMB anisotropy, origin and significance.

Unit III: Early Universe & Inflationary Cosmology

Thermal history and very early universe, neutrino decoupling, reheating, big bang nucleosynthesis, relic particles, primordial abundances, baryon asymmetry, origin of the elements.

Limitations of the standard model, flatness, horizon, monopole problems, cosmic inflation, inflaton scalar field, conditions for inflation, slow roll inflation, reheating, chaotic inflation, power law inflation.

Unit IV: Cosmological Perturbations & Structure formation

Origin and growth of density perturbations, linear perturbation theory, hydrodynamic equations, Jeans' instability and gravitational collapse.

Structure formation, cold and hot dark matter hierarchical models, ΛCDM model, dark energy and dark matter, Galaxy cluster, distribution and evolution.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.

- Use of smart board for power point presentation
- Use of audio-visual aids wherever applicable.

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Assessment Framework

Out of three internal assessments, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination with questions of objective, short and long types.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination of 2 hours with objective, short and long questions.

Suggested Readings:

1. *A First Course in General Relativity*, Bernard Schutz, Cambridge University Press (2009).
2. *An Introduction to Relativity,* Jayant V. Narlikar, Cambridge University Press (2010).
3. *Gravitiy, Black Holes, and the Very Early Universe, An Introduction to General Relativity and Cosmology*, Tai L. Chow, Springer, New York (2008).
4. *Cosmology*, Steven Weinberg, Oxford University Press (2008).
5. *Physical Foundations of Cosmology*, Viatcheslav Mukhanov, Cambridge University Press (2005).
6. *An Introduction to Modern Cosmology*, Andrew Liddle, John Wiley & Sons Ltd (2015).
7. *Modern Cosmology*, Scott Dodelson and Fabian Schmidt, Academic Press, Elsevier (2020).
8. *Inflationary Universe: The Quest for a New Theory of Cosmic Origins*, Alan H. Guth, Addison-Wesley Publishing Company Inc (1997).
9. *Cosmological Inflation and Large-Scale Structure*, Andrew R. Liddle, and David H. Lyth, Cambridge University Press (2000).
10. *Introduction to Cosmic Inflation and Dark Energy*, Konstantinos Dimopoulos, CRC Press, Boca Raton (2020).

PHY-E-655: Conformal Field Theory

Course Learning Outcomes: On completion of the course, the students will be able to

- understand the motivation and basic properties of conformal field theories.
- understand the quantization and operator formalism.
- learn classification of CFT and analysis of various models relevant in physics.
- understand modular transfromations, modular invariance and its various aspects

Course content:

Unit 1: Introduction and motivations
Examples of conformal invariance, brief outline about applications in critical and the renormalization group.

Basic properies of CFT: Conformal transformations, their infinitesimal form,, the conformal algebra and group, representations of the conformal group; Stress-energy tensor and conserved currents; Radial quantization, the state-operator correspondence, unitarity bounds.

Unit 2: CFTs in two dimensions:
Global conformal transformations,; Primary fields, radial quantisation, free fields, the operator product expansion, The free boson (periodic boson, the boson on an orbifold), the free fermion, the bc ghost theory, central charge, trace anomaly.
Operator formalism: radial quantization, Virasoro algebras, conforml generators and Hilbert space. Vertex operators. Twisted boundary condition. Free fermions, descendant fields, operator algebra, conformal blocks, crossing symmetry, conformal bootstrap.

Unit 3: Minimal models:
Verma modeules, Virasoro characters, Kac determinant, overview of minimal modes; Examples: Yang-Lee singularity, Ising model, 3-states Potts models, O(n) model.
Irreducible modules and minimal characters, differential equations for two and four point functions of the minimal models, fusion rules.

Unit 4: Modular Invariance:
CFT on torus, partition function, free bosons and fermions on torus, modular invariance. Models with c=1, compactified boson, Z2 orbifold. Modular transformation , characters, partition function, fusion rules, Verlinde formula.
Conformal bootstrap program.

Suggested Teaching Learning Strategies
- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation
- Use of audio-visual aids wherever applicable.

Assessment Framework
Out of three internal assessments, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination	Written examination with questions of objective,	Written examination with questions of objective,	Written examination of 2

with questions of objective, short and long types.	short and long types. Can also be conducted through Assignments/presentatio ns.	short and long types. Can also be conducted through Assignments/presentatio ns.	hours with objective, short and long questions.

Suggested Readings:

1. Conformal Field Theory, P D Francesco, P Mathieu and D Senechal, Graduate Texts in Contemporary Physics, Springer, 2011.
2. Introduction to Conformal Field Theory: With Applications to String Theory, by Ralph Blumenhagen, Erik Plauschinn, (Lecture Notes in Physics 779) Springer, 2011.
3. Lectures on Conformal Field Theory, Joshua D. Qualls, available at http://arxiv.org, arXiv:1511.04074v2 [hep-th]
4. EPFL Lectures on Conformal Field Theory in D ≥ 3 Dimensions, (Lausanne, Switzerland, École polytechnique fédérale de Lausanne, December), by S. Rychkov available at http://arxiv.org
5. Applied Conformal Field Theory, by P. Ginsparg, available at http://arxiv.org; arxiv:hep-th/9108028
6. Jaume Gomis PIRSA 2011/2012 online lectures on CFT.
7. John Cardy lecture notes on CFT.
8. Slava Rychkov lecture notes on CFT, available at ”arXiv:1601.05000”.
9. Xi Yin lecture notes on CFT.

PHY-E-656: Physics in Nanoscale

Course Learning Outcomes: On completion of the course, the students will be able to

- Learn the electronic structure in nanoscale and molecular systems.
- Learn the fundamentals of coherent electron transport in nanoscale and molecular systems.
- Learn the methodologies of non-coherent electron transport in non-equilibrium steady state situations.
- Learn molecule junction fabrication methods, characteristics and thermoelectric properties.

Course Contents:

Unit I: Electronic Structure of Quantum Systems

Hückel (tight-binding) model, LCAO approximation, electronic structure of molecular chain, quantum ring and quantum dot, tight-binding Hamiltonian in second quantization, dispersion relation for the 1D chain and 2D lattice square, hopping integral in magnetic field, electron in 1D-nano ring, energy spectrum, magnetic field effects, Hofstadter's butterfly in finite lattice.

Unit II: Coherent Electron Transport in Quantum Systems

Characteristic length scales, different transport regime, scattering theory of electron transport, conduction channels, Landauer formalism, conductance, equilibrium Green’s functions and self-energy, model junction device, broadening function, transmission from Green’s function, *Landauer current formula, electron transport through quantum dots.*

Unit III: Quantum Transport Methodologies

Basics of non-equilibrium Green’s function technique for electron transport, interacting electrons, Meir-Wingreen current formula, inelastic effects, master equation approach to electron transport, density matrix formalism for relaxation and decoherence.

Unit IV: Molecular Junction Devices and Thermoelectricity

Single molecule junction fabrication methods, scanning tunneling microscopy-based break junction, mechanically controllable break junction , I-V characteristics, rectification and NDR in molecular junctions

Thermal transport through molecular junctions, thermal conductance, nanoscale and molecular thermoelectricity, thermopower, figure of merit, thermoelectric measurements.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation.
- Use of audio-visual aids.

Assessment Framework

Out of three internal assessments, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination with questions of objective, short and long types.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination of 2 hours with objective, short and long questions.

Suggested Readings:

1. *Electronic Transport in Mesoscopic Systems,* Supriyo Datta, Cambridge University Press, Cambridge (1997).
2. *Mesoscopic Systems, Fundamentals and Applications*, Yoshimasa Murayama, Wiley-VCH Verlag, Berlin (2001).
3. *Quantum Transport: Atom to Transistor*, Supriyo Datta, Cambridge University Press, NY (2005).
4. *Chemical Dynamics in Condensed Phases, Relaxation, Transfer and Reaction in Condensed Molecular Systems,* Abraham Nitzan, Oxford University Press, NY (2006).
5. *Electrical Transport in Nanoscale Systems*, Massimiliano Di Ventra, Cambridge University Press, NY (2008).
6. *Quantum Kinetics in Transport and Optics of Semiconductors*, Harmut Haug and Antti-Pekka Jauho, Springer, Berlin (2008).
7. *Transport in Nanostructures*, David K. Ferry, Stephen M. Goodnick and Jonathan Bird, Cambridge University Press, NY (2009).

PHY-E-657: QUANTUM FIELD THEORY

Course Learning Outcomes: On completion of the course, the students will be able to

- understand the basics of free scalar and spinor fields.
- understand interaction among fields and compute the cross sections and decay rates.
- understand the basic idea of renormalization and its various aspects
- understand the field theory of non Abelian gauge field.

Course Content:

Unit I: Scalar and Spinor Fields

Need for Field Theoretic description, Klein-Gordon Field: Lagrangian formulation, symmetries and conservation laws, canonical quantization, propagators, Feynman diagrams

Dirac Field: Canonical quantization, propagators, Symmetries: Gauge Symmetries, Gauge Field: Elementary realization of BRST symmetry and gauge fixing.

Unit II: Interactions

Hamiltonian formulation, S-matrix, Interacting Fields and Feynman Diagrams, Yukawa Theory, Elementary processes of Quantum Electrodynamics, radiative corrections.

Unit III: Renormalization

Functional Methods, Systematics of Renormalization, Renormalization and Symmetry, Renormalization Group, Critical Exponents. Wilsonian renormalization.

Unit IV: Non-Abelian Gauge Field

Non-Abelian Gauge invariances, Quantizations, Quantum Chromodynamics, Operator products, effective vertices, Gauge theory with spontaneous symmetry breaking, Higgs mechanism.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation
- Use of audio-visual aids wherever applicable.

Assessment Framework

Out of three internal assessments, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination with questions of objective, short and long types.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination of 2 hours with objective, short and long questions.

Suggested Readings:

1. M. E. Peskin, D. V. Schroeder: *An Introduction to Quantum Field Theory*, Addison-Wesley, 1995.
2. F. Mandl and G. Shaw: *Quantum Field Theory*, John Wiley, 1992.
3. S. Weinberg, The Quantum Theory of Fields, Vol. I and II, Cambridge
4. University Press, 2005
5. C. Itzyksion and J B Zuber, Quantum Field Theory, Dover Publications, 2006
6. T. P. Cheng and L.-F. Li: *Gauge Theory of Elementary Particle Physics*, Oxford University Press, 1984.
7. S. Pokorski: *Gauge Field Theories*, Cambridge University Press, 2000.
8. L. H. Ryder: *Quantum Field Theory*, Cambridge University Press, 1996.
9. D. Bailin and A. Love: *Introduction to Gauge Field Theory*, IOP Publishing, Graduate Student Series in Physics, 1986.
10. P. B. Pal and A. Lahiri: *A First Book of Quantum Field Theory*, CRC Press, 2001.
11. A. Zee, Quantum Field Theory in a nutshell, Princeton University Press, 2010.

PHY-E-658: X-RAY CRYSTALLOGRAPHY AND MOLECULAR BIOPHYSICS

Course Learning Outcomes: On completion of the course, the students will be able to

- learn the basic structure of materials.
- learn the production and scattering of x-rays.
- learn the interpretation and analysis of x-ray diffraction.
- learn about the applications of x-rays in understanding the structure of bio-molecules.

Course Content:

Unit I The Crystalline state of solids:
Crystalline and amorphous states , covalent solids, ionic solids, hydrogen bonded solids and metals. Space lattice, unit cell, Bravais lattices, crystal planes and Miller indices, spacing of planes in crystal lattices, symmetry operations, point groups and crystal classes, screw axis and glide planes, space groups.

Unit II X-rays
Origin of X-rays, Continuous and Characteristics spectra, Absorption of X-rays, Absorption edge, filters, production of X-rays, modern X-ray generator. Scattering of X-rays by an electron, an atom and a unit cell, atomic scattering factors, Diffraction of X-rays, the Bragg's law.

Unit III Diffraction methods
Laue method, powder method, precision determination of lattice parameters, x-ray diffractometer. Reciprocal lattice, sphere of reflection, rotating crystal method, use of oscillation photograph, determination of lattice parameter from oscillation photograph.Integrated intensity and their measurement, Lorentz polarization correction, Debye-Waller temperature factor.Structure analysis by Fourier Synthesis.

Unit IV: Bio molecules:
Chemistry of monomers and polymers, amino acids, lipids, nucleic acids, proteins, DNA, RNA, Protein crystallization, X-ray diffraction from Protein crystals, crystals structures of some protein molecules, Fibre diffraction, interpretation of fibre-pattern x-ray diffraction.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation
- Use of audio-visual aids wherever applicable.

Assessment Framework

Out of three internal assessments, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination with questions of objective, short and long types.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination of 2 hours with objective, short and long questions.

Suggested Readings:

1. B. D. Culity: *Elements of X-ray diffraction*, Addison-Wesley, 3rd Printing, (1967).
2. Henry, M. F. M.Lipson, W.A. Wooster, Henry: *Interpretation of x-ray diffraction*
3. *Photograph.* Macmillan, London, (1961)
4. Harold, P. Klug and E. L. Alexender: *X-ray diffraction procedures for polycrystalline and Amorphous Materials*. Wiley-Interscience, 2nd Edn. (1974).
5. Wolfram Saenger: *Principle of Nucleic Acid Structure.* Springer, (1988).
6. J. M. Berg, J. L. Tymoczko, Lubert Stryer: *Bio Chemistry*. W. H. Freeman, 5th Edn. (2002).

PHY-E-659: General Relativity

Course Learning Outcomes: On completion of the course, students will be able to

- learn techniques of Tensor analysis in the context of curved spacetime.
- have a clear conceptual ideas regarding general relativity and Einstein equation, including implications of the motion of the particles.
- understand special aspects of gravitational theory such as Schwarzschild black holes, its properties and significances; and bending of light.
- understand evidences of GTR: perihilion shift of Mercury, gravitational waves. To study basics of cosmology.

Course content:

Unit I:

Review of Lorentz transformations and special theory of relativity.

Tensors and their transformation laws; Christoffel symbol and Riemann tensor; geodesics; parallel transport along open lines and closed curves; general properties of the Riemann tensor.

Unit II:

Equivalence principle and its applications: gravity as a curvature of space-time; geodesics as trajectories under the influence of gravitational field; generalisation to massless particles; gravitational red-shift; motion of a charged particle in curved space-time in the presence of an electric field; Maxwells equation in curved space-time.

Einsteins equation, Lagrangian formulation, Einstein-Hilbert action.

Unit III:
Schwarzschild solution: construction of the metric and its symmetries; motion of a particle in the Schwarzschild metric; Schwarzschild black hole; white holes and Kruskal extension of the Schwarzschild solution: construction of the metric and its symmetries; Motion of a particle in the Schwarzschild metric; precession of the perihelion; bending of light; horizon, its properties and significance.

Unit IV:
Precession of the perihelion; bending of light; radar echo delay. Linearised theory, gravitational waves, field far from a source, energy in gravitational waves, quadrupole formula
Elementary cosmology: principles of homogeneity and isotropy; Friedman-Robertson-Walker metric; open, closed and flat universes; Friedman equation and stress tensor conservation, equation of state, big bang hypothesis and its implications.

Suggested Teaching Learning Strategies
- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation
- Use of audio-visual aids wherever applicable.

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Assessment Framework
Out of three internal assessments, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination with questions of objective, short and long types.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination of 2 hours with objective, short and long questions.

Suggested Readings:

1. A Relativist's toolkit, by Eric Poisson, Cambridge University Press
2. Gravitation and Cosmology, by Steven Weinberg, Wiley
3. Introduction to General Relativity, by Lewis Ryder, Cambridge University Press
4. A first course in general relativity, by Bernard F Schutz, Cambridge University Press
5. General Relativity: An Introduction for Physicists, by M P Hobson, G P Efstathiou, A N Lasenby, Cambridge University Press
6. Gravitation: Foundations and Frontiers, by T Padmanabhan, Cambridge University Press
7. General Relativity, by Robert Wald, The University of Chicago Press
8. Gravitation, by C W Misner, K S Thorne, J A Wheeler, Princeton University Press
9. Gravity: An introduction to Einstein's General Relativity, by James B Hartle, Pearson Education
10. Relativity, by Wolfgang Rindler, OUP Oxford
11. Semi-Riemannian Geometry, by Barrett O'Neill, Elsevier
12. Spacetime and Geometry: An introduction to General Relativity, by Sean M Carroll, Cambridge University Press

13. Exploring Black Holes, by Edwin F Taylor, John Archibald Wheeler, Addison Wesley Longman
14. General Relativity, by Norbert Straumann, Springer Berlin Heidelberg
15. The Mathematical Theory of Black Holes, by S Chandrasekhar, Clarendon Press

PHY-E-660: ADVANCED ELECTRONICS

Course Learning Outcomes: On completion of the course, the students will be able to

- understand the basic concepts of modulation and demodulation techniques
- learn the basics of optical communications
- learn techniques of satellite communications
- learn techniques of cellular communications

Course content:

Unit I Modulation & Demodulation:

Modulation, types (AM, FM and PM), Pulse Width Modulation, mathematical analysis of Amplitude Modulated and Frequency modulated carrier wave, AM signal detection using diode detector & transistor detector, FM detection using quadrature detector, basic concept of vestigial side band modulation.

Unit II Optical Fibre Communication:

Introduction, advantages & disadvantages over transmission lines, classification of optical fibres, light propagation through optical fibres: Snell's law, total internal reflection, acceptance angle and numerical aperture, block diagrammatic description of fibre- optic communication system, Frequency Division Multiplexing (FDM) and Time Division Multiplexing (TDM), Losses in optical fibres.

Unit III Satellite communications:

Introduction to digital communication techniques, satellite orbits, satellite orbital patterns, Geo-synchronous satellites, Satellite system link models: Uplink model, transponders & downlink model (*Block diagrammatic description only*).

Unit IV Cellular communication:

Introduction to cellular telephone service, evolution of cellular telephone, fundamental concepts, frequency re-use, interference (co-channel and adjacent channel)

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation
- Use of audio-visual aids wherever applicable.

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Assessment Framework
Out of three internal assessments, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination with questions of objective, short and long types.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination of 2 hours with objective, short and long questions.

Suggested Readings:

1. Simon Haykin: *Communication Systems* : 4th Ed., John-Wiley & Sons (2000)
2. W. Tomasi: *Advanced Electronic Communication Systems*, 6th Ed., P.H.I. (2005)
3. Martin S. Roden: *Analog & Digital Communication Systems*, 3rd Ed., PHI (2005)
4. B. P. Lathi: Modern digital and Analog *Communication Systems,* Oxford University Press, 3rd ed., (1998).
5. Das, Mallik and Jain:*Communication Systems.*

PHY-E-661: Thin Film Technology

Course Learning Outcomes: On completion of the course, the students will be able to

- understand various techniques for the fabrication of thin films.
- understand electrical, transport and optical properties of thin films.
- understand fabrication of semiconductor thin films for solar cell applications.

Course Content:
Unit I: Introduction
Preparation: Spray pyrolytic process – characteristic feature of the spray pyrolytic process – ion plating– Vacuum evaporation – Evaporation theory – The construction and use of vapor sources– sputtering Methods – Reactive sputtering – RF sputtering - DC planar and magnetron sputtering, atom beam/ion beam sputtering.
Thickness measurement: electrical methods – optical interference methods – multiple beam interferometry – Fizeau – FECO methods – Quartz crystal thickness monitor.
Nucleation & growth– Four stages of film growth incorporation of defects during growth.
Unit II: Electrical properties of metallic thin films
Sources of resistivity in metallic conductors – sheet resistance - Temperature coefficient of resistance (TCR) – influence of thickness on resistivity – Hall effect and magneto resistance – Annealing – Agglomeration and oxidation.
Unit III: Transport properties of semiconducting and insulating Films
Semiconducting films; Theoretical considerations - Experimental results – Photoconduction – Field effect in thin films – transistors, Insulating films Dielectric properties – dielectric losses – Ohmic contacts – Metal – Insulator and Metal – metal contacts – DC and AC conduction mechanism.

Unit IV: Optical properties of thin films and thin films solar cells
Thin films optics –Theory – Optical constants of thin films – Experimental techniques – Multilayer optical system – interference filers – Antireflection coating, thin films solar Cells, Single & multi junction solar cells, Role, Progress, and production of thin solar cells – Photovoltaic parameter, thin film silicon (Poly crystalline) solar cells: current status of bulk silicon solar cells –Fabrication technology – Photo voltaic performance: Emerging solar cells: GaAs and CdlnSe.

Suggested Teaching Learning Strategies
- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation.
- Use of audio-visual aids to show the 3D configurations of the models and instruments.

Assessment Framework

Out of three internal assessment, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Students will summarise and present their learning in the class. The evaluation will be on the basis of their quality of presentation.	Written examination of 1 hour duration with questions of objective, short and long types. Can also be conducted through Assignments/presentations . can also be used.	Written examination of 1 hour duration questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination of 3 hours duration with questions of objective, short and long questions.

Suggested Readings:
1. L I Maissel and R Glang: *Hand book of thin films technology*, McGraw Hill, 1970.
2. K L Chopra: *Thin film Phenomena*, McGraw Hill, 1970.
3. George Hass et al.: *Physics of thin films*, vol. 12, New York Academic Press, 1975.
4. K L Chopra and S R Das: *Thin films solar cells*, Plenum Press, 1983.
5. John A. Venables: *Introduction to Surface and Thin films processes*, Cambridge University Press, 2000.
6. L. Holland: *Vacuum deposition of thin films*, Chapman and Hall, 1966.
7. J C Anderson: *The Use of Thin Films in Physical Investigations*, New York, 1966.

PHY-E-662: Nonlinear Science: Solitons and Chaos

Course Learning Outcomes: On completion of the course, the students will be able to

- gain an idea of nonlinear system of equations, challenges in it's solutions, bifurcation theories, stability and fixed point analysis,
- learn about chaos, it's sensitivity on initial condition, integrable systems and their applications,
- learn about the applications and theories of solitons, their mutual interactions, as well as existence in laboratory systems and in nature.

Course Content:

Unit I: Introduction

Nonlinear equations in physics: an overview, Non-linear mechanics. Sensitive dependence on initial conditions. Discrete-time systems, Continuous time systems, Phase space, Poincare section, Spectral analysis of time series and power spectra, attractors, Bifurcation diagrams.

Stability: Fixed points, Lyapunov Stability, Asymptotic Stability, Poincare Stability, Lagrange Stability, Periodic and quasi-periodic motions, Logistic map-period doubling, periodic windows, Entropy and direction of time, Prediction of chaotic states-methods of analogues-linear approximation method.

Unit II: Chaotic Motion

Intermittency mechanism (Type I, II and III intermittencies), Bifurcations of homoclinic orbits, saddle point, turbulence, Fractal and fractal dimensions, self-similarity and self-affinity.

Hamiltonian theory, Duffing oscillator- Nonlinear oscillator – Standard map – integrable mapping- Non integrable mappings, Kepler's problem - order and chaos – Simple applications of chaos in physical systems - Quantum chaos applications.

Unit III: Solitons & Coherent Structures

Linear waves, weakly nonlinear and dispersive waves, solitons, Kdv, NLS, Sine-Gordon systems, examples and applications in physics and engineering; Nonlinear optical phenomena second harmonic generation, parametric processes, optical solitons, soliton based all optical communications.

Unit IV: Applications

Non-linear systems, Nonlinear optics - Optical communications - Fluid dynamics - Magnetic systems – Liquid crystals – Biomolecules - Medical physics - Plasma and Astro physics -Electrical circuits -, management systems, chaos in-earthquake dynamics - quantum physics - statistical mechanics.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation.
- Use of audio-visual aids and ICT tools.
- Assign research projects that align with the coursework objectives.

Assessment Framework

Out of three internal assessment, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Students will summarize and present their learning in the class. The evaluation will be on the basis of their quality of presentation.	Written examination of 1 hour duration with questions of objective, short and long types. Can also be conducted through Assignments/presentations . can also be used.	Students will present their understanding and conclusions in a written report. Assessment will evaluate the clarity of writing, organization of content, appropriate use of scientific terminology, and adherence to formatting guidelines.	Written examination of 3 hours duration with questions of objective, short and long questions.

Suggested Readings:

1. Thierry Vialar, *Complex and chaotic nonlinear dynamics*, Springer-Verlag, 2009.
2. Ali H. Nayfeh and B. Balachandran, *Applied nonlinear Dynamics*, WILEY-VCH, Verlag, 2004.
3. M. Lakshmanan (Ed.,) *Introduction to Solitons*, Springer-Verlag, 1988.
4. M.J. Ablowitz and H. Segur, *Solitons and Inverse Scattering Trasform*, Philadelphia, 1981.
5. P.G. Drazin and R.S. Johnson, *Solitons: An Introduction*, Cambridge University Press, 1989.
6. A.J. Licthenberg and M.A. Lieberman *Regular and Stochastic Motion*, Spinger Verlag, Berlin, 1983.
7. J.M. Thompson and H.B. Stewart, *Nonlinear Dynamics and Chaos*, John Wiley and Sons, 1989.
8. A.S. Davydov, *Solitons in Molecular Systems*, Kluwer Academic Publishers, 1991
9. A. Hasegawa and Y. Kodama, *Solitons in Optical Communications,* Oxford Press, 1995.

PHY-E-663: High Energy Physics

Course Learning Outcomes: On completion of the course, the students will be able to

- learn connection between classical conservation laws and continuous symmetry,
- distinguish between different symmetries in quantum dynamics and their applications in the world of fundamental particles,
- learn fundamentals of gauge theory, covariant perturbation theory, Lie groups and their applications in particle physics.
- acquire knowledge of deep inelastic scattering, QCD evolutions, standard model of electroweak theory and neutrino physics.

Course Content:

Unit I: Introduction

Special theory of relativity and kinematics, Classification of fundamental interactions and elementary particles. Yukawa's proposal on meson exchange. Noether's theorem in classical mechanics, continuous space time symmetries and associated conservation laws of momentum, energy, angular momentum. Lorentz invariance.

Unit II: Symmetries and Conservation Laws

Symmetries in quantum mechanics, Discrete Symmetries, Parity, Charge conjugation and time reversal. Examples of determination of intrinsic quantum numbers, mass and spin. Charge independence of nuclear forces, isospin and strangeness. Application of isospin invariance to pion nucleon scattering. Strangeness charm and other additive quantum numbers. Resonance and their quantum numbers with special reference to pion nucleon scattering. Gell-Mann Nishijima formula.

Violation and symmetries: Isospin violation in electromagnetic interactions, Parity non-conservation in weak interactions, CP violation and K0 system.

Unit III: Theoretical Techniques I

Introduction to Gauge theory of fundamental interactions, Covariant Perturbation theory, Feynman diagrams in momentum space and its applications in QED and QCD. Lie groups: SU(2), SU(3) and SU(5) and their applications: Higgs Mechanism and Goldstone theorem and its application in gauge theories.

Unit IV: Theoretical Techniques II

Feynman Rules for spin 0 and spin ½ particles and their applications, Parton model, Deep-Inelastic Scattering (DIS), QCD-evolution equations. Standard model of electroweak interaction, Minimal supersymmetric standard model (MSSM), neutrino masses and mixing angles.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation.
- Use of audio-visual aids.
- Encourage students to engage in independent study and research.

Assessment Framework
Out of three internal assessment, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination of 1 hour duration with questions of objective, short and long types.	The students will have to submit assignments delivered in the class. The assignments can be solving exercise problems of a textbook or filling the gaps between analytical steps showed in the class.	Written examination of 1 hour duration questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination of 3 hours duration with questions of objective, short and long questions.

Suggested Readings:
1. T.P. Cheng and Li: *Gauge theory of Elementary Particles*, Oxford University Press, 2000.
2. David Griffiths*, Introduction to Elementary Particles*, Wiley VCH, 2008.
3. Donald Perkins*, Introduction to High Energy Physics*, Cambridge University Press, 2008
4. *G. L. Kane: Modern Elementary Particle Physics*, Addison Wesley, 1993.
5. B. Zwiebach, A first course in string theory, Cambridge University Press, 2004.
6. J. Hartle, Gravity: *An introduction to Einstein's general relativity*, Pearson education, 2003.
7. A. Das and T. Ferbel: *Introduction to Particle & Nuclear Physics*, World Scientific Publishing, 2004.

PHY-E-664: Magnetism and Superconductivity

Course Learning Outcomes: On completion of the course, the students will be able to
- understand the origin of various magnetism and their theoretical descriptions.
- understand magnetism in various materials and their applications.
- understand the origin of superconductivity and theoretical description within GL and BCS theories.
- understand various class of superconducting materials and their applications.

Course Content:
Unit I: Magnetism - I
Static phenomena: Diamagnetism; Para-magnetism; Crystal-field effects; John-Teller effects; Adiabatic demagnetization; Molecular field theory of ferromagnetism; Heisenberg-exchange interaction; Super exchange; Ruderman-Kasuya and Yosida interaction; Series-expansion and Bethe-Peierls-Weiss methods; Spin Waves; Ginzburg-Landau theory of the ferromagnetism.
Unit II: Magnetism - II
Slater-Puling Curve; Shape, magneto-crystalline and other types of anisotropy; Micromagnetic; Origin and observation of ferromag - neticdomins; Soft and hard magnetic materials; magnetic exchange bias, Different stages of magnetic ordering in alloys; Kondo, spin-glass, cluster spin-glass, inhomogeneous long-range characterization and the relevant theoretical concepts. Applications of bulk and thin film magnetic materials and multi layers.

Dynamic Phenomena: Linear Response Theory: Magnetic response and relaxation; Generalized magnetic susceptibility; Kramers-Kronig relations.

Unit III: Superconductivity I

Basic properties of superconductors. Phenomenological thermodynamic treatment. Two fluid model; Magnetic behavior of superconductors, intermediate state, London's equations and penetration depth, quantized flux. Pippard's non-local relation and coherence length. Ginzburg-Landau theory, variation of the order parameter and the energy gap with magnetic field, isotope effect; Energy gap and its measurement; magnetization, specific heat and thermal conductivity; electron-phonon interaction and cooper pairs, brief discussion of the B.C.S. theory, its results and experimental verification; (p- and d- wave pairs).

Unit IV: Superconductivity II

Tunneling in SIN and SIS sandwiches, practical details; Coherence of the electron-pair wave, Weak links; dc and ac Josephson effects, superconducting Quantum Interference Devices (SQUID).
Type II superconductivity, magnetization of type-II superconductors, mixed state, surface energy, specific heat, critical currents of type-II superconductors flux lattice, flux flow (creep).
Superconducting materials (only qualitative description) conventional low temperature superconductors, High temperature superconductors, heavy fermions system, boro-carbides.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation.
- Use of audio-visual aids to show the 3D configurations of the models and instruments.

Assessment Framework

Out of three internal assessment, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination of 1 hour duration with questions of objective, short and long types.	Written examination of 1 hour duration with questions of objective, short and long types. Can also be conducted through Assignments/presentations . can also be used.	Students will summarize and present their learning in the class. The evaluation will be on the basis of their quality of presentation.	Written examination of 3 hours duration with questions of objective, short and long questions.

Suggested Readings:

1. A. H. Morrish*: Physical Principles of Magnetism*, R. E. Krieger Pub. Co., 1980.
2. S. Chikazumi: *Physics of Magnetism*, R. E. Krieger Pub. Co., 1978.
3. Wolfgang Nolting, Anupuru Ramakanth: Quantum Theory of Magnetism, Springer, 2009.
4. R. M. White: *Quantum Theory of Magnetism*, Springer, 2007.
5. S. Dattagupta: *Relaxation Phenomena in condensed matter,* Academic Press, 1987.
6. M. Tinkham: *Introduction to Superconductivity,* McGraw Hill, 1996.

7. P. G. deGennes: *Superconductivity of Metals and Alloys*, Advanced Book Program, Perseus Books, 1999.
8. K. H. Bennemann, J. B. Ketterson: The Physics of Superconductors, Springer Verlag, 2003.

VALUE ADDED COURSES

PHY-V-504: INDIAN CONTRIBUTION IN PHYSICS

Course Learning Outcomes: On completion of the course, the students will be able to
- Understand contributions and contributors from India to Physics and allied disciplines.
- understand traditional methods that are still in practice for different purposes.
- understand the contribution of several eminent Indian scientists in the last century.
- understand ongoing research works and international collaborations in different fields of Physics from India.

Course Content:

Unit-I: Ancient India:
Mathematics: Discovery of Zero, Pi, Roots of quadratic equation etc.
Astronomy: Works of Aryabhatta, Varahamihir, Brahmagupta, Bhaskaracharya
Medicine: Understanding the human body to develop instruments for surgery.
Chemistry: Metallurgy, medicine preparation, herbal medicine, Ayurveda
Musical instruments in ancient India, Architectures and town-planning of Indus-valley civilisation.

Unit-II: Traditional Knowledge:
Traditional Indian metal casting: Lost-Wax method (e.g. Dhokra Casting),
Iron smelting by Agariyas, Ashta-dhatu work, Brass-mirror work.
Natya-shastra's classification of musical instruments, Jewellery making (Jaipur gold plating, diamond cutting).
Running water supply in Vijaynagar and Golconda (Hyderabad) townships.
Astronomical observatories: Works of Sawai Jai Singh

Unit-III: Modern Contributions:
Works of Jagadish Chandra Bose, Prafulla Chandra Roy, Meghnad Saha, Satyendra Nath Bose, S Ramanujan, C V Raman, S Chandrasekhar, Homi Jehangir Bhabha, Vikram Sarabhai, APJ Abdul Kalam, Harish Chandra, Amal Kumar Raychaudhuri.

Unit-IV: Ongoing Contributions:
Gravitational Wave Astronomy (LIGO), International Thermonuclear Experimental Reactor (ITER), Indian Neutrino Observatory (INO), Liquid Crystals and other soft matter, Quantum Computation, any other recent scientific contributions.
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Suggested Teaching Learning Strategies
- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation.
- Use of audio-visual aids to show traditional knowledge, scientific contributions and contributors.

Assessment Framework

Out of three internal assessments, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination with questions of objective, short and long types.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination of 2 hours with questions of objective, short and long questions.

Suggested Readings:

1. Indian Contribution to Science, Compiled by Vijnana Bharati
2. Prafulla Chandra Roy, A History of Hindu Chemistry (1909) Williams and Norgate, London
3. J V Narlikar, The Scientific Edge - The Indian Scientist from Vedic to Modern Times, Penguin Books
4. N G Dongre and S G Nene, Physics in Ancient India, National Book Trust (2016)
5. Helaine Selin and Roddam Narasimha, Encyclopaedia of Classical Indian Sciences, University Press (2020)

PHY-V-555: CYBER SECURITY

Course Learning Outcomes: On completion of the course, the students will

- Learn the foundations of Cyber security and threat landscape.
- Be equipped with technical knowledge and skills needed to protect and defend against cyber threats.
- develop skills that can help them plan, implement, and monitor cyber security mechanisms to ensure the protection of information technology assets.
- Be exposed to governance, regulatory, legal, economic, environmental, social and ethical contexts of cyber security.
- Be able to responsibly use online social media networks.
- Understand the necessity to understand the impact of cyber crimes and threats with solutions in a global and societal context.

Course Contents:

Unit I: Cyber security and Crimes

Cyber security increasing threat landscape, Cyber security terminologies- Cyberspace, attack, attack vector, attack surface, threat, risk, vulnerability, exploit, exploitation, hacker., Non-state actors, Cyber terrorism, Protection of end user machine, Critical IT and National Critical Infrastructure, Cyberwarfare.

Cyber crimes targeting Computer systems and Mobiles- data diddling attacks, spyware, logic bombs, DoS, DDoS, APTs, virus, Trojans, ransomware, data breach., Online scams and frauds- email scams, Phishing, Vishing, Smishing, Online job fraud, Online sextortion, Debit/ credit card fraud, Online payment fraud, Cyberbullying, website defacement, Cyber-squatting, Pharming, Cyber espionage, Cryptojacking, Darknet- illegal trades, drug trafficking, human trafficking., Social Media Scams & Frauds- impersonation, identity theft, job scams, misinformation, fake newscyber crime against persons - cyber grooming, child pornography, cyber stalking., Social Engineering attacks, Cyber Police stations, Crime reporting procedure.

Unit II: Cyber Law and Data Security

Cyber crime and legal landscape around the world, IT Act,2000 and its amendments. Limitations of IT Act, 2000. Cyber crime and punishments, Cyber Laws and Legal and ethical aspects related to new technologies- AI/ML, IoT, Blockchain, Darknet and Social media, Cyber Laws of other countries.

Defining data, meta-data, big data, non-personal data. Data protection, Data privacy and data security, Personal Data Protection Bill and its compliance, Data protection principles, Big data security issues and challenges, Data protection regulations of other countries- General Data Protection Regulations (GDPR),2016 Personal Information Protection and Electronic Documents Act (PIPEDA)., Social media- data privacy and security issues.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation.
- Use of audio-visual aids.

Assessment Framework

Out of three internal assessments, the best two will be chosen.

Internal Assessment 1 (25marks)	Internal Assessment 2 (25 marks)	Internal Assessment 3 (25 marks)	End Semester Examination (50 marks)
Written examination with questions of objective, short and long types.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination with questions of objective, short and long types. Can also be conducted through Assignments/presentations.	Written examination of 2 hours with objective, short and long questions.

Suggested Readings:

1. Sumit Belapure and Nina Godbole, Cyber Security Understanding Cyber Crimes, Computer Forensics and Legal Perspectives, Wiley India Pvt. Ltd.
2. Dorothy F. Denning. Information Warfare and Security, Addison Wesley.
3. Henry A. Oliver, Security in the Digital Age: Social Media Security Threats and Vulnerabilities, Create Space Independent Publishing Platform.
4. Natraj Venkataramanan and Ashwin Shriram, Data Privacy Principles and Practice, CRC Press.
5. W. KragBrothy, Information Security Governance, Guidance for Information Security Managers, 1st Edition, Wiley Publication.
6. Martin Weiss, Michael G. Solomon, Auditing IT Infrastructures for Compliance, 2nd Edition, Jones Bartlett Learning.

Skill Enhancement Courses

PHY-S-506: Physics Teaching

Course Learning Outcomes: On completion of the course, the students will be able to

- ask basic questions related to their field of interest to start the learning and teaching processes.
- do basic research by collecting the information about the topic to be learnt.
- present their understanding in a systematic way.

Course Content:

Unit 1 Conventional Teaching

How to introduce a new topic, its importance to science and real life, different teaching platforms and practices, lecture, tutorial and practical.

Levels of teaching physics, use of different audio-visual aids, experimental methods and demonstration (e.g. pendulum motion, rotational motion, projectile motion, static electricity etc), discussion on few basic topics of physics, such as, Laws of motion, laws of thermodynamics, laws of reflection and refraction. Describing a few important experiments that changed physics.

Importance of dimensional analysis, designing experiments to explain the basic physics.

Teaching simple topic, how to conduct duties of teaching assistance in theory as well as experimental labs. Different modes of evaluation.

Unit 2 Unconventional Teaching

Teach through story telling (e.g. Archimedes Principle), how to use different ICT tools in teaching, animation, simulation (electronic circuit using PSPICE, equation of motion etc), online teaching/learning materials, showing relevant movies and video clips followed by discussion and analysis.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation
- Use of different kinds of teaching practices through ICT
- Weekly show of relevant movies and video clips

Assessment Framework

Internal Assessment (25marks)	End Semester Examination (25 marks)
Students will teach one particular topic of their choice in physics to the classroom. It will be of around 20 minutes. The course instructor will do the evaluation.	Students will present and teach in 20 minutes on a topic of their choice in physics to the committee constituted by the department to evaluate it.

Suggested Readings:

1. *Physics Today,* The Physics Teacher, American journal of Physics, published by American Institute of Physics.
2. *Physics Education*, published by IOP Publishing Ltd.
3. *Resonance*, published by Indian Academy of Sciences
4. Other audio-visual online materials

PHY-S-507: Disaster Management

Course Learning Outcomes: On completion of the course, the students will be able to**:**

- understand different disasters that are beyond human control and the degree of damage possible by them.
- understand principles and practices that should be adopted to deal with disasters in general, prediction and warning, evacuation and rehabilitation etc.
- understand the technology for mitigation and handling of different kinds of disaster.

Course Contents:

Unit-1 Introduction

Hazard, Risk, Vulnerability, Disaster, types of disasters, Meaning, Nature, Importance, Dimensions and Scope of Disaster Management;
Hydrological Disasters - Flood, Flash flood, Drought, cloud burst;
Geological Disasters - Earthquakes, Tsunamis, Landslides, Avalanches, Volcanic eruptions, Mudflow;
Wind related Disasters - Cyclone, Storm, Storm surge, Tidal waves, Heat and cold Waves
Climatic Change - Global warming, Sea Level rise

Unit-2 Geographical Information System and IT in Disaster Management

Principles and Practices; concepts of Disaster management, Pre-and post-disaster management, Real time management, rehabilitation and long term disaster management
Prediction and warning system, preparedness, evacuation, Rescue and relief operation, rehabilitation and reconstruction, community disaster management, resilience, Definition of GIS, Concept of Space and Time, Spatial data, Map Projection and Datum, GIS Functionalities for end user / system (Data Acquisition, Data Input, Data Management, Data Analysis, Data Modeling and Data Output); Remote Sensing Application in Disaster Management, Communication System, Wireless Communication, Bluetooth Wireless Technology, HAM Radio, GPS Application in Emergency Communication.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation
- Use of different kinds of teaching practices through ICT

Assessment Framework

Internal Assessment (25marks)	End Semester Examination (25 marks)
Students will give a presentation of 20 minutes related to the course to be evaluated by course instructor.	Written examination of 1 hr consisting of short and long questions.

Suggested Readings:

1. Disaster Management, by Mrinalini Pandey. Publisher: Wiley, 2014.
2. Disaster Management, by R. Subramanian. Publisher: Vikas Publishing House, 2018.
3. Disaster Management, by Harsh K. Gupta, Publisher: Universities Press, 2003.
4. Thomas D Schneid; Larry Collins (2001) Disaster Management and Preparedness, Boca Raton, Fla.: Lewis Publishers.

5. Piers Blaikie, Terry Cannon, Ian Davis (2003) At Risk: Natural Hazards, People's Vulnerability and Disasters, Routledge.
6. W. Nick Carter, Disaster Management: A Disaster Manager's Handbook, 2008, Asian Development Bank.

PHY-S-508: ICT in Physics

Course Learning Outcomes: On completion of the course, the students will be able to

- learn the essential skills for creating a simple sensor-driven physical computing system in microcontrollers and microprocessors.
- reinforce their skills by making a simple interactive project.

Course Content:

Unit I:

Basic idea of microcontrollers, Basic terminology, Operating Arduino, Loading simple programs, Writing programs to blink the onboard LED, Creating simple temporal patterns, Program notation: variables, functions, control flow and Arduino conventions, delay functions, Analogue and Digital conversions, Data sampling, Using I/O pins.

Unit II:

Microprocessors and its different variations, Introduction to Raspberry Pi, Understanding of SoC architecture and SoCs used in Raspberry Pi, Pin description, On board components, Introduction to Raspbian Operating system, Sensor interfaces, Interfacing using C, IoT applications based on Raspberry, GPIO Control, Data communication using on-board module.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation
- Use of different kinds of teaching practices through ICT

Assessment Framework

Internal Assessment (25marks)	End Semester Examination (25 marks)
Students will make a presentation of 20 minutes related to the course to be evaluated by course instructor.	Written examination of 1 hr consisting of short and long questions.

Suggested Readings:

1. Basics of Arduino: https://www.arduino.cc/
2. Raspberry Pi Cookbook by Simon Monk.
3. The official raspberry Pi Projects Book, https://www.raspberrypi.org/magpi-issues/Projects_Book_v1.pdf

PHY-S-559: Laser Technology & Applications

Course Learning Outcomes: On completion of the course, the students will be able to**:**
- understand the fundamental concepts of laser physics
- understand different kinds of laser and their applications

Course Contents:

Unit1:
Laser fundamentals: Spontaneous and stimulated emission, absorption, Einstein's coefficients, active medium, population inversion, laser-pumping, laser gain, metastable state, condition for light amplification.
Types of Laser: Principle and working of different kinds of laser, gas laser, He-Ne laser, ion laser, semiconductor laser, Semiconductor diode lasers, LED versus Laser diode, continuous wave and pulse laser, narrowing of linewidth, threshold frequency.

Unit 2: Applications
Material processing with lasers, interaction mechanism, Lattice heating, Material processing mechanism. Applications of Laser in Medical Science and Optical Communication.

Suggested Teaching Learning Strategies
- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation
- Use of different kinds of teaching practices through ICT

Assessment Framework

Internal Assessment (25marks)	End Semester Examination (25 marks)
Students will make a presentation of 20 minutes related to the course to be evaluated by course instructor.	Written examination of 1 hr consisting of short and long questions.

Suggested Readings:
1. Laser Principles, Types and Application by KR Nambiar, New Age International.
2. Modern Spectroscopy by J Michael Hollas, Fourth Edition, John Wiley and Sons.
3. Lasers Theory and Applications by K. Thyagarajan and A.K. Ghatak, Mcmillan (1981)
4. Laser Fundamentals, by William T. Silfvast, Cambridge University Press, 2008.
5. Principles of Lasers, by Orazio Svelto; Springer, 2009.
6. Laser Spectroscopy and Instrumentation by W. Demtroder.
7. Industrial Applications of Lasers, by K. Koebner (ed.), Wiley (1984).

PHY-S-560: Microscopy Techniques

Course Learning Outcomes: On completion of the course, the students will be able to**:**

- account for optical principles of image formation in a light microscope and relate these principles to different microscopes.
- explain the principles for image resolution and brightness in light microscopy.
- choose a suitable objective/eye-piece depending on the specific application and understand concepts such as numerical aperture and working distance.
- use a microscope in practice.
- explain polarisation microscopy, atomic force microscopy (AFM), scanning electron microscopy (SEM) and transmission electron microscopy (TEM).
- judge information from scientific literature on advanced microscopy techniques.

Course Contents:

Unit 1 Basic Optics and Optical Microscopes

Nature of light, lenses, polarization. Image formation, Conjugate image and aperture planes. Kohler illumination. A standard microscope. Bright and dark field light microscopy.
Resolving Power and limit of Optical Microscopes; use of UV, X-rays and finally electrons.
Selection of objectives.
Digital microscopy and CCD cameras. Scanning confocal microscopy – theory and application. Image processing and analysis. Dark-field microscopy: optical design, theory, image interpretation. Polarization Microscopy: Design, theory, interpretation, Differential Interference Contrast: equipment and optics, interpretation, Modulation contrast microscopy: contrast methods using oblique illumination. Epifluorescence microscopy, Phase contrast microscopy, XPS

Unit 2 Other Microscopes

Interaction of electrons with matter, elastic and inelastic scattering, secondary effects.
Components of electron microscopy: Electron sources, pumps and holders, lenses, apertures, and resolution. Scanning Electron and Transmission Electron Microscopy: Principle, construction, applications and limitations.
Principles of STM, AFM etc. Comparison with standard microscopy, Microsocopy of living cells.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation
- Use of different kinds of teaching practices through ICT

Assessment Framework

Internal Assessment (25marks)	End Semester Examination (25 marks)
Students will make a presentation of 20 minutes related to the course to be evaluated by course instructor.	Written examination of 1 hr consisting of short and long questions.

Suggested Readings:

1. Fundamentals of Optics, F A Jenkins and H E White, McGraw Hill International Edition 1981.
2. Fundamentals of Light Microscopy and Electronic Imaging, Douglas B. Murphy, John Wiley & Sons, New York ISBN 0-471-25391-X.

PHY-S-561: Plasma Technology

Course Learning Outcomes: On completion of the course, the students will be able to**:**

- understand fundamental characteristics of plasma, various plasma generation methods, various applications of plasma technology in nanomaterial synthesis, energy production and storage, medicine/health care, etc.
- acquire comprehensive knowledge of how plasmas are utilized for different types of materials processing specially in nanotechnology and developing advanced materials

Course Contents:

Unit 1 Plasma Production Techniques Basics of Plasma, Debye length, Plasma sheath, Plasma frequency, DC discharges, Glow discharge, I-V characteristic of electrical discharge, Paschen curve, Arc discharge, Transferred and non-transferred arcs, RF discharge, Capacitively and inductively coupled plasmas, Microwave discharge, Vacuum arcs.
Basic plasma diagnostics: electric probes (single and double), Optical emission spectroscopy (basic idea), Laser based diagnostics

Unit 2 Industrial Plasma Processes

Etching, Plasma cleaning, Surfactants removal, Non transferred plasma torches, Plasma-Enhanced Chemical Vapor Deposition (PECVD), Physical vapor deposition (PVD), Pulsed laser deposition (PLD), Plasma nitriding
Arc plasma melting, Synthesis of nanomaterials (Al_2O_3 and SiC) by plasma reactor/furnace, Plasma cutting, Plasma Welding
Plasma waste processing (Plasma pyrolysis), Biomedical and health applications

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation
- Use of different kinds of teaching practices through ICT

Assessment Framework

Internal Assessment (25marks)	End Semester Examination (25 marks)
Students will give a presentation of 20 minutes related to the course to be evaluated by course instructor.	Written examination of 1 hr consisting of short and long questions.

Suggested Readings:

1. Principles of Plasma Discharges and Materials Processing, M. A. Lieberman and A. J. Lichtenberg (John Wiley and Sons, 2005)
2. Introduction to Plasma Physics and Controlled Fusion, 3rd edition, Francis F. Chen, (Springer, 2018)

3. Plasma Technology, B. Gross, B. Greyz and K. Miklossy, (Iliffe Books Ltd., London, 1968).
4. Handbook of Advanced Plasma Processing Techniques, Eds. R.J. Shul and S.J. Pearton.
5. Handbook of Plasma Processing Technology: Fundamental, Etching, Deposition and Surface Interactions, S. M. Rossnagel, J. J. Cuomo, W. D. Westwood, (Noyes Publications, 1990) SAP 4005 Plasma Processing of Materials.

PHY-S-615: Spectroscopic Techniques

Course Learning Outcomes: On completion of the course, the students will be able to

- understand the basic physics about the available spectroscopic technologies.
- understand various physical phenomenon which are utilised to probe the atomic and molecular systems using light.
- understand the spectroscopic techniques based on spin orientation and mass.
- interprete the data recorded by using the various spectroscopic techniques.

Course Content:

Unit-1: Optical Spectroscopy

Brief overview of Light matter interactions, Fluorescence-based spectroscopic Techniques: Theory, Instrumentations, Interpretations of data, Absorption-based spectroscopic Techniques: Theory, Instrumentations and analysis, Raman scattering based spectroscopic techniques: Theory, Instrumentation and Analysis

Unit-2: Spin and Mass Spectroscopy

NMR spectroscopy: Theory, Instrumentation and interpretation of data, ESR Spectroscopy: Basic Principle, Instrumentation and interpretation of data, Mossbauer spectroscopy: Basic Principle, Instrumentation and interpretation of data, Mass Spectroscopy: Theory, Instrumentation and Technique, Analysis

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation
- Use of different kinds of teaching practices through ICT

Assessment Framework

Internal Assessment (25marks)	End Semester Examination (25 marks)
Students will give a presentation of 20 minutes related to the course to be evaluated by course instructor.	Written examination of 1 hr consisting of short and long questions.

Suggested Readings:

1. Practical NMR Spectroscopy, M. L. Martin. J. J. Deepish and G. J. Martin, Heyden. 2. Spectrometric Identification of Organic Compounds, R. M. Silverstein, G. C. Bassler and T. C. Morrill, John Wiley. 3. Introduction to NMR spectroscopy, R. J. Abraham, J. Fisher and P. Loftus, Wiley.
2. Books from Biophysical techniques

PHY-S-616: Medical Physics

Course Learning Outcomes: On completion of the course, the students will be able to
- know about the different ideas and concepts of physics used extensively in medical work.
- learn how physics helps in medical diagnosis and treatment.

Course Content:

Unit 1. Nuclear Physics in Medicine
Basic concepts of nuclear physics, nuclear models, semi-empirical mass formula, interaction of radiation with matter, nuclear detectors, nuclear structure.
Radiation physics: radioactivity, radiation producing devices, different types of radiation (photons, charged and uncharged particles) and their interactions with materials.
Essentials of determination of absorbed doses from ionizing radiation sources used in clinical situations and for health physics purposes.
Introduction to instrumentation and physics used in clinical nuclear medicine and PET, with emphasis on detector systems, tomography.

Unit 2 Diagnostic Radiology and Radiotherapy Physics
Physics of medical imaging. Imaging techniques: radiography, fluoroscopy, computed tomography, mammography, ultrasound, magnetic resonance. Includes conceptual, mathematical / theoretical, and practical clinical physics aspects.
Review of x-ray production. Detailed analysis of radiation absorption and interactions in biological materials as specifically related to radiation therapy and radiation therapy dosimetry. Surveys of use of teletherapy isotopes and X-ray generators in radiation therapy plus the clinical use of interstitial and intracavitary isotopes. Principles of radiation therapy treatment planning and dose calculations.

Suggested Teaching Learning Strategies
- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation
- Use of different kinds of teaching practices through ICT

Assessment Framework

Internal Assessment (25marks)	End Semester Examination (25 marks)
Students will give a presentation of 20 minutes related to the course to be evaluated by course instructor.	Written examination of 1 hr consisting of short and long questions.

Suggested Readings:

1. B H Brown, R H Smallwood, D C Barber, P V Lawford and D R Hose, Medical Physics and Biomedical Engineering, Institute of Physics Publishing, Bristol and Philadelphia, USA, 1999.
2. John C Draper, A Textbook of Medical Physics, Lea Brothers and Company, Philadelphia, USA, 1885
3. Erika Garutti and Florian Grüner, Biomedical Physics, https://www.desy.de/~garutti/LECTURES/BioMedical/Lecture1_EG.pdf

PHY-S-617: Parallel Computing

Course Learning Outcomes: On completion of the course, the students will be able to

- appreciate different memory architectures, thread structures of shared as well as distributed memory computation.
- understand basic debugging and profiling tools and computation in shared and distributed memory platforms will also be taught.

Course Content

Unit I: Computation on Shared Memory Architecture
Basic concepts of parallel computing; The OpenMP execution model; Compiler directives, clauses, "sentinels" and pragmas; Data sharing of variables (shared, private, default); Race conditions; Constructs and Regions; Parallel loops, Parallel sections, Load balancing, Scheduling of parallel operations; Collapsing loops, Orphan directives, Environment variables; Hands-on and Optimisation.

Unit II: Parallel Computing on Distributed Memory
Memory classification, Message passing (MPI) vs shared memory (OpenMP) parallel computing ; Rank and size; error checking; MPI datatypes, Blocking communication, deadlocks and Non-blocking communication; Barriers, Broadcasts, Gathering and Scattering data; Constructing MPI datatypes for Fortran types and C structures.; Generating shell-scripts for HPC; Basic HPC commands; Hands-on, Performance optimisation tools and techniques.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation
- Use of different kinds of teaching practices through ICT

Assessment Framework

Internal Assessment (25marks)	End Semester Examination (25 marks)
Students will give a presentation of 20 minutes related to the course to be evaluated by course instructor.	Written examination of 1 hr consisting of short and long questions.

Suggested Readings:

1. Parallel Programming Patterns: Working with Concurrency in OpenMP, MPI, Java, and OpenCL – by Timothy G. Mattson, Berna Massingill and Beverly Sanders; Pearson Press
2. An Introduction to Parallel Programming with OpenMP, PThreads and MPI – by Robert Cook; Cook's Books (2011)
3. The OpenMP Common Core: Making OpenMP Simple Again (Scientific and Engineering Computation), by Timothy G. Mattson, Yun He, Alice E. Koniges; The MIT Press (2019)
4. Using MPI: Portable Parallel Programming with the Message-Passing Interface, by William Gropp, Ewing Lusk, Anthony Skjellum; The MIT Press (2014)
5. MPI: The Complete Reference, by Marc Snir, Jack Dongarra, Janusz S. Kowalik, The MIT Press

PHY-S-665: Scientific Methods & Writing

Course Learning Outcomes: On completion of the course, the students will be able to

- develop a strong understanding of research design principles and methodologies, gain the ability to select appropriate research designs based on research objectives, data availability, and constraints.
- demonstrate the skills to develop a comprehensive research plan and outline research questions that align with the chosen methodology.
- demonstrate the ability to apply these techniques to analyse complex datasets and draw meaningful conclusions from the results.

Unit 1: Introduction to Research Methodology:
Definition and objectives of Research, Introduction to some physics research topics and their progresses (brief review), selection of research problem, Hypothesis- Meaning, function and types of hypotheses, Research design: Types of research design- exploratory, descriptive, diagnostic and experimental. Statistics and its significance in research, Error Analysis, Introduction to some common softwares used in physics research (e.g. Density Functional Software, Molecular Dynamics Software, Electromagnetic Simulation Software etc.), Data Analysis, Origin/Excel.

Unit 2: Research Reports & Publication: Structure and component of research report, Types of reports, Lay-out of research reports, Preparing scientific reports: introduction to latex, GnuPlot and Sage/Mathematica/Matlab, Scientific Publication: Journals, Impact factors, h-index, i-index, g-index. Database: Indexing database, Citation database: Web of Science, Scopus etc. Ethics of Publication, copyrights and plagiarism, Patent writing and filing, Use of plagiarism software like Turnitin, Urkund and other open-source software tools.

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation
- Use of different kinds of teaching practices through ICT

Assessment Framework

Internal Assessment (25marks)	End Semester Examination (25 marks)
Students will give a presentation of 20 minutes related to the course to be evaluated by course instructor.	Written examination of 1 hr consisting of short and long questions.

Suggested Readings:

1. R.P. Mishra *Research Methodology: a handbook*, Concept Publishing Company, New Delhi, 2002.
2. Jonathan Anderson and M.E. Poole: *Assignment & Thesis Writing*, John Wiley, 2002.
3. S.D. Sharma: *A Textbook on Scientific and Technical Communication Writing for Engineers and Professionals,* Sarup and Sons, 2007.
4. Robert A. Dey and B. Gastel: *How to Write and Publish a Scientific Paper*, Cambridge, 2006

5. Thomas R. Mc Calla: *Introduction to Numerical methods and Fortran programming*, John Wiley & Sons, Inc. New York 1967.
6. Anthony Rabston: *A First course in Numerical Analysis,* McGraw Mill Co., New York 1965.
7. Evous, D.J*: Software for Numerical Methods*, Academic Press Inc. New York, 1974.
8. E.V. Krishnamurthy: *Numerical Analysis and algorithm*, Wiley Eastern, 1982.
9. D. C. Rapaprt : The art of Molecular Dynamics Simulation, Cambridge University Press, 2nd Edition, 2004.
10. Levent Sevgi: Electromagnetic Modelling and Simulation, Wiley-IEEE Press (2014)
11. David Sholi and Janice A Steckel, Density Functional Theory: A Practical Introduction, Wiley-Interscience, 1st Edition (2009).

PHY-S-666: Physics of Defense Application

Course Learning Outcomes: On completion of the course, the students will be able to

- understand the basic physics of navigation and communication systems for defence purpose
- understand laser and its applications in defence strategy.
- understand the importance of fluid dynamics in water and air based defence equipments.

Course Content:

Unit 1: Physics of Navigation and Communication Systems
Role of Physics in defense technology, Introduction on navigation and guidance systems, Understanding the Global Positioning System (GPS), GNSS (Global Navigation Satellite System), Mathematical modelling, Advanced capabilities of MATLAB & Simulink.
Free space optical communication, Fiber optics communication, Wireless/cellular communications. Analog and digital communications systems. Introduction to RADAR, Plasma RADAR, Radar parameters/definitions, radar equations. Radar cross section (RCS) & Theory of detection.
Unit 2: Physics of Aerospace and marine technology
Laser Communication: navigation, control, guidance. Types of military Lasers, Chemical Lasers, Solid State Lasers, Gas Lasers, Fibre Laser, Advantages of Laser weapons, Future trends.
Classification & mode of operation of various propulsion systems, Computational fluid dynamics (flow modelling strategies, physical modelling, finite difference equations, etc.)
Basics of Missile Physics, Classification of Missiles, Missile Aerodynamic Configurations, Effect of Curvature of Earth, Rotation of Earth, Variation of Gravity on Missile Trajectory.
Sea Water as Physical medium, thermodynamics of seawater, interaction of light and other em-waves with seawater, SONAR Technology, Physics of Submarine Technology

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation
- Use of different kinds of teaching practices through ICT

Assessment Framework

Internal Assessment (25marks)	End Semester Examination (25 marks)
Students will give a presentation of 20 minutes related to the course to be evaluated by course instructor.	Written examination of 1 hr consisting of short and long questions.

Suggested Readings:

1. "Satellite communication", by T. Pratt, C. W. Bostian, J. E.Allnut. Publisher: John Willey and sons
2. "Satellite Communications Systems: systems, techniques and technology", by G. Maral, M. Bousquet, Z. Sun. Publisher:John Willy and sons
3. "Digital Communications: Fundamentals and Applications", B. Sklar . Prentice-Hall, Inc.
4. "Introduction to Radar Systems",by M.I. Skolnik. Publisher: Tata Mcgraw hill edition, 2001.
5. "Radar Systems Analysis and Design using MATLAB",by B.R.Mahafza. Publisher CRC Press, 2013.
6. "High Power Laser-Matter Interaction", by Mulser, Peter, Bauer, Dieter. Publisher : Springer.
7. "An Introduction to Computational Fluid Dynamics: The Finite Volume Method" by H. Versteeg. Publisher : Pearson; 2nd edition.
8. "Modeling and Simulation of Systems Using MATLAB and Simulink" by Deven-dra K. Chaturvedi, Publisher: CRC Press, 2010

PHY-S-667: Machine Learning & Artificial Intelligence

Course Learning Outcomes: On completion of the course, the students will be able to

- learn the basic mathematical and computational tools of machine learning.
- familiarise with using public data-set, loading them in open-source ML tools categorise the data and test efficiency of their models.

Course Content:

Unit I: Basic concepts of Machine Learning
Philosophy of Artificial Intelligence; Machine Learning and its applications; Familiarisation with the numerical tools; Various training models; Linear regression theory; Gradient descent; Polynomial regression; Logistic regression; Image classification; Image processing; Text processing; Introduction to Genetic Programming

Unit II: Hands-on implementation on open-source platforms
Introduction to Computer Vision; Detecting Features in Images; Convolutions; Pooling; Implementing Convolutional Neural Networks; Using Public Datasets with TensorFlow Datasets; Recurrent Neural Networks

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation
- Use of different kinds of teaching practices through ICT

Assessment Framework

Internal Assessment (25marks)	End Semester Examination (25 marks)
Students will give a presentation of 20 minutes related to the course to be evaluated by course instructor.	Written examination of 1 hr consisting of short and long questions.

Suggested Readings:

1. Deep Learning with Python, François Chollet
2. AI and Machine Learning for Coders by Laurence Moroney
3. Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow, by Aurélien Géron
4. Genetic Programming, J R Koza
5. Fundamentals of Data Science - Theory & Practice, Kalita, Bhattacharyya, Roy; Academic Press, Elsevier, USA