SIKKIM UNIVERSITY

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

LEARNING OUTCOME - BASED CURRICULUM

PH.D. COURSEWORK IN PHYSICS

(With effect from Academic Session 2023-24)

DEPARTMENT OF PHYSICS

SIKKIM UNIVERISTY

6TH MILE, TADONG - 737102

GANGTOK, SIKKIM, INDIA

Preamble

The coursework for Doctor of Philosophy (Ph.D.) in physics is a one semester, 18 credit course. The course is designed to provide students a well-structured framework for learning advanced knowledge and skills in the research area of their interest. The department focuses research primarily on the following areas; Experimental Condensed Matter and Soft Material physics, Atomic, Molecular and Optical Physics, Laboratory and Space Plasma Simulations, Theoretical High Energy Physics.

Program Learning Outcome

PLO-1: Acquiring a comprehensive and deep understanding of the chosen discipline or field of study, including its theories, concepts, methodologies, and current research trends.
PLO-2: Developing advanced research skills, including the ability to critically analyze existing literature, identify research gaps, formulate research questions, design appropriate methodologies, collect and analyze data, and draw meaningful conclusions.
PLO-3: Enhancing critical thinking abilities to evaluate complex problems, develop innovative approaches, and make informed decisions based on evidence and logical reasoning.
PLO-4: Cultivating the capacity for independent inquiry and original research, demonstrating the ability to contribute new knowledge or insights to the chosen field through a doctoral dissertation or thesis.
PLO-5: Improving oral and written communication skills to effectively present research findings, engage in scholarly discussions, and disseminate research outcomes to both academic and non-academic audiences.
PLO-6: Developing skills for collaborative research and interdisciplinary work, including the ability to work effectively in teams, build professional networks, and engage in scholarly discussions with peers and experts in the field.
PLO-7: Understanding and adhering to ethical principles and professional standards in research, including issues related to plagiarism, data integrity, human subjects' protection, and responsible conduct of research.
PLO-8: Gaining experience and expertise in teaching, mentoring, and guiding undergraduate students, contributing to the education and professional development of future scholars in the field.

Course Structure

Course Code	Course Title	L-T-P	Credits	IA	EA	Total Marks
PHY-C-701	Research Methodology	3-1-0	4	50	50	100
PHY-C-702	Research and Publication Ethics	2-0-0	2	25	25	50
PHY-R-703	Research Proposal and Preparation	0-0-8	4	50	50	100
Elective I		3-1-0	4	50	50	100
Elective II		3-1-0	4	50	50	100
Total			18	225	225	450

For course PHY-C-702, students may earn the required credits of the course from MOOCs (Massive Open Online Courses) offered on SWAYAM (Study Webs of Active–Learning for Young Aspiring Minds) platform subject to the 75% matching of the course contents as verified by the SWAYAM coordinator of the department.

For Elective I and Elective II, students will have to choose any two courses from the following list.

List of Elective Papers

Course Code	Course Title
PHY-E-704	Atomic, Molecular and Optical Physics
PHY-E-705	Solid state Spectroscopy
PHY-E-706	High Energy Physics
PHY-E-707	Semiconductor Physics and Devices
PHY-E-708	Quantum Optics & Quantum Information Processing
PHY-E-709	Nonlinear Science: Solitons and Chaos
PHY-E-710	Magnetism and Superconductivity
PHY-E-711	Semiconductor Laser Physics
PHY-E-712	Solar Energy and its Utilization
PHY-E-713	Physics of Nanomaterials and Devices
PHY-E-714	Plasma Physics
PHY-E-715	Thin Film Technology
PHY-E-716	Quantum Field Theory

PHY-E-717	General Relativity and Cosmology
PHY-E-718	Nuclear Fission and Fusion
PHY-E-719	Introduction to String Theory

PHY-C-701: Research Methodology

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 analyze complex datasets and draw meaningful conclusions from the results.
- develop critical thinking skills to evaluate research findings and interpret the results in the context of the research objectives.
- learn how to assess the validity and reliability of research findings, identify potential biases or limitations, and make sound conclusions based on the data analysis.
- demonstrate the ability to synthesize and communicate the implications of research findings effectively.
- apply the learned research methodologies and computational analysis techniques to real-world research problems within the chosen field of study.
- demonstrate the ability to adapt and customize research methods to address specific research questions and challenges.
- showcase the capacity to use computational tools and techniques to solve complex problems and generate insights with practical implications.

Course Content

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.

Unit II: Numerical Techniques

Solution of polynomial and transcendental equations, ordinary differential equations with initial conditions, matrix algebra and simultaneous equations, eigenvalues and eigenvectors of a real symmetry matrix. Numerical differentiation and integration – trapezoidal rule – Simpson' rule – Gaussian quadrature formula. Numerical solution of ordinary differential equations solution by Taylor's series – Euler's method – Runge Kutta method with Runge's
coefficients. Numerical solution of partial differential equations using finite difference method.

Unit III: Data Analysis and Curve Fitting

Sources of Data, graphical representation of data, Interpretation of results.
Drawing conclusions and making inferences. Presenting data in tables.
Using graphs to visualize data. Data Analysis Softwares, Origin/ Excel etc.

Error analysis, Importance of sampling, Curve fitting – evaluation of linear parameters – weighted least square fitting – Binomial, Poisson, Normal distribution, Chi-square goodness of fit test, Random Spectral data analysis.

Unit IV: Technical Writing

Language of Science and technology, technical presentations design and delivery, collecting materials for research, organization of research paper/dissertation – symbols – the observations – tables and figures – equations – the style – sentence length – word length – page and chapter format – referencing.

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.
- students will have to present literature reviews on relevant topics of their choice of research fields to their peers and instructors.

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.	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. 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. S.S. Sastry: *Introduction methods of Numerical analysis,* Prentice Hall of India P. Ltd., 1977.
10. M.K. Jain: *Numerical analysis for Scientists &Engineers,* SBW Publishers, Delhi, 1971.

11. Kurt Binder and D.W. Heermann: *Monte Carlo Simulation in Statistical Physics: an Introduction,* Springer, 2010.

PHY-C-702: Research and Publication Ethics

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

- Understand the fundamental ethical principles and guidelines governing research and publication.
- Identify and address ethical challenges and dilemmas that may arise during the research process.
- Demonstrate knowledge of responsible conduct of research and research integrity.
- Understand the importance of data management, privacy, and confidentiality in research.
- Apply ethical guidelines to the process of authorship, acknowledgments, and peer review.
- Recognize and manage conflicts of interest in research and publication.

Course Outline:

Unit 1: Introduction

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, Ethical principles and guidelines in research and publication. Historical cases of research misconduct. The importance of ethics in maintaining scientific integrity. Responsible Conduct of Research. Understanding research misconduct and questionable research practices. Data fabrication, falsification, and plagiarism. Ethical considerations in experimental design and data analysis,

Unit 2: Authorship and Publication Ethics

Criteria for authorship and acknowledgments. Plagiarism and self-plagiarism. Duplicate publication and salami slicing. Peer Review and Editorial Processes. The role of peer review in ensuring research quality. Ethical responsibilities of peer reviewers and editors. Conflicts of interest in peer review. Conflicts of Interest and Research Funding. Identifying and managing conflicts of interest. Disclosure requirements in research funding. Balancing objectivity and financial considerations. Ethics in Data Management and Sharing. Data ownership and intellectual property rights. Patents.

Suggested-teaching learning strategy

- Lecture with interactive discussions and problem-solving activities.
- Assignments and individual presentations.
- Student-led classroom teaching.
- Group discussions.

Assessment Framework

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

Suggested Readings:

1. Research and Publication Ethics (2021) by Wakil Kumar Yadav
2. Research and Publication Ethics in Social Science 2nd Edition-2022. Sumanta Dutta.
3. Manual for Research Ethics Committees: Centre of Medical Law and Ethics, King's College London (2011) by Sue Eckstein (Editor)

PHY-R-703: Research Proposal and Preparation

Course Learning Outcomes: On completion of the course, the students will be able to
- conduct literature survey for the relevant topic(s) that he/she is interested in.
- understand the objective, concepts and methodologies to conduct research in the relevant field.
- understand essential elements of successful PhD study, including time management, ethical considerations, and academic writing skills.
- prepare synopsis or research proposal in the relevant field.

Course Content:
The students will have to identify the field of research proposal with consultation of the respective course supervisor. It will be followed the extensive literature survey, identifying the objectives of the research proposal. The methods and relevant tools to conduct the research have to be identified. The students will have to understand and develop the necessary techniques for that purpose. The research proposal should reflect scope for personal growth as a researcher and include next steps in the PhD research journey.

Suggested Teaching Learning Strategies
- One to one discussion with the course supervisor.
- Reading and presentation of relevant scientific articles.
- Learning the working of relevant experimental facilities and software.

Assessment Framework
The respective supervisor will have to continuously monitor the progress of the student. The final evaluation will consist of presentation and submission of the research proposal carrying 50 marks each, to the department. The student will have to review and revise their research proposal based on the feedbacks and ensure alignment with ethical guidelines and institutional requirements.

PHY-E-704: Atomic, Molecular and Optical Physics

Course Learning Outcomes: On completion of the course, the students will be able to
- learn about basics of lasers and resonators, distinguish between different interferometers,
- gain idea about physics of collisions and scattering phenomena,
- solve Schrodinger equation, differentiate between para and oath states and different types of couplings, Zeeman and Stark effect, different spectra of atoms
- learn different spectroscopy, such as NMR, ESR and Mossbauer.

Course Content:

Unit I: Introduction

Basic Optics: Fourier optics, two beam and multiple beam interference, Fabry-Perot interferometer. Interaction of radiation with matter, light amplification and gain saturation. Laser rate equations, three level and four level systems; Free electron laser, Optical

Resonators: resonator stability; modes of a spherical mirror resonator, mode selection; Qswitching and mode locking in lasers.

Atomic Collisions: Types of collisions, channels, thresholds, cross-sections, potential scattering, general features, Born approximation. Phase shift analysis (low energy), Atomic collisions in solids, nuclear and electronic stopping.

Unit II: One, two and many electrons' atoms

Schrodinger equation, para and ortho states, Pauli Exclusion Principle, Excited states, doubly excited states, Auger effect, resonance. Central field approximation, Thomas-Fermi model, Hartee-Fock method and self-consistent field, Hund's rule, L-S and j-j coupling.

Interaction with Electromagnetic fields: Selection rules, spectra of alkalis, Helium and alkaline earths, multiplet structure, Zeeman and Stark effect, Paschen-Back effect

Unit III: Molecular Structure and spectra

Molecular Structure: General nature, Born-Oppenheimer separation, rotation and vibration of diatomic molecules, electronic structure of diatomic molecules, structure of polyatomic molecules.

Molecular spectra: Rotational, vibrational, electronic spectra of diatomic molecules, electronic spin and Hund's cases and nuclear spin, Raman and Infra-Red spectrums.

Unit IV: Resonance Spectroscopy

NMR: Principle, chemical shift, shielding, relaxation process, chemical & magnetic nonequivalence, local diamagnetic shielding and magnetic anisotropy, spin splitting, Pascal triangle, coupling constant, mechanism of coupling, quadrupole broadening and decoupling. Effect of stereochemistry on the spectrum, shift reagent, applications

ESR: Principle and correlation with proton magnetic resonance, derivative curves, g values, hyperfine splitting, applications. PR of triplet states; Structural applications to transition metal complexes.

Mössbauer Spectroscopy: Principle, Spectral parameters (Isomer shift, electric quadrupole interactions, magnetic interactions), temperature-dependent effects, structural deductions for iron and tin complexes, applications. Basic concepts of FTIR and Raman and its applications to various materials

Suggested Teaching Learning Strategies

- Use of black /white board for explanation and derivation.
- Use of smart board for power point presentation.
- Use of ICT tools to show the molecular structure, spectra of diatomic molecules etc.

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.	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. H. Bransden and C. J. Joachain, *Physics of Atoms and Molecules,* Longman, 1996.
2. G. K. Woodgate, *Elementary Atomic Structure,* Clarendon Press, 1989.
3. F. L. Pilar, *Elemntary Quantum Chemistry,* McGraw Hill, 1990.
4. H. E. White, *Introduction to Atomic Spectra,* Tata McGraw Hill, 1934.
5. C. N. Banwell and E. M. McCash, *Fundamentals of Molecular Spectroscopy,* Tata McGraw Hill, 1994.
6. J. M. Hollas, *Modern Spectroscopy*, John Wiley & Sons, 2004.
7. C. N. Banwell and E.M. Mc Cash, *Fundamentals of Molecular Spectroscopy*, Tata McGraw Hill, 1994.
8. R.J. Abraham and J. Fishe and P. Loftus, *Introduction to NMR Spectroscopy* John Wiley & Sons, 1994.
9. J. A. Weil, J.R. Balton & J.E. Wertz, *Electron Paramagnetic Resonance: Elementary Theory and Practical Applications.* John Wiley and Sons, 1994.

PHY-E-705: 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-706: 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-707: 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-708: 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-709: 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-710: 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.

PHY-E-711: Semiconductor Laser Physics

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

- understand fundamentals of radiation-atom interaction and laser mechanism.
- understand the principle of semiconductor hetero-junction design, different techniques and physics of quantum wells and their characteristics.
- understand modelling of rate equations for laser mechanism.
- understand various uses of laser from home appliances to industrial applications.

Course Content:

Unit I: Introduction

Physics of interaction between radiation and atomic systems including: stimulated emission, emission line shapes and dispersion effects. Physics of semiconducting optical materials, degenerate semiconductors and their homojunctions and hetrojunctions. Light emitting diodes (LED's), Junction lasers. Characteristics of diode laser arrays and applications.

Unit II: Double Hetero Structure & Quantum Wells

Double Hetero Structure: Materials and growth techniques – brief outlook, electronic properties of heterojunctions, optical properties of hetero-junctions, lateral mode control.

Quantum Wells: Semiconductor multi quantum wells, density of states in 2-D systems, optical transitions, gain, strained quantum wells, optical and electrical confinement, strained layer superlattices (SLS)

Unit III: Diode Laser Modelling

Rate equations of idealised diode laser, gain compression, small signal rate equations,
real laser diodes: InGaAsP/InP quantum well lasers, three level rate equation models for
quantum well SCH lasers.

Unit IV: Applications of Laser

Application of lasers in data storage, communication and information technology: CD players, DVDs, laser printers, bar-code scanners, and optical communication; Surface profile and dimensional measurements using diffraction and its variations; High-power laser applications: marking, drilling, cutting, welding, and hardening; laser fusion; Laser Doppler velocimetry, LIDAR, laser spectroscopy, medical applications of lasers.

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.	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 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. D. Sands*: Diode Lasers,* Institute of Physics, UK, 2005.
2. S. Hooker and C. Webb: *Laser Physics*, Oxford University Press, 2010.
3. W. W. Chow and S. W. Koch: *Semiconductor Laser Fundamentals*, Springer-Verlag, 1999.
4. C. Hammaguchi: *Basic Semiconductor Physics*, Springer-Verlag, 2010.
5. K. Seeger: *Semiconductor Physics*, Springer-Verlag, 2004.
6. L. A. Coldren and S. W. Corzine : *Diode lasers and photonic integrated circuits*, John Wiley & Sons, Inc., 1995.
7. *Eli Kapon: Semiconductor lasers – Part – I., (Fundamentals),* Academic Press, 1999.
8. P. S. Zory Jr.: *Quantum Well Lasers*, Academic Press 1993.

PHY-E-712: Solar Energy and Its Utilization

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

- grasp the basic concepts of solar energy and it's storage mechanisms, study heat flow dynamics in different solar ponds,
- gain an idea about thermal radiation, radiation spectrum of black body, different heat transfer mechanisms,
- learn about solar thermal systems, heating and drying of agricultural products, photovoltaics, quantum dots, thin films of solar cells etc.

Course Content:

Unit I: Radiation & Energy Storage

Radiation Geometry: Basis earth sun angles - Determination of Solar time - Derived Solar angles - Day length - Solar Radiation measurements - selective surfaces - Heat balance energy lost by radiation, convection and conduction - Physical characteristics of selective surface - Anti reflection coatings - Solar reflector materials - production methods of coatings.

Energy storage and solar applications: Types of energy storage Thermal storage Latent heat storage – Electrical storage Principle of operation of solar ponds-Non convective solar ponds – Theoretical analysis of solar pond – solar distillation – solar cooking –solar pumping.

Unit II: Fundamentals of Heat Transfer

Transfer of Heat by Conduction: Study heat flow in a slab-steady heat flow in a cylindrical shell- Heat transfer through fins – Transient heat conduction.

Thermal Radiation: Basic laws of radiation – Radiant heat transfer between two black bodies- Radiant heat transfer between grey bodies.

Conduction heat loss Evaluation of convective heat transfer co-efficient –Free convection from vertical planes and cylinders – Forced convection – Heat transfer for fully established flow in tubes.

Unit III: Solar Thermal systems

General description of plate collector – thermal losses and efficiency of FPC –Energy balance equation – Evaluation of overall loss coefficient – Thermal analysis of flat plate collector and useful heat gained by the fluid performance of solar air heaters – Heating and drying of agricultural products Types of drier in use.

Solar concentrators and Receiver geometries – General characteristics of focusing collector systems Evaluation of optical losses – Thermal performance of focusing collectors.

Unit IV: Photovoltaics

Description of the photovoltaic effect – Electrical characteristics calibration and efficiency measurement – silicon solar energy converters – Thermal generation of recombination centers silicon. Role of thin films in solar cells, Quantum dots, Properties of thin films for solar cells CdSe, CeTe, InP, GaAs, CdCu2, CuIn SnO2, Cd2SnO4 ZnO)- Transport properties of metal films – poly crystalline film silicon solar cells (Photovoltaic characteristics, junction analysis loss mechanisms) Amorphous silicon solar cells (Structural compositional optical and electrical properties)

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.
- Encourage active participation, debate, and the exchange of diverse perspectives.

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 demonstrate their ability to critically analyze and interpret available results. Assessment will consider the clarity of explanations, logical reasoning, and the ability to relate the findings to underlying physical principles.	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. GD. Raj: *Solar energy utilization*, Khanna Publishers, New Delhi, 2005.
2. H.P. Garg and J Prakash: *Solar Energy: Fundamental and Applications,* Tata McGraw Hill, 2000.
3. Charles E.: *Solar cells,* IEEE Press, 1976.
4. K. L. Chopra and S. Ranjan Das: *Thin film solar cells,* Plenum, New York, 1983.

PHY-E-713: Physics of Nanomaterials and Devices

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

- understand physics of quantum dots and wells, and the basics of electron transport mechanisms.
- understand various methods for the fabrication of hetero-structure devices.
- understand the working principle of various photonic devices.
- understand various characterization techniques for nanomaterials.

Course Content:

Unit I: Physics of quantum dots & wells

Introduction, quantum dots, wires, wells. Density of states in 0, 1 & 2D.Growth of quantum dots – SK quantum dots – basics of semiconductor quantum dots –Electron photon scattering - Exciton dynamics in quantum dots – carrier relaxation in quantum dots – optical spectroscopy of single and multiple quantum dots – basics of metal quantum dots and their applications.

Infinite deep square wells – parabolic wells –triangular wells –sub-band formation in low dimensional system –occupation of sub-bands –quantum wells in hetero-structures, strained layer super-lattices – basics of tunneling transport – current and conductance – current in one dimension – current in two and three dimensions – basis of coherent transport

Unit II: Growth of hetero-structures

Growth of hetero-structures by MBE and MOCVD method – band gap engineering by swift heavy ion beam methods –modulation doping – 2DEG formation – Strained layers and its effect – wire and dot formation – optical confinement – effective mass approximation in hetero-structures – photon, electron and proton beam lithography methods –methods in the nanoscale device fabrication

Unit III: Photonic devices

Metal semiconductor contacts – space charge region – Schottky effect – ohmic contact –Basic microwave technology – tunnel diode – impatt diodes – transferred electron devices –quantum effect devices – light emitting diodes – basics of Solar cells – lasers and quantum well lasers, VCSEL, Plasmons.

Unit IV: Characteristics of Nanomaterials

Spectroscopy of nanomaterials, bulk, Raman Scattering, STS, TEM, SCM, XRD, Raman spectroscopy.

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 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. John H. Davies: *The Physics of Low dimensional semiconductors*, Cambridge University Press, 2000.
2. S. M. Sze: *Semiconductor devices: Physics and Technology*, John Wiley &Son, 2009.
3. Garnett W. Bryantand Glenn Solomon: *Optics of quantum dots and wires*, Artech House, 2005.
4. Marius Grundmann: *The Physics of Semiconductors: An Introduction including nanophysics and Applications,* Springer, 2010.
5. S. L. Chuang: *Physics of Photonic Devices*, John Wiley & Sons, 2009.
6. Paul Harrison, *Quantum Wells, Wires and Dots,* John Wiley & Sons, 2005.

PHY-E-714: Plasma Physics

Course Learning Outcomes: On completion of the course, the students will be able to
- learn about basic concepts of plasma, Debye screening, properties of plasma, single particle drifts in presence of electric and magnetic fields, fluid models to understand plasma dynamics,
- distinguish scenarios where kinetic and fluid models of plasmas to be applied to explain experimental features,
- grasp an idea about trapped particle and their corresponding effects in instabilities, discern between different resistivities and wave damping mechanisms in plasmas,
- gain an overview of current research on dusty plasmas, fusion plasmas, plasma confinement mechanisms in laboratory fusion devices, applications in space plasmas.

Course Content:
Unit I: Introduction
Introduction to plasma, definition, concept of temperature– Debye Shielding – The Plasma parameters – Criteria for Plasma.
Applications of Plasma physics (basis ideas) single – Particle motions; uniforms E and B fields – Gravitational field – Non uniform B fields – Gravitational field – Non – uniform B field – Curve B - magnetic mirrors non-uniform E filed Time – varying B field – Adiabatic Invariants.
Unit II: Fluid Models
Fluid theory in plasma, Fluid equations of motion, single fluid magneto-hydrodynamics, magnetic Reynolds number, magnetic equilibrium-the concept of beta, diffusion, resistivity and collision in plasma, Fokker-Plank equation
Waves in Fluid Plasma: Representation of waves – Group velocity – plasma Oscillations –Waves in unmagnetized plasmas – Electron Plasma waves-Langmuir waves and oscillations-ion sound waves, high frequency electromagnetic waves in unmagnetized plasma.
Unit III: Kinetic Theory & Plasma Instabilities
Kinetic Theory: Need for Kinetic theory, $f(v)$ equations by kinetic theory, Vlaslov equations, kinetic effects on plasma waves and in a magnetic field, Landaus treatment, BGK and van Kampen modes – Experimental verification.
Plasma Instabilities: Instability in plasma; streaming instability, ion drag force induced, drift wave instability and parametric instability.
Chaos and time series analysis; Fourier theory, Liapunov exponent, Attractors, self-similarity, Hurst exponent and Fractal dimension
Unit IV: Applications
Waves in space-plasma, plasma turbulence and particle heating. Fundamentals of plasma processing. Gas discharge processes, dc discharge, rf discharge, capacitive and inductively coupled plasma systems, theory and description of different plasma production systems, Dusty plasma. Introduction to controlled thermonuclear fusion, magnetic confinement; Tokamak, Spheromak and ITER.

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.
- Organize seminar-style discussions where students can present and critically analyze research papers, case studies, or theoretical frameworks relevant to the coursework.

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 provide a written explanation of their class learning and their interpretation. They will demonstrate their understanding of underlying physical concepts and their ability to draw logical conclusions based on the theories taught in class.	Students will demonstrate their ability to critically analyse and interpret experimental results. Assessment will consider the clarity of explanations, logical reasoning, and the ability to relate the findings to underlying physical principles.	Written examination of 3 hours duration with questions of 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-715: 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-716: Quantum Field Theory

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

- gain an understanding of field theoretic description of scalar, vector and spinor fields, Klein-Gordon theory, it's Lagrangian formulation, Gauge fixing, kernels and propagators, Feynman diagram
- learn about Hamiltonian formulation of field theory, quantum electrodynamics and radiative corrections,
- grasp an idea of renormalization, critical exponents and Wilson renormalization, non-Abelian gauge gauge invariance, quantum chromodynamics, spontaneous symmetry breaking and Higgs mechanism.

Course Content:

Unit I: Introduction

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

Spinor & Vector Fields: 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 to show the 3D configurations of the models, observations and instruments.
- Organize seminar-style discussions where students can present and critically analyze research papers, case studies, or theoretical frameworks relevant to the coursework.

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. F. Mandl and G. Shaw: *Quantum Field Theory*, Wiley, 1992.
2. T. P. Cheng and L.-F. Li: *Gauge Theory of Elementary Particle Physics*, Oxford University Press, 1984.
3. S. Pokorski: *Gauge Field Theories*, Cambridge University Press, 2000.
4. L. H. Ryder: *Quantum Field Theory*, Cambridge University Press, 1996.
5. D. Bailin and A. Love: *Introduction to Gauge Field Theory*, IOP Publishing, Graduate Student Series in Physics, 1986.
6. F. Mandl and G. Shaw: *Quantum Field Theory*, John Wiley, 2009.
7. P. B. Pal and A. Lahiri: *A First Book of Quantum Field Theory*, CRC Press, 2001.
8. M. E. Peskin, D. V. Schroeder: *An Introduction to Quantum Field Theory*, Addison-Wesley, 1995.

PHY-E-717: General Relativity and Cosmology

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

- understand basics of general relativity, Einstein field equations and applications.
- understand different types of black holes, their characteristic features and thermodynamics.
- understand big bang model of cosmology and the origin of CMB radiation.
- understand inflation model of cosmology and structure formation in the cosmos.

Course Content:

Unit I: Tensor Analysis

Elements of tensor analysis, Affine transplantation of tensors, concept of the metric tensor and geodesics, Curvature, Reimann Tensor and its properties, Energy Momentum tensor, Ricci Tensor and Einstein tensor. Einstein Equations. Newtonian limit.

Unit II: General Relativity

Foundations of general relativity, Schwarschild solution and its consequences. Schwarzschild and Kerr space times, black hole physics, gravitational radiation, gravitational lensing, cosmological models, observational tests, the early universe, the microwave background, formation of structured dark matter and dark energy, Hawking radiation.

Unit III: Cosmology I

Galaxies and the expanding Universe; Hubble's Law; the age of the Universe; the Big Bang; cosmic microwave background (blackbody radiation); big bang nucleo-synthesis (cosmic abundances, binding energies, matter & radiation).

Unit IV: Cosmology II

Introductory cosmology (the cosmological principle, homogeneity and isotropy, Olber's paradox); cosmological models (critical density, geometry of space, the fate of the Universe); cosmological constant, dark energy and the accelerating Universe.

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, observations 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 present their learnings 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. Steven Wienberg, *Cosmology,* Oxford University Press, 2008.
2. Robert M Wald, *General Relativity*, University of Chicago Press, 1984.
3. Landau, L.D. & Lifshitz, E.M.: *The Classical Theory of Fields*, 2nd ed., Pergamon Press, 1995.
4. Hartle, J. B.: Gravity: *Introduction to Einstein's General Relativity*, Pearson Education, 2003.
5. Peebles, P.J.E.: *Principles of Physical Cosmology*, Princeton University Press, 1993.

PHY-E-718: Nuclear Fission and Fusion

Course Learning Outcomes: On completion of the course,
- The student will be able to understand the basic working principle of different fission reactors, distinguish the underlying physics of different fusion reactors world-wide.
- They will be able to estimate the capacity of different nuclear weapons and its direct and long-term effects.
- Stress will be given on the coherent world venture to harness the nuclear fusion energy for production of electricity from terrestrial reactors.
- Students will also be exposed to cutting edge research problems on industrialization of nuclear fusion reactors.

Course Content:
Unit I: Nuclear Fission: Theory
Neutron interactions with matter, Cross section, Beam attenuation, Radiative absorption; Neutron energy distribution, Logarithmic energy decrement, Four-factor formula, Neutron flux spectrum, Fast reactors; Neutron spatial distribution, spatial diffusion equation, Critical mass of uranium sphere and enrichment; Time-dependent phenomena and reactor safety, Reactor stability; The nuclear fuel cycle, Enrichment, Burnup, Interim storage.

Unit II: Nuclear Fission: Applications
Nuclear weapons; Direct effect of nuclear war; Long term effect of nuclear war; Estimation of capacity of nuclear weapons; History of nuclear proliferation, Proliferation risks; Advanced reactor design, Generation III and III+ and IV reactors, Thorium cycle, Breed and burn in place.
Unit III: Nuclear Fusion: Theory
Fusion reactions, Power and particle balance; Particle motion, Passing and trapped orbits, Bootstrap current; Plasmas as fluids, Plasma control; Macroscopic stability, Ideal MHD modes, Ballooning and kink modes; Collisions and their effects; Turbulent transport, Bohm and GyroBohm diffusion, Transport barriers, Global scaling.
Unit IV: Nuclear Fusion: Applications
Nuclear fusion via magnetic confinement; Mirrors, Helimacs, Q-machines, Stellarators, Tokamaks; Divertors and scrape-off-layers, Edge localized modes; Neutron interactive materials; Blankets, safety, waste and proliferation; Inertial fusion energy; Power plant concepts, development path and deployment

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, observations and instruments.
- Teach students advanced reading and writing techniques to critically evaluate scholarly articles, develop coherent arguments, and synthesise complex ideas.

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.	Students will provide a written explanation of their class learning and their interpretation. They will demonstrate their understanding of underlying physical concepts and their ability to draw logical conclusions based on the theories taught in class.	Written examination of 3 hours duration with questions of objective, short and long questions.

Suggested Readings:
1. Theory of Nuclear Fission, by H J Krappe; K Pomorski, Springer, 2012.
2. Nuclear Reactor Engineering: Reactor Design Basics, by S. Glasstone, A. Sesonske, Springer, 2014.
3. Nuclear Energy: Principles, Practices and Prospects, by D. Bodansky, Springer (2005)

4. Plasma Physics and Fusion Energy, by Jeffrey P. Freidberg; Cambridge University Press, 2010.
5. Methods in Nonlinear Plasma Theory, by Ronald C Davidson, Elsevier, 1972.

PHY-E-719: Introduction to String Theory

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

- understand relativistic strings and various approaches of its quantization.
- Have a clear idea about open strings and D-branes, its quantization and the necessary machinery of conformal field theory.
- understand it from the viewpoint of Polyakov path integrals and the string interactions.
- Understand the effective theories which make connections to Einstein equations and other aspects as well as have a notion of compactification, T-duality and mirror symmetry

Course content:
Unit 1:
Introduction and motivations
Relativistic string: Relativistic point particle, quantization; Nambu-Goto action, symmetries, equations of motion; Polyakov action, symmetries, gauge fixing; mode expansions.
Quantum string: Covariant quantization, ghosts, constraints; lightcone quantization, lightcone gauge; String spectrum, tachyon, excited states; Lorentz invariance.
Unit 2:
Open strings and D-branes: Quantization, ground state and excited states, higher excite states, Regge trajectories; Brane dynamics, Dirac action, multiple branes.
Conformal field theory: Euclidean space, holomorphy; Stress energy tensor, Noether currents, example of free scalar field. Operator product expansion, Ward identities, primary operators; Example of free scalar field. Radial quantization, Virasoro algebra, central charge, representations of Virasoro algebra.
Unit 3:
Polyakov path integrals: The path integral, Fadeev-Popov method, ghosts, critical dimension; states and vertex operators examples of closed strings and open strings in flat space.
String interactions: Tree level amplitude, closed string,scattering, Virasoro-Shapiro amplitude, Open string scattering, Veneziano amplitude; One-loop amplitudes, Moduli space of torus, one-loop partition function, finiteness of string theory.
Unit 4:
Low energy effective action: Einstein equations, beta function and Ricci flow; charged strings, B-field, dilaton; effective action, string and Einstein frame, corrections to Einstein's equations; Simple solutions, compactification, string, magnetic branes.
D-brane, beta function, Born-Infeld action, Dirac-Born-Infeld action, coupling to closed string; D-branes in type II superstring theory.

Compactifications and T-duality: Spacetime perspective, world-sheet perspective, massless states, enhanced gauge symmetries. T-duality: Path integral derivation, T-duality for open string, T-duality for superstrings, Mirror symmetry.

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 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.	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. String Theory: An Introduction to the Bosonic String by Joseph Polchinski, (Cambridge Monographs on Mathematical Physics), Cambridge University Press, 2005 Volume 1 and 2.
2. Superstring Theory by Michael B. Green John H. Schwarz and Edward Witten, Cambridge Monographs on Mathematical Physics, Cambridge University Press (2012), Volumes 1 and 2
3. Lectures on String theory, David Tong, (2009) available at url: https://www.damtp.cam.ac.uk/user/tong/teaching.html

4. First Course In String Theory, by Barton Zwiebach Cambridge University Press (2009) 2nd edition
5. String Theory and M-Theory: A Modern Introduction by Katrin Becker, Melanie Becker and John H. Schwarz, Cambridge University Press (2006)
6. String Theory in a Nutshell: by Elias Kiritsis, Princeton University Press; 2nd edition (2019)
7. Conformal Field Theory, by P D Francesco, P Mathieu and D Senechal, Graduate Texts in Contemporary Physics, Springer, 2011.
8. D-Branes by Clifford V. Johnson, (Cambridge Monographs on Mathematical Physics), Cambridge University Press (2002)

String Theory on the Web

1. Video Lectures on String Theory by Shiraz Minwalla.
2. String Theory by Angel Uranga.
3. Applied Conformal Field Theory by Paul Ginsparg.
4. Sigma Models and String Theory TASI Lectures by Curt Callan and Lárus Thorlacius. (Warning: this link directly downloads a large pdf file of about 45 Mb)
5. What is String Theory? by Joe Polchinski.
6. Errata for Joe Polchinski's String Theory Book.