UNIVERSITY OF KERALA

Syllabus for

M.Sc. Degree Program in Physics with Specialization in Nanoscience

(With effect from 2020 admissions)

UNIVERSITY OF KERALA

M. Sc Degree Program in Physics (with Specialization in Nanoscience)

Objectives: Major objective of the M. Sc Physics program of University of Kerala is to equip the students for pursuing higher studies and employment in any branches of Physics and related areas. The program also envisages developing thorough and in-depth knowledge in Mathematical Physics, Classical Mechanics, Quantum Mechanics, Statistical Physics, Electromagnetic Theory, Nuclear Physics, Atomic and Molecular Spectroscopy and Electronics. The program also aims to enhance problem solving skills of students so that they will be well equipped to tackle national level competitive exams. The program also acts as a bridge between theoretical knowhow and its implementation in experimental scenario. Since the specialization of this program is nanoscience it covers basic ideas of nanostructured materials, physics of nanosolids and nanoelectronics. The program also introduces the students to the scientific research approach in defining problems, execution through analytical methods, systematic presentation of results keeping in line with the research ethics through M. Sc dissertations.

Program Outcome

(i) Define and explain fundamental ideas and mathematical formalism of theoretical and applied physics.

(ii) Identify, classify and extrapolate the physical concepts and related mathematical methods to formulate and solve real physical problems.

(iii) Identify and solve interdisciplinary problems that require simultaneous implementation of concepts from different branches of physics and other related areas.

(iv) To define and explain fundamental ideas of size effect in materials science and propose new applications of nanoscience and nanotechnology.

(v) To define a research problem, translate ideas into working models, interpret the data collected draw the conclusions and report scientific data in the form of dissertation.

(vi) To disseminate scientific knowledge and scientific temper in the society to contribute towards greater human cause.

UNIVERSITY OF KERALA

M. Sc, Physics (with Specialization in Nanoscience)

(Effective from 2020 admissions)

A: COURSE STRUCTURE & MARK DISTRIBUTION

Semester	Paper Code	Title of Paper	Contact hours per week			UE duration (h)	Maximum marks		
			L	T	P		IA	UE	Total
I	PH 211	Classical Mechanics	6	1	…	3	25	75	100
	PH 212	Mathematical Physics	6	1	…	3	25	75	100
	PH 213	Basic Electronics	6	1	…	3	25	75	100
	PH 251	General Physics Practicals	…	1	3	…	…	…	…
	PH 252	Electronics & Computer Science Practicals	…	1	4	…	…	…	…
	Total for Semester I (S1)		18	5	7	…	75	225	300
II	PH 221	Modern Optics & Electromagnetic theory	6	1	…	3	25	75	100
	PH 222	Thermodynamics, Statistical Physics & Basic Quantum Mechanics	6	1	…	3	25	75	100
	PH 223	Computer Science & Numerical Techniques	6	1	…	3	25	75	100
	PH 251	General Physics Practicals	…	1	3	6	25	75*	100
	PH 252	Electronics & Computer Science Practicals	…	1	4	6	25	75*	100
	Total for Semester II (S2)		18	5	7	…	125	375	500

III	PH 231	Advanced Quantum Mechanics	6	1	…	3	25	75	100
	PH 232	Atomic and Molecular Spectroscopy	6	1	…	3	25	75	100
	PH 233	Condensed Matter Physics	6	1	…	3	25	75	100
	PHN 234	Nanostructured Materials	7	1	…	3	25	75	100
	Total for Semester III (S3)		25	4			100	300	400
IV	PH 241	Nuclear & Particle Physics	6	1	…	3	25	75	100
	PHN 242	Physics of Nanosolids	5	1	…		25	75	100
	PHN 243	Nanoelectronics	5	1			25	75	100
	PHN 244	Lab: Nanoscience	…	…	5	6	25	75*	100
	PHN 245	Project	…	…	4	…	25	75	100
	PHN 246	Viva voce	…	…	…	…	…	100	100
	Total for Semester IV (S4)		16	3	9	…	125	475	600
Grand Total							**425**	**1375**	**1800**

* 10 marks for records

L - Lecture IA - Internal Assessment

T - Tutorial UE - University Exam

P - Practical

B: SPECIAL COURSES FOR THIRD AND FOURTH SEMESTERS

Sl. No	Specialization	Code Nos of Special Papers	Name of Special Papers
1	Nanoscience	PHN 234 PHN 242 PHN 243 PHN 244	Nanostructured Materials Physics of Nanosolids Nanoelectronics Lab. Nanoscience

C: GENERAL GUIDELINES

C-1**Theory papers**

Books of study and corresponding chapters are given for most of the theory papers in the syllabus to define the scope of the syllabus.

For internal evaluation of theory papers at least one Viva must be conducted for each paper

For assignments and seminars current developments in the areas of the syllabus may be chosen for improving the general awareness of the student

In tutorial sessions of theory papers problem solving in different topics of the syllabus may be discussed.

C-2**Lab Courses**

Rough records may be properly maintained for each practical paper and should be produced during the University Practical Examinations along with original record book.

Each student is encouraged to include critical comments on each experiment done in the original records including sources and estimates of errors, limitations in the experiments done and scope for improvements/additions in the experimental work.

In performing Electronics Practicals: Bread Board Practice is recommended in addition to soldering of electronic circuits.

C3-Project work and Project Evaluation

The project work should be carried out in the area of nanoscience or related areas. The project may be started during the third semester of the M.Sc programme. 25 marks of the project are to be awarded on the basis of internal assessment carried out in the College for each student concerned. A Project rough record may be maintained by each student to help to evaluate the progress of the project. Each student is required to present the completed project along with experimental demonstration if any in the college before the final University examinations in the Fourth Semester of the MSc (Physics) Programme.

For University Examinations for the Project: 50 marks is allotted for Project report evaluation and 25 marks allotted for Project based Viva Voce to be conducted along with General Viva Voce examination by the University.

D Pattern of University Question papers **D-1**

Theory Papers

Each question Paper has three parts: Part A, Part B and Part C

Part A: Eight short answer questions covering the entire syllabus. *One of the questions from this section may be used to test the CURRENT AWARENESS (general knowledge) of the student in the areas of syllabus covered for this paper.* Each question carries 3 marks.

Part B: contains three compulsory questions with internal choice. Questions cover all the three units in the syllabus. Each question carries 15 marks.

Part C: contains six problems covering the entire syllabus. The student needs to answer any three. Each question carries five marks.

The question paper pattern for the theory papers is given separately.

D-2 PRACTICALS

Each practical paper carries a total of 75 marks. 10 marks are allotted for practical records.

PH 251 General Physics Practicals (6h): Section A (45 marks) and Section B (20 marks)

PH 252: Electronics and Computer Science (6h): Unit A-Electronics practical (45 marks)

Unit B- Computer Science (20 marks)

PHN 244: Lab: Nanoscience (5h) (65 marks)

PHN 245 Project: Internal Evaluation for project is 25 marks

For University Examinations: 50 marks for Project Dissertation/report evaluation and 25 marks for Project based Viva Voce

PHN 246 General Viva Voce: For General Viva Voce covering the entire MSc Syllabus,

University Examinations: 100 marks

(University Question Paper pattern given separately)

Question Paper Pattern

MSc Degree Examination

Branch II PHYSICS

PH.. 2xy……………………………………………

Duration: 3 hours **Maximum marks: 75**

Instructions to question paper setter

1. Each question paper has three parts - Part A, Part B and Part C
2. Part A contains eight short answer questions spanning the entire syllabus, of which the candidate has to answer any *five* question carries *three* marks.
3. Part B contains *three* compulsory questions with internal choice. Each question shall be drawn from each unit of the syllabus. Each question carries 15 marks
4. Part C contains six problems spanning the entire syllabus. The candidate has to answer any *three*. Each question carries *five* marks

PART A

(Answer any five questions. Each question carries three marks)

1.

2.

3.

4

5.

6.

7.

8.

(5 x 3 = 15 marks)

PART B

Answer three questions each question carries 15 marks

9 (a)

(b)

OR

10 a) (15 marks)

(b)

11 a)

(b)

OR

12 a) (15 marks)

b)

13 a

b

OR

14 a)

b) (15 marks)

Part C

(Answer any three questions. Each question carries five marks)

16

17

18

19

20

21

(3 x 5= 15 marks)

PH 211: CLASSICAL MECHANICS (6L, 1T)

Objectives: This course is aimed to provide basic and advanced concepts in classical mechanics. The course discusses Lagrangian and Hamiltonian formalisms, central force problems, theory of small oscillations, Hamilton -Jacobi equations, Kepler's problem, Rigid body dynamics and Euler's equations, Concepts of special and general theory of relativity, Non linear dynamical systems and chaos.

Unit I

Lagrangian Mechanics (12 hours)

Mechanics of a particle and system of particles- constraints- D'Alemberts principle and Lagrange's equations-simple applications of Lagrangian formulation-Hamilton's principle-techniques of calculus of variations-derivation of Lagrange's equations from Hamilton's principle-conservation theorems and symmetry properties

Two body central force problem (14 hours)

Reduction to one body problem-equations of motion-equivalent one dimensional problem-differential equation for the orbit in the case of integrable power law potentials- Virial theorem- Kepler's problem-inverse square law of force-scattering in central force field-transformation of the scattering problem to laboratory coordinates

Theory of small oscillations (10 hours)

Equillibrium and potential energy-theory of small oscillations-normal modes- two coupled pendula- longitudinal vibrations of carbon dioxide molecule

Unit II

Hamiltonian Mechanics (12 hours)

Generalised momentum and cyclic coordinates-conservation theorems-Hamilton's equations-examples in Hamiltonian dynamics (harmonic oscillator, motion of a particle in a central force field, charged particle in an electromagnetic field, compound pendulum)- canonical transformations-generating functions- poisson brackets- Liouoville's theorem

Hamilton-Jacobi equations (10 hours)

Hamilton-Jacobi equation-harmonic oscillator as an example-separation of variables in Hamilton-Jacobi equation-action angle variables-Kepler's problem

Rigid body dynamics (14 hours)

Generalised coordinates of rigid body-Euler's angles- infinitesimal rotations as vectors-angular momentum and intertia tensor- Euler's equations of motion of a rigid body-force free motion of symmetrical top-motion of heavy symmetrical top.

Unit III

Special and General Theory of Relativity (16 hours)

Postulates of special theory- four-vectors and tensors- relativistic particle dynamics- Lorentz transformations -relativistic Lagrangian- mass-energy equivalence- covariant Lagrangian, Relativistic Langrangian, Mass energy equivalence.

General theory of relativity principle of equivalence applications - ideas of Riemannian geometry-space time curvature geodesics –Einstein's equations of General theory of relativity, Observational evidence to general theory of relativity.

Introduction to non-linear dynamics (10 hours)

Linear and nonlinear systems-integration of second order non-linear differential equations-pendulum equation-phase plane analysis of dynamical systems-linear stability analysis-limit cycles

Elements of classical chaos (10 hours)

Bifurcation- logistic map-strange attractors- Lyapunov exponent and Chaos-ideas of fractals- solitary waves- Kdv equations and solutions

Course Outcome

(i) Students are able to learn the concepts of Lagrangian and Hamiltonian mechanics and use them to solve problems in mechanics. Able to learn concepts of generating functions, Poisson brackets Hamilton Jacobi equations and action angle variables.

(ii) To equip the students to deal with central force problem and analyzing Kepler's laws.

(iii) To inculcate the students the concepts of special and general theory of relativity and related problems.

(iv) To acquaint the students about the theory of small oscillations and Euler's equations of motions of rigid bodies.

(v) To analyze nonlinear dynamical systems and to explain the concepts of classical chaos.

Books for study

a. H. Goldstein, C.Pooleabd S. Safko, *Classical Mechanics*,3rd Edn, Pearson Education Inc (2008 Print)
b. V.B. Bhatia, *Classical Mechanics with introduction to nonlinear oscillations and chaos*, Narosa Publishing House (1997)
c. J.C. Upadyaya, *Classical Mechanics*, Revised Edition, Himalaya Publishing Company (2005)
d. G. Aruldas, *Classica lMechanics*, Prentice Hall of India Pvt Ltd (2008 Print)
e. K.D.Krori, *Fundamentals of Special and General Relativity*, PHI Learning Pvt Ltd (2010)
f. S.K. Srivastava, *General Relativity and Cosmology*, PHI learning Pvt Ltd (2008)
g. P.G Drazin and R.S Johnson, *Solitons – an Introduction*, Cambridge University Press (1989)

References

1. N.C. Rana and B.S. Joag, ClassicalMechanics,TataMcGrawHill (1991)
2. M. Tabor Chaos and integrability in nonlinear dynamics,Johnwiley& Sons (1989)
3. R.K. Pathria, The Theory of Relativity, Second Edition, Over Publications (2003)

PH 212: Mathematical Physics (6L, 1T)

Objectives: This course is aimed to equip the students with the mathematical techniques used for developing strong back ground in the basic and advanced level problems. The course describes about curvilinear coordinates, Fourier series and transforms, probability distributions, partial differential equations and different integral transforms, special functions, tensors and group theory.

Unit I

Vector analysis and matrices (8 hours)

Review of vector analysis-vector calculus operators-orthogonal curvilinear coordinates-gradient, divergence, curl, Laplacian in cylindrical and spherical polar coordinates-orthogonal and unitary matrices- Hermitian matrices- diagonalization of matrices- normal matrices- Cayley-Hamilton theorem

Complex analysis (8 hours)

Cauchy-Riemann conditions-Cauchy's integral theorem and formula-singularities and mapping-calculus of residues-dispersion relations

Fourier series and applications (8 hours)

General principles of Fourier series, Complex representation, Parseval's identity, Fourier's Integrals, Fourier transforms and its properties.

Probability (12 hours)

Definitions and simple properties of probability-random variables- Chebychev inequality and moment generating function-discrete and continuous probability distributions-binomial distributions- poisson distributions- Gauss Normal distribution-error analysis and least square fitting-chi-square and student 't' distributions

Unit II

Differential equations (16 hours)

Partial differential equations-first order equations-separation of variables-singular points-series solutions and Frobenius method- non-homogeneuous partial differential equations-Green's functions-Laplace transforms and inverse Laplace transforms-applications to solution of simple differential equations

Special functions (20 hours)

Bessel functions of the first kind-orthogonality-Neumann functions-Hankelfuctions-modified Bessel functions-spherical Bessel functions-Legendre functions-generating function-recurrence relations and orthogonality-associated Legendrefunctions-spherical harmonics-Hermite functions-Lagurerre functions-Chebyshev polynomials-hypergeometric functions

Unit III

Tensor analysis (18 hours)

Notations and conventions in tensor analysis-Einstein's summation convention-covariant and contravariant and mixed tensors-algebraic operations in tensors-symmetric and skew symmetric tensors-tensor calculus- Christoffel symbols-kinematics in Riemann space-Riemann- Christoffel tensor.

Group theory (18 hours)

Definitions of a group-elementary properties-sub groups-homomorphism and isomorphism of groups-representation of groups-reducible and irreducible representations-simple applications in crystallography and molecular symmetry- Lie groups- SU(2) groups and their representations

Course Outcome

(i) To apply and analyze the various vector and matrix operations and to perform complex analysis for solving physical problems.
(ii) To demonstrate and utilize the concepts of Fourier series and its transforms.
(iii) To explain and differentiate different probabilistic distributions.
(iv) To apply partial differential equations and special functions for solving mathematical problems.
(v) To illustrate and apply concepts of group theoretical operations and tensors.

Books for study

1. G.B. Arfken and H.J. Weber, *Mathematical methods for Physcisits*,6th Edition,Elsavier (2005).
2. H.K. Dass and R. Verma, *Mathematical Physics*, S.Chand & Co Pvt Ltd (1997)
3. A.W. Joshi, *Matrices and Tensors in Physics*,3rd Edition,New Age International Pub (1995)
4. B.D. Gupta, *Mathematical Physics*, 4th Edition, Vikas Publishing House (2004)
5. A.W. Joshi, *Elements of Group Theory for Physicists*, Fourth Edition, New Age International Pub (1997).
6. S.C. Bagchi, S.Madan, A, Sitaram,V.B Tewari, *A first course in representation theory and linear Lie groups*, Universities Press (India) Pvt Ltd (2000).
7. C. Harper, Introduction to Mathematical Physics, Prentice Hall (1986)

References

1. Harry Lass, Vector and Tensor Analysis, McGraw Hill Pub (1950)
2. M.L.Jain,Vector Spaces and Matrices in Physics, Alpha Science International (2001)
3. W.W.Bell, Special Functions for Scientists and Engineers, Dover Publications (2004)
4. W.K.Tung, Group theory in Physics, World Scientific Pub Co (1999)
5. A.K. Ghatak, I.C. Goyalamd S.T. Chua, Mathematical Physics, Macmillan India (1985)

PH 213: BASIC ELECTRONICS (6L,1T)

Objectives: This course is aimed to introduce the students with the basic knowledge of analog and digital circuits. The course illustrates the concepts of various amplifier circuits, solid state electronic devices, sequential digital circuits, optoelectronics devices and measurements using electronic instruments.

Unit I

Selections from electronic circuits (10 hours)

Frequency response of an amplifier circuits-power and voltage gain- impedance matching- Bode plots- Miller effects- rise time bandwidth relations- frequency analysis of BJT and FET amplifier stages

Operational amplifier and its applications (18 hours)

Opamp - frequency response, poles and zeroes, transfer functions (derivation not required), expression for phase angle- Active filters-first order and second order Butterworth transfer function-first order and second order active filters- low pass, high pass and band pass filters- comparators-OP Amp as a voltage comparator-zero crossing detectors-Schmitt trigger-voltage regulators- square, triangular and saw tooth wave form generators-Weinberg oscillator- monostable and astable multivibrator circuits using IC 555 timer- Phase Locked Loop circuits (PLL)

Microwave solid state electronic devices (8 hours)

Tunnel diode-varacter diode-IMPATT diode- QWITT diode- TRAPATT diode- Gunn diode

Unit II

Digital electronics

Arithmetic and data processing digital circuits (16 hours)

Binary adder and subtractor- arithmetic logic unit- binary multiplication and division- arithmetic circuits using HDL- multiplexers- demultiplexers- BCD to decimal decoder- seven segment decoder- parity generators and checkers- magnitude comparator- programmable logic arrays

Sequential digital circuits (20 hours)

Flip flops- edge triggered- SR flip flops- JK flip flop- D- flip flop- JK master-slave flip flop- different types of registers (SISO, SIPO, PISO, PIPO)- universal shift registers- applications- counter asynchronous and synchronous electronic counters- decade counters-digital clock.

Unit III

Optoelectronics (22 hours)

Optical fibre as a wave guide-mode theory of circular wave guide- -modes in step index fibres- signal distortion in optical fibres- group delay, material dispersion, wave guide dispersion- sources of attenuation- absorption, scattering, bending loss, core and cladding loss- optical sources- LED's- structure, quantum efficiency and power- laser diodes- modes and threshold conditions, rate equations, efficiency and resonant frequency- photo detector- pin and avalanche photodiodes- principles- optical amplifier- basic applications and types, semiconductor optical amplifiers, erbium doped fibre amplifiers.

Electronic Instrumentation (14 hours)

Electronic measurements and instruments-comparison between analog and digital instruments- performance and dynamic characteristics-ideas of errors and measurement standards- voltmeters-ammeters- CRO- Block diagram, CRT, CRT circuits, vertical deflection system- delay line, multiple trace, horizontal deflection system, oscilloscope probes and transducers, oscilloscope techniques, storage oscilloscope, digital storage oscilloscope- classification of transducers-active and passive transducers-force and displacement transducers-strain gauges- temperature measurements-thermistors-thermocouples-flow measurements.

Course Outcome

(i) To equip the students design and analyze different analogue and digital circuits.
(ii) To summarize the knowledge of basic arithmetic and data processing circuits and memory devices.
(iii) To equip the students to explain various components in optical communications systems and microwave devices.
(iv) To measure and analyze the different electronic signals.

Books for study

1. A. Malvino and D.J.Bates, *Electrinics Prinicples*,7th Edition,Tata McGraw Hill (2007)
2. R.A. Gayakwad, *Operational Amplifiers and Linear integrated Circuits*, Prentice Hall of India (2000)
3. M.S. Tyagi, *Introduction to semiconductior materials and devices*, Wiley India (2005)
4. B.G. Streetman, S.K. Banerjee, *Solid state electronic devices*. Pearsoninc (2010)
5. J. Millman, C. Halkias and C.D. Parikh, *Integrated Electronics*, Tata McGraw Hill (2010)
6. D.P. Leach,A.P. Malvino, and G. Saha ,*Digital principles and applications*,Tata Mc Graw Hill (2011)

7. G.Keiser, *Optical Fibre Communication*,3rd edition,McGraw Pub (2000)
8. Lal Kishore*, Electronic measurements and Instrumentation*, Dorling Kindersley (India) Pvt Ltd (2010)
9. W.D. Cooper, A.O. Helfrik and H. Albert, *Electronic Instrumentation and measurement Techniques*, PHI (1997)
10. Electronic Devices and Circuits Theory, Robert L. Boylestad, Louis Nashelsky, Pearson 10th edition (2009).

References

1. T.F. Bogart Jr, J.S. Beasley and G. Reid, Electronic devices and circuits, Sixth Edition, Pearson Inc (2004)
2. Thomas. L. Floyd, Digital Fundamentals, 10th edition, Dorling Kindersley (India) Pvt Ltd (2011)
3. Joachion Piprek, Semiconductor Optoelectronic Devices, Academic Press (2003)

PH 221: MODERN OPTICS AND ELECTROMAGNETIC THEORY (6L, 1T)

Objectives: This course covers linear and non-linear optical phenomenon, propagation of electromagnetic waves, relativistic electrodynamics, radiation and antenna theory.

Unit I

Modern optics (24 hours)

Multiple beam interference-Fabry-Perot interferometer- theory of multilayer films-antireflection films and high reflectance films -Fresnel- Kirchoff integral theorem and formula- Fraunhofer and Fresnel diffraction patterns and theory-applications of Fourier transforms to diffraction- acoustic- optic modulation- basic ideas of Raman-Nath diffraction and Bragg diffraction- holography as wavefront reconstruction-propagation of light in crystals-optical activity and Faraday rotation

Non-linear optics (12 hours)

Harmonic generation- second harmonic generation- phase matching- third harmonic generation- optical mixing- paramagnetization of light- self focusing- multiquantum photoelectric effect- two photon process and theory- multiphoton processes- three photon processes- second harmonic generation- parametric generation of light.

Unit II

Electromagnetic waves (12 hours)

Electromagnetic wave equations-electromagnetic waves in non-conducting media-plane waves in vacuum-energy and momentum of electromagnetic waves-propagation through linear media- reflection and transmission at normal and oblique incidence-electromagnetic waves in conductors-modified wave equations and plane waves in conducting media-reflection and transmission at a conducting interface

Relativistic electrodynamics (14 hours)

Vector and scalar potential- gauge transformations- Coulomb gauge and Lorentz gauge-Magnetism as a relativistic phenomena- transformation of the field-electric field of a uniformly moving point charge-electrodynamics in tensor notation-electromagnetic field tensor-potential formulation of relativistic electrodynamics

Radiation (10 hours)

Dipole radiation- electric dipole radiation- magnetic dipole radiation- radiation from an arbitrary source- point charges- power radiated by a point charge- radiation reaction

Unit III

Transmission lines (12 hours)

Transmission line parameters and equations-input impedance-standing wave ratio and power- The Smith Chart-applications of transmission lines

Waveguides (12 hours)

Rectangular wave guides-transverse magnetic (TM) modes-Transverse electric (TE) modes- wave propagation in the wave guide-power transmission and attenuation

Antennas (12 hours)

Radiation from Hertzian dipole-half wave dipole antenna-quarter wave monopole antenna- antenna characteristics -antenna arrays-effective area and Friji's equations

Course Outcome

(i) To demonstrate the linear and nonlinear optical phenomena.

(ii) To explain and discuss propagation of electromagnetic waves through different media.

(iii) To restate formulations and relativistic effects in electrodynamics.

(iv) To analyse the propagation of electromagnetic waves through waveguides.

(v) To use radiation theory in developing different antennas.

Books for study

1. G.R. Fowles,, *Introduction to Modern Optics*, Second Edition, Dover Publications (1989).
2. A. Yariv, *Introduction to Optical electronics*, Holt, Reinhart and Winston (1976).
3. A. Ghatak and K. Thyagarajan, *Optical Electronics*, Cambridge University Press (1998)
4. D. Roody and J. Coolen, *Electronic Communications*, Fourth Edition, Dorling Kindersley (India) Pvt Ltd (2008)
5. D.J. Griffiths ,*Introduction to Electrodynamics*, PHI Learning India Pvt Ltd (2007).
6. M.N.O. Sadiku, *Elements of electromagnetics*, Oxford University Press (2007).
7. B.B. Laud, *Lasers and Non-linear Optics*, Second Edition, Wiley-Eastern Limited (1991)

References

1. J.R. Meyer-Arendt, Introduction to Classical and Modern Optics, Prentice Hall Intl (1995)
2. J.C. Palais, Fibre optic communications, Fifth Edition, Pearson Education Inc (2005)
3. E.C. Jordan and K.G. Balmain, Electromagnetic waves and radiating systems, Second Edition, Pearson Education (2002)
4. D.K.Cheng, Field and Wave electromagnetics , Second Edition ,Addison Wesley (1999).
5. L.Ganesan and S.S.Sreejamole,Transmission lines and wave guides, Second Edition, Tata McGraw Hill (2010)

PH 222: THERMODYNAMICS, STATISTICAL PHYSICS AND BASIC QUANTUM MECHANICS (6L, 1T)

Objectives: This course is aimed to introduce the concepts of thermodynamic equations, foundations of classical and quantum statistics, theory of phase transitions and foundations quantum mechanics together with problems.

Unit I

Thermodynamic relations and consequences (20 hours)

Thermodyanamic functions and Maxwells's equations-Clausius -Claepyrans equations-Properties of thermodyanamic potentials-Gibbs-Helmoltz relation-thermodynamic equilibrium-Nernst –heat theorem and its consequences-Gibb's phase rule-chemical potential-vapour pressure relation and chemical constants

Foundations of classical statistical physics (16 hours)

Phase space-ensembles-Lioville's theorem-statistical equilibrium-microcanonical ensemble-partition functions and thermodynamic quantities-Gibb's paradox-Maxwell-Boltzmann distribution laws-grand canonical ensemble

Unit II

Quantum statistics (26 hours)

Quantum statistics of classical particles-density matrix in microcaonical, canonical and grand canonical ensembles-Bose Einstein statistics and Bose Einstein distribution law-Maxwell Boltzmann statistics and Maxwell Boltzmann distribution law—Fermi Dirac statistics and Fermi Dirac distribution law-comparison of three types of statistics-applications of quantum statistics-Planck radiation laws-Bose Einstein gas and Bose Einstein condensation—Fermi Dirac gas-electron gas in metals-thermionic emission-statistical theory of white dwarfs

Phase transitions (10 hours)

Triple point-Vanderwal's equation and phase transitions-first and second order phase transitions- Ehrenfest's equations- Ising model

Unit III

Foundations of quantum mechanics (14 hours)

Basic postulates if quantum mechanics- Hilberts space- observables- Hermitian operators-general statistical interpretation-Uncertainty principle-minimum uncertainty wave packet-energy time uncertainty principle-Dirac notation-Matrix representation of state vectors and operators-change of representations- eigenvalue problem in matrix mechanics-energy and momentum representations-unitary transformations involving time- Schrodinger, Heisenberg and interaction pictures.

Exactly solvable problems in quantum mechanics (22 hours)

One dimensional eigen value problems-square well potential-potential barrier-alpha particle emission-Bloch waves in periodic potential-linear harmonic oscillator problem using wave mechanics and operator methods-free particle wave functions and solutions-three dimensional eigen value problems-particle moving in spherical symmetric potential-rigid rotator-hydrogen atom problem-three dimensional potential well- Deuteron

Course Outcome

(i) To explain the basic thermodynamic relations, Maxwell's equations and its consequences.
(ii) To equip the students to demonstrate and apply classical and quantum statistics in different physical phenomena.
(iii) To distinguish the different phase transitions using Ising model.
(iv) Outline and apply foundations of quantum mechanics.

Books for study

1. R. K. Pathria, *Statistical Mechanics*, Pergamon Press (1991)
2. Satya Prakash, *Statistical Mechanics*, Kedarnath Ram Nath Publishers,Meerut and Delhi (2009)
3. B.K. Agarwal and HariPrakash, *Quantum Mechanics*, Prentice Hall of India (2002)
4. S. Devanarayanan, *Quanrtum Mechanics*, Sci Tech Publications (India) Pvt Ltd (2005)
5. D.J. Griffiths, *Introduction to Quantum Mechanics*, Second Edition, Pearson Education Inc ((2005)
6. G. Aruldas, *Quantum Mechanics*, Second Edition, PHI learning Pvt Ltd (2009).
7. J. J Sakurai , Modern Quantum Mechanics, Second edition, Pearson (2010).
8. N. Zettili, Quantum Mechanics concepts and Applications, Second edition, Wiley (2009).

References

1. R.K. Srivastava and J. Asok , Statistical Mechanics, Wiley Easter Ltd (2005)
2. S.K. Sinha, Statistical Mechanics-Theory and Applications, Tata Mc Graw Hill
3. P.M. Mathews and K.Venkitesan, A Text Book of Quantum Mechanics, Tata Mc Graw Hill (2010)
4. A. Ghatak and S. Lokanathan ,Quantum Mechanics Theory and Applications, Kluewer Academic Publishers (2004).
5. V.K. Thankappan, Quantum Mechanics, Second Edition, New Age International Pvt Ltd (2003).

PH 223: COMPUTER SCIENCE AND NUMERICAL TECHNIQUES (6L, 1T)

Objectives: This course provides introduction to computer architecture, microprocessors, programming in python and C++ and computational numerical methods.

Unit I

Foundations of computer science (12 hours)

Introduction to computers-computer architecture-memory (RAM and ROM, cache) and storage- I/O devices- operating systems-data communications, computer networks and topology

Introduction to microprocessors (12 hours)

Evolution of microprocessors-microcontrollers and digital signal processors- Intel 8085 8 bit microprocessor- pin description-functional description- 8085 instruction format-addressing modes of 8085- interrupts of 8085- memory interfacing- 8085 machine cycles and Bus timings- assembly language programming of 8085

Introduction to Python Programming (12 hours)

Python - Python shell, number, variables, comparisons and logic, Python objects - strings, lists, tuples, loops; control flow, file input and output functions

Unit II

Programming with C++ (36 hours)

C++- flow control-conditional statements-iterative statements-switch statements-conditional operators as an alternative to IF-nested loops-break statements-ext( ) functions-structured data types-arrays-storage classes-multidimensional arrays-sorting of strings-functions-built in and user defined- accessing function and passing arguments to functions-calling functions with arrays-scope rule for functions and variables-structures in C++-classes abd objects – definition- class declaration-class function definitions-creating objects-use of pointers in the place of arrays-file handling in C++-basic file operations-serial and sequential files-reading and writing on to disks.

Unit III

Numerical Techniques (36 hours)

Solution of simultaneous linear algebraic equations-Gauss elimination method-Gauss

Jordan method-inverse of a matric using Gauss elimination method-Finite differences-forward and backward differences-central differences-difference of a polynomial-error propagation in difference table-Interpolation with equal intervals-Gregory Newton forward and backward formula- error in polynomial interpolation-central difference interpolation formula-Gauss's forward and backward formula- Striling's formula-Lagrange interpolation formula-numerical differentiation-numerical integration using general quadrature formula-Trapezoidal rile- Simsons 1/3 and 1/8 rules-numerical solutions to ordinary differential equations-Euler and modified Euler methods-Runge Kutta methods-numerical solution to partial differential equations-solutions to Poisson and Laplace equations.

Course Outcome

(i) To summarize computer hardware and its operating systems

(ii) Explain internal architecture of microprocessors 8085 and create assembly language programing.

(iii) To develop and compile programs in python and C++.

(iv) Apply numerical methods to solve physical problems.

Books for study

1. ITL Education Solutions Ltd, *Introduction to Computer Science*, Second Edition, Dorling Kindersley (India) Pvt Ltd (2011)
2. V.N. Vedamurty and N. Iyengar,*Numerical Methods*,Vikas Publishing Pvt Ltd (1998)
3. K. Udayakumar, and B.S. Umasankar,*The 8085 microprocessor*,Dorling Kindersley (India) Pvt Ltd (2008)
4. Christian Hill, *Learning Scientific Programming with Python*, Cambridge University Press (2015)
5. V. Carl Hamacher, Z.G.Vranesic and S.G. Zaky, *Computer Organization*, Fourth Edition, McGraw Hill International Edition (1996)
6. Peter Norton etal., *Beginning Python*, Wiley Publishing (2005)
7. Abishek Yadav, *Microprocessor 8085 8086*,University Science Press, New Delhi (2008)
8. D.Ravichandran, *Programming in C++*,Tata McGraw Hill (2011)
9. M.T.Somasekhara, *Programming in C++*, PHI Pvt Publishing (2005).
10. B. Ram, Fundamentals of Microprocessors and Microcontrollers, Dhanpat Rai Publications (2008).
11. S. S. Sastry, Introductory method of Numerical analysis, Fifth Edition, PHI (2012).

References

1. V. Rajaraman, Fundamentals of Computers, Fifth Edition, PHI (2010)
2. R.S.Gaonkar, Microprocessor-Architecture, Programming and Applications with 8085
3. S.S. Sastry, Introductory method of Numerical analysis, Fifth Edition, PHI
4. P. Ghosh, Numerical Methods with computer programs in C++,PHI learning Pvt Ltd
5. Bjorne Stroustrup, The C++ Programming Language ,Fourth Edition, Addison Wesley

PH231: ADVANCED QUANTUM MECHANICS (6 L, 1 T)

Objectives: This course describes a thorough conceptual understanding of advanced quantum mechanics covering variation method, WKB approximation, perturbation theory, symmetry and conservation laws, theory of scattering, system of identical particles, angular momentum and relativistic quantum mechanics.

Unit I

Variation method (6 hours)

The variational principle-Rayleigh Ritz method-variation method for excited states-ground state of Helium and Deutron.

WKB approximation (8 hours)

WKB method-connection formulas-barrier potential-penetration-alpha particle emission-bound states in a potential well

Time dependent and time-independent perturbation theory (22 hours)

Time independent perturbation- basic concepts- non-degenerate energy levels- anharmonic oscillator- ground state of helium- effect of electric field on the ground state of hydrogen-degenerate energy levels- effect of electric field on the n=2 state of hydrogen- spin-orbit interaction.

Time dependent perturbation- first order, harmonic, transition to continuous states, absorption and emission of radiation- Einstein's coefficients- selection rules.

Unit II

Symmetry and conservation laws (10 hours)

Symmetry transformations-space translation and conservation of angular momentum-time translation and conservation of energy-rotation in space and conservation of angular momentum-space inversion-time reversal

Quantum theory of scattering (12 hours)

Scattering cross section and scattering amplitude-partial wave analysis and scattering by a central potential-scattering by attractive square well potential-scatteriing length-expression for phase shifts-Born approximation-scattering by Coulomb potential-Laboratory and centre of mass coordinate transformations.

System of identical particles (14 hours)

Identical particles- Pauli's exclusion principle-inclusion of spin-spin function for a two electron system-Helium atom-central field approximation-Thomas Fermi model of an atom-Hartree and Hartree-Fock equations.

Unit III

Angular momentum (12 hours)

Angular momentum in operators and commutation relations-eigen values and eigen functions of L^2 and L_z –general angular momentum-eigen values of J^2andJ_z-angular momentum matrices-spin angular momentum –spin vectors for a spin ½ system-addition of angular momentum-Clebsch-Gordan coefficients.

Relativistic quantum mechanics (24 hours)

Klein-Gordon equations and its relevance-particle in a Coulomb's field-Dirac's relativistic theory-Dirac's equation for a free particle-Dirac matrices-covariant form of Dirac's equations-probability density-plane wave solutions-negative energy starts-spin in Dirac's theory-magnetic moment of an electron-relativistic corrections of Hydrogen atom spectrum-spin orbit correction-Lamb shift

Course Outcome

(i) To extend the use of approximation methods viz variation, WKB, time dependent and time independent perturbations.
(ii) To summarize different types of symmetry, conservation laws and quantum theory of scattering.
(iii) To distinguish different approximation methods, to study the structure and properties of many electron systems.
(iv) To compute eigen values of angular momentum and evaluation of CG coefficients.
(v) Infer the requirements of relativistic quantum mechanics.

Book for study

1. G.Aruldas,*QuantumMechanics*,SecondEdition,PHI learning Pvt Ltd (2009)
2. D.J.Griffiths,*Indroducion to Quanum Mechanics*, Second Edition, Pearson Education Inc (2005)
3. J.J.Sakurai,Advamced Quantum Mechanics, Pearson Education Inc (2009).

References

1. P.M.Mathews and K.Venkitesan,A Text Book of Quantum Mechanics,TataMcGraw Hill (2010)
2. A.Ghatak and S.Lokanathan ,QuantumMechancis Theory and Applications, Kluwer Academic Publishers (2004)
3. V.K.Thankappan,QuantumMechancics, Second Edition, New Age International Pvt Ltd (2003)
4. S.Devanarayanan,QuanrtumMechanics, Sci Tech Publications (India) Pvt Ltd (2005)
5. L.H.Ryder,Quantum Field TheorySecondEdition,Cambridge University Presss (1996)
6. Steven Weinberg,Quantum Theory of Fields(in Three Volumes), Cambridge University Presss (2002)

PH 232: ATOMIC AND MOLECULAR SPECTROSCOPY (6L, 1T)

Objectives: This course provides an overview of symmetry of molecules, concepts of atomic spectra, Photoelectron and photo acoustic spectroscopy, Rotational, vibrational, electronic, Raman, Mossbauer, nuclear and electron spin resonance spectroscopic techniques.

Unit I

Atomic Spectroscopy (14 hours)

Spectra of Atoms - Spectroscopic terms– selection rules– exchange symmetry of wave functions- Pauli's exclusion principle. Many electron atoms- Building principle- the spectra of Li and hydrogen like elements, The L-S and j-j coupling schemes- total angular momentum – term symbols- The spectra of Helium-Zeeman effect – The magnetic moment of atom, Lande's g factor- The normal Zeeman effect- Emitted frequencies in anomalous Zeeman transitions- Nuclear spin and Hyperfine structure, Stark Effect, Paschen Bach effect

Molecular symmetry (10 hours)

Symmetry operations-symmetry elements-algebra of symmetry operations-multiplication tables-matrix representation of symmetry operators-molecular point groups-reducible and irreducible representations-great orthogonality theorem-character tables for C_{2V} and C_{3V} point groups, symmetry species of point groups-IR and Raman activity

Photoelectron and Photo-acoustic spectroscopy (12 hours)

Photoelectron spectroscopy-experimental methods-photoelectron spectra and their interpretation-Auger electron and X ray Fluorescence spectroscopy-Photo-acoustic effect-basic theory-experimental arrangement-applications.

Unit II

Molecular rotational spectroscopy (12hours)

Classification of molecules-rotational spectra of diatomic molecules-isotope effect and intensity of rotational lines-non rigid rotator-linear polyatomic molecules-symmetric and asymmetric top molecules-microwave spectrometer-analysis of rotational spectra.

IRspectroscopy (12 hours)

Vibrational spectra of diatomic molecules-characteristic IR spectra-vibrations of polyatomic molecules- anharmonicity- Fermi resonance-hydrogen bonding-normal modes of vibration in a crystal- interpretation of vibrational spectra- IR spectrometer-Fourier transform IR spectroscopy

Electronic spectra of molecules (12 hours)

Vibrational coarse structure and analysis of bound systems- Deslanders table-Frank-Condon principle-vibrational electronic spectra-rotational fine structure- Fortrat parabola-electronic angular momentum in diatomic molecules

Unit III

Raman spectroscopy (12 hours)

Theory of Raman scattering-rotational and vibrational Raman spectra-Raman spectrometer-structure determination using Raman and IR spectroscopy-nonlinear Raman effects-Hyper Raman effect- stimulated Raman scattering- coherent anti-stokes Raman scattering

ESR and NMR spectroscopy (16 hours)

Principle of NMR-ESR spectrometer-Hyperfine structure-ESR spectra of Free radicals-Magnetic properties of nuclei-resonance condition-NMR instrumentation-chemical shift-NMR spectra of solids-NMR imaging-interpretation of NMR spectra

Mossbauer spectroscopy (8 hours)

Recoilless emission and absorption-Mossbauer spectrometer-experimental techniques-isomer shift- quadrupole interaction-magnetic hyperfine interaction

Course Outcome

(i) Explain different symmetry operations and deduction of molecular structure.
(ii) Distinguish and classify the different spectra shown by atoms and molecules
(iii) Illustrate the various spectroscopic experimental techniques.

Books for study

1. J.M. Hollas, *Modern Spectroscopy*, Fourth Edition, John Wiley &Sons (2004)
2. G. Aruldas, *Molecular Structure and Spectroscopy*, PHI learning Pvt Ltd (2007)
3. Suresh Chandra, *Molecular Spectroscopy*, Narosa Publishing Co (2009)
4. H E White, Introduction to Atomic Spectroscopy McGraw-Hill Inc. 1st Edition. (1934).

References

1. C.N. Banwell and E.M. McCash, Fundamentals of Molecular Spectroscopy, Fourth edition, Tata McGraw Hill (1995).
2. D.N. Satyanarayana, Vibrational spectroscopy-Theory and applications, New Age International Pvt Ltd (2004)
3. J.L.McHale, Molecular Spectroscopy, Pearson education Inc (2008).

PH 233: CONDENSED MATTER PHYSICS (6L, 1T)

Objectives: To understand and familiarize fundamentals of crystals, lattice vibrations, band theory, dielectric, magnetic and superconducting properties of materials. To introduce the synthesis and characterization techniques of nanomaterials.

Unit I

Crystal physics (10 hours)

Lattice points and space lattice-basis and crystal structure-unit cells and lattice parameters-symmetry elements in crystals –space groups-Bravais lattice-density and lattice constant relation-crystal directions, planes and Miller indices-reciprocal lattice-allotropy and polymorphism in crystals-imperfections in crystals.

Lattice vibrations and thermal properties (10 hours)

Dynamics of identical atoms in crystal lattice-dynamics of linear chain-experimental measurement of dispersion relation-anharmonicity and thermal expansion-specific heat of solids-classical model-Einstein's model-Debye model-thermal conductivity of solids-role of electrons and phonons-thermal resistance of solids.

Free electron and band theory (16 hours)

Electrons moving in one dimensional potential well-Fermi-Dirac statistics-effect of temparature on Fermi distribution-electronic specific heat-electrical conductivity of metals-Wiedmann- Franz- Lorentz law-electrical resistivity of metals-Hall effect-energy bands in solids-Kronig- Penny model-construction of Brillouin zones-nearly free electron model-conductors, semiconductors and insulators-elementary ideas of Fermi surfaces

Unit II

Semiconductors (12 hours)

Free carrier concentration in semiconductors-mobility of charge carriers-temperature effects-electrical conductivity of semiconductors-Hall effect in semiconductors - semiconductor junction properties.

Dielectric and magnetic properties of materials (24 hours)

Dipole moment-polarisation-local electric field in an atom-dielectric constant and its measurement-polarizability-classical theory-Peizo, Pyro and Ferro electric properties of Crystals-Ferreoelectric domains-classification of magnetic materials-atomic theory of magnetism- Langevin's theory-paramagnetism and quantum theory-Weiss molecular exchange field-ferromagnetic domains-anti ferromagnetism-Ferrites.

Unit III

Superconductivity (20 hours)

Experimental attributes to superconductivity-critical temperature, critical current and critical magnetic field of superconductors-effects of magnetic field on superconductors-Type I and II superconductors-intermediate and vortex states-thermal conductivity, specific heat and energy gap in superconductors-microwave and IR properties-coherence length-Theories of superconductivity-London equations-Ginzberg-Landau theory-BCS theory-AC and DC Josephson effects in superconductors- Examples and properties of High Temperature Superconductors.

Introduction to nano science and technology (16 hours)

Introduction to nanomaterials, properties, classification of nanomaterials, quantum confinement effects, Density of states-nano material preparation techniques-sputtering-chemical vapor deposition-pulsed laser deposition-sol-gel technique-characterization of nano materials-X-Ray diffraction- Scanning Probe Microscopy-atomic force microscopy-SEM and TEM techniques.

Course Outcome

(i) Discuss crystal physics, lattice vibrations, models of thermal properties and band theory of solids.

(ii) Explain the theoretical concepts of semiconductors, dielectric, magnetic and superconducting materials.

(iii) To describe the synthesis and characterization techniques of nanomaterials.

(iv) To apply the concepts in condensed matter physics to meet the challenges.

Books for study

1. N.W. Ashcroft and N.D. Merwin, *Solid State Physics*, Cenage Learning India (2001)

2. Charles.C. Kittel, *Introduction to Solid State Physics*, wiley Student Edition (2007)

3. M. Ali Omar, *Elementary Solid State Physics*, Pearson Education Inc (1999)

4. K.K. Chattopahyay, A.N. Banerjee, *Introduction to Nano Science and NanoTechnology*, Prentice Hall of India (2009)

5. Gabor L Hornyak, H F Tibbals and Joydeep Dutta, *Introduction to Nanoscience and Nanotechnology, CRC press (2009)*

References

1 S.O. Pillai, *Solid State Physics*, Third Edition New Age International Pvt. Ltd (1999).

2. M.A. Wahab, *Solid State Physics*, Narosa Publishing House (1999).

3 R.J. Singh, Solid State Physics, Dorling Kindersley (India) Pvt Ltd (2012).

4 P. Phillips, Advanced Solid State Physics, Second Edn, Cambridge University Press (2012).

PHN 234 Nanostructured Materials (7L,1T)

Objectives: This course is to introduce the student to the world of nanostructured materials. Different types of nanostructured materials, their general and specific characteristics will be discussed. Understanding the optical properties of metal nanoparticles and excitation processes in nanosystems is also intended. A broad understanding of different chemical and physical techniques employed for the synthesis of different types of nanomaterials and nanostructures is also envisaged through this course.

Unit I (42 hours)

Characteristic scales in mesoscopic systems – nanoparticles - surface to volume ratio - grain boundary volume - surface energy - lattice contraction in nanostructured materials - semiconductor nanoparticles - Quantum confinement - artificial atoms - Quantum dots, Quantum wires, and Quantum wells - blue shift of band gap. Magic numbers - theoretical modelling of nanoparticles - geometric structure - electronic structure reactivity.

Optical properties of metal nanoparticle - surface plasmon resonance (SPR) – size, shape and composition dependence of SPR – dephasing of SPR – non-radiative decay of the SPR – plasmon wave guiding. Plasmonics-metallic nanoparticles and nanorods-metallic nanoshells-local field enhancement-plasmonic wave guiding-applications of metallic nanostructures. Nanocontrol of excitation dynamics-nanostructure and excited states-rare earth doped nanostructures-up converting nanophores-quantum cutting.

Unit II (42 hours)

Synthesis of nanomaterials– bottom-up and top-down approaches - metal nanoparticles - properties of individual nanoparticles - consequences of small particle size - increase of mechanical frequencies in small systems - dominance of viscous forces - disappearance of frictional forces.

Synthesis of zero-dimensional nanostructures - fundamentals of homogeneous nucleation - subsequent growth of nuclei - colloidal nanosynthesis - inorganic surface modification - shape control - phase transition and phase control - nanocrystal doping - synthesis of metallic (Au, Ag) nanoparticles - synthesis of semiconducting nanoparticles (CdSe, CdS) - synthesis of oxide nanoparticles - sol-gel method - synthesis of multicomponant nanostructures - fundamentals of heterogeneous nucleation - synthesis of nanoparticles.

Epitaxial core-shell nanoparticles – core-shell quantum dots - type I and type II core-shell quantum dots - quantum dot quantum wells – Sonochemical synthesis of nanoparticles - spray pyrolysis – electrospinning.

Unit III (42 hours)

Synthesis of 1D nanostructures - spontaneous growth - vapor-liquid-sold growth – template based synthesis - electrochemical deposition - electrophoretic deposition - template filling - synthesis of GaN nanostructures - synthesis of ZnO nanowires and heterostructures - GaP nanostructures.

Synthesis of 2D nano structures – fundamentals film growth – Physical vapour deposition – sputtering – chemical vapour deposition – atomic layer deposition – self assembly – Lagmuir-Blodgett films.

Lithography techniques – optical lithography – electron beam lithography – focussed ion beam lithography – X-ray lithography.

Assignments: Applications of nanomaterials in various fields of science and technology including physics chemistry and biology and medicine.

Course Outcome

(i) Distinguish between different classes of nanostructured materials and nanostructures based on dimension.

(ii) Understand the surface Plasmon resonance phenomena in metal nanoparticles as well as excitation processes involved in upconversion and down conversion.
(iii) Gain a broad understanding of the different chemical synthesis techniques of different types of nanostructured materials.
(iv) Gain broad understanding of advanced physical techniques employed for the preparation of 1D and 2D nanostructures including lithography.

Books for Study

1. Frank J. Owens, Charles P. Poole Jr, The Physics and Chemistry of Nanosolids, John Wiley & Sons, 2008.
2. Dieter Vollath, Nanomaterials: An introduction to Synthesis, Properties, and Applications (second edition), Wiley-VCH, 2013.
3. Charles P. Poole Jr, Frank J. Owens, Introduction to Nanotechnology, Wiley India Edition, 2006.
4. Edward L. Wolf, Nanophysics and Nanotechnology - An Introduction to Modern Concepts in Nanoscience, Wiley-VCH, 2006.
5. A.S. Edelstein, R.C. Cammaratra, Nanomaterials: Synthesis, Properties and Applications (second edition), CRC Press, 1998.
6. V. I. Klimov (Ed.), Smiconductor and Metal Nanocrystals - Synthesis and Electronic and Optical properties, Marcel Dekker Inc., 2004
7. Kenneth J. Klabunde (Ed.), Nanoscale Materials In Chemistry, John Wiley & Sons, 2001.
8. Guozhong Cao, Nanostructures and Nanomaterials- Synthesis, properties and Applications,Imperial college press, 2004.
9. Victor I. Klimov (Ed.), Semiconductor and Metal Nanocrystals- Synthesis and Electronic and Optical properties, Marcel Dekker, Inc., 2004.
10. Challa Kumar (Ed.). Semiconductor Nanomaterials, Wiley-VCH, 2010.
11. S.C. Tjong, Nanocrystalline Materials - Their Synthesis- Structure, Property Relationships and Applications, Elsevier, 2006.
12. Ampere A Tseng (Ed.), Nanofabrication-Fundamentals and Application, World Scientific, 2008.

PH 241: **NUCLEAR AND PARTICLE PHYSICS (6L, 1T)**

Objectives: To familiarize the fundamental properties of nucleus, its structure, models, nuclear reactions, nuclear detectors and accelerators. To introduce the concept of elementary particles and their interactions.

Unit I

Nuclear forces (10 hours)

Deuteron-neutron –proton scattering and proton-proton scattering at low energies-non central forces- nuclear exchange force-meson theory of nuclear forces

Nuclear models (12 hours)

Detailed studies on liquid drop, shell and collective models of the nuclei.

Nuclear reactions (14 hours)

Conservation laws-energetic nuclear reactions-Q value equation-partial wave analysis of nuclear reaction cross section- compound nuclear hypothesis-resonance reactions-Brot-Wigner one level formula-optical model-theory of stripping reactions.

Unit II

Nuclear fission (20 hours)

Mechanism of nuclear fission-calculation of critical energy based on liquid drop model-fission products and energy release-fission chain reactions-neutron cycle and four factor formula-general features and classification of nuclear fission reactors.

Nuclear fusion (16 hours)

Nuclear fusion in stellar interiors-proton-proton reactions-carbon-nitrogen cycle-thermo nuclear reactions in the laboratary-conditions for the construction of nuclear fusion reactor-critical ignition temperature-Lawson criterian-plasma confinement in fusion- principles of pinch, magnetic an inertial confinements.

Unit III

Nuclear detectors and particle accelerators (20 hours)

Gas filled detectors-ionization chamber and proportional counters-GM counter-scintillation detectors-semiconductor detectors- Cerenkov detector-bubble chamber. Particle accelerators-electrostatic accelerators-cyclotron accelerators-synchrotrons-linear accelerators-colliding beam accelerators.

Elementary particle physics (16 hours)

Elementary particle interactions-symmetries and conservation laws-quark model of elementary particles-colored quarks and gluons-ideas of charm, beauty and truth-quark dynamics-ideas of grand unified theories of fundamental forces

Course Outcome

(i) To describe and analyze nuclear structure, models and reactions.
(ii) To illustrate the mechanisms of nuclear fission and fusion reactions.
(iii)Discuss various nuclear detectors and particle accelerators.
(i) To classify elementary particles and discuss their interactions.

Books for study

1 D.C. Tayal, *Nuclear Physics*,5thEdition,Himalaya Publishing Co (2008)
2 J. Verma, R.C.Bhandari, D.R.S.Somayajulu, *Fundementals of Nuclear Physics*, CBS Publishers and Distributors (2005).
3. K.S. Krane, *Introductory Nuclear Physics*, Wiley India Pvt. Ltd (1988)

References

1 S.B. Patel, Nuclear Physics-An Introduction, New Age International Pvt. Ltd (1996).

2. B.R. Marhu, Nuclear and Particle Physics- an Introduction, Second Edition, Wiley (2012)

3. S.N. Ghoshal, Nuclear Physics, S. Chand Ltd (1997)

4. M.P. Khanna, Introduction to Particle Physics, PHI (2011)

5. J. Freidberg, Plasma Physics and Fusion Energy, Cambridge University Press (2007)

6. FF.Chen, Introduction to Plasma Physics, Springer, London (2002)

PHN 242: PHYSICS OF NANOSOLIDS (5L,1T)

Objectives: This course will discuss the physical and chemical aspects of nanosolids starting from the dependence of electronic energy band structure on dimensionality. Understanding of the electrical and magnetic properties of nanomaterials that has both theoretical and practical importance is also envisaged. Nanophotonics, which is an emerging area of research that deals with light matter interaction at nanoscale is also discussed.

UNIT I (30 hours)

Low-dimensional systems - density of states in semiconductor materials - Quantum wells, Quantum wires, and Quantum dots - lithographic defined quantum dots - epitaxially self-assembled Quantum dots – colloidal quantum dots – weak confinement regime - strong confinement limit – Quantum-chemical calculations for semiconductor clusters –exciton –Darkexciton - Quantum dot lasers

Quantum wire devices - transport in one-dimensional electron systems (1 DES) - ideal 1 DES – semiconductor 1 DESs- silicon 1 DESs - semiconductor quantum dots as zero dimensional electron systems (0 DES)

Unit II (30 hours)

Magnetism in nanostructures - characteristics of nanomagnetic materials - magnetic properties of single-domain particles – superparamagnetism- coercivity of small particles - measurements of superparamagnetism and blocking temperature - antiferromagnetic nanoparticles.

Electrical properties of semiconductor nanocrystals- theory of electron transfer between localized States - photoinduced charge transfer at nanoscale semiconductor interface - electrical conduction in bulk and nanostructured - charge transport in nanocrystal films.

Superconductivity in Nanomaterials- introduction - zero resistance – Meissnereffect - dependence of superconducting properties on size effects - Resistivity and sheet resistance - proximity effect - superconductors as nanomaterials- tunneling and Josephson junctions - superconducting Quantum interference device (SQUID)

Unit III (30 hours)

Nanophotonics- foundation for nanophotonics– free-space propagation - confinement of photons and electrons - propagation through a classically Forbidden zone - localization under a periodic potential - nanoscale optical interactions - near field-optics - theoretical modeling of near-field nanoscopic interactions - photonic crystals - basic concepts - theoretical modeling of photonic crystals - features of photonic crystals - methods of fabrication - photonic crystals and optical communication.

Assignment: Characterization techniques for nanostructures (i) XRD (ii) TEM (iii) AFM (iv) VSM

Course Outcome

(i) Explain the electronic band structure and density of states of different types of nanostructures.
(ii) Understand how the magnetic properties of materials change due to nanometer crystallite sizes
(iii) Understand the effect of small size of the electrical response of semiconductors
(iv) Discuss superconductivity in nanomaterials
(v) Understand basic ideas about nanophotonics- phenomena and systems

Books for Study

1. Omar Manasresh, Introduction to Nanomaterials and Devices, John Wiley and Sons, 2012.
2. Gunter Schmid (Ed.), Nanoparticles- From Theory to Application, Wiley-VCH, 2004.

3. S. V Gaponenko, Optical Properties of Semiconductor Nanocrystals, Cambridge University Press, 1998.
4. Byung- Gook Park, Sung Woo Hwang, Young June Park, Nanoelectronic Devices, Pan Stanford Publishing, 2012,
5. Kenneth J. Klabunde, Nanoscale Materials in Chemistry, John Wiley and Sons, 2001.
6. Victor I. Klimov (Ed.), Semiconductor and Metal Nanocrystals- Synthesis and Electronic and Optical properties, Marcel Dekker, Inc., 2004.
7. Frank J Owens, Charles P. Poole Jr., The Physics and Chemistry Nanosolids, John Wiley and Sons, 2008.
8. Paras N Prasad, Nanophotonics, Wiley-Interscience, 2004.
9. S. Zhang, Lin Li, A. Kumar, Materials Characterisation Techniques, CRC Press, 2008.
10. Y. Leng, Materials Characterisation: Introduction to Microscopic and Spectroscopic Methods, John Wiley & Sons (Asia), 2008.
11. D.A. Skoog, F.J. Holler, S. R. Crouch, Instrumental Analysis, Cengage Learning, 2007.
12. W. W. Wendlandt, Thermal Methods of Analysis, John Wiley, 1974.
13. D. B. Williams and C. B. Carter, Transmission Electron Microscopy, Vol. I-III. Springer, 1996

PHN 243: NANOELECTRONICS (5L,1T)

Objectives: This course will provide basic and advanced concepts on nanoelectronics. Understanding quantum electronic devices including single electron transistor is also intended. Basic ideas of the use of carbon nanostructures in electronic devices is also included. A detailed discussion of the spintronic devices of practical importance is also included.

UNIT I (30 hours)

Nanoscale electronics – Moor's law - limits of micro miniaturization in Silicon – scaling - milestones of Silicon Technology - estimation of Technology limits - introduction to nanoscale electronics - three-dimensional nanostructures - two-dimensional nanostructures - one-dimensional nanostructures - MOSFET scaling trend.

Quantum electronic devices – short-channel MOS transistor - electronic devices based on nanostructures – MODFETs -heterojunction bipolar transistors – Resonant tunnel effect- tunneling diode - resonant tunneling diode - hot electron transistors - resonant tunneling transistor.

Unit II (30 hours)

Single electron tunneling - Coulomb blockade - single electron transistor(SET) - performance of SET - fabrication of SET - operation of single electron transistors -mesoscopicarrays with nano electrodes - from single particle properties to collective charge transport – one, two, and three-dimensional arrangement of particles - logic circuits with single electron transistors - bias conditions for SETs – design scheme for SET logic circuits.

Carbon nanostructures – fullerene - graphene - carbon nanotubes (CNTs) - synthesis of carbon nanotubes - functionalization - doped carbon nanotubes - geometrical structure - electronic structure of graphene - electronic structure of CNT - metallic and semiconducting CNTs - electron transport in CNTs - operation and performance of CNFETs – CNT circuits - scalimg of CNFETsto the sub - 10nm regime - prospects of an all -CNTnanoelectronics.

Unit III (30 hours)

Spintronics – spin-tight diffusion length – spin dependent resistivity in transition metal alloys-giantmagnetoresistance (GMR) – Mott's two-current model - experiments on GMR- GMRspin value - spin injection - spin injection into a non-magnetic conductor - spin injection in semiconductors - magnetic Random Access Memory (MRAM) – Silicon-based spin transistor - design and fabrication - electrical characterization – spin-FETs - spin-MOSFETs.

Course outcome

(i) Understand the idea of miniaturization of electronic devices

(ii) Understand the basic phenomena and devices in nanoelectronics.

(iii) Understand the working of a single electron transistor and circuits involving it

(iv) Familiarize nanoelectronic devices employing carbon nanostructures

(v) Understand spintronic devices and phenomena involved such as giant magnetoresistance.

REFERENCES

1. K. Goser, P. Glosekotter, J. Dienstuhl, Nanoelectronics and Nanosystems: From Transistors to Molecular and Quantum Devices, Springer, 2004.
2. Seng Ghee Tan ,Mansoor B. A. Jalil, Introduction to the Physics of Nanoelectronics, Woodhead Publishing Liinited, 2012.
3. Byung- Gook Park, Sung Woo Hwang, Young June Park, Nanoelectronic Devices, Pan Stanford Publishing, 2012.

4. J. M. Martinez- Duart, R.J Martina- Palma, F. Agullo-Rueda, Nanotechnology for Microelectronics and Optoelectronics, Elsevier, 2006.
5. Gunter Schmid (Ed.), Nanoparticles - From Theory to Application, Wiley-VCH, 2004.
6. Rainer Waser (Ed.), Nanoelectronics and Information Technology- Advanced Electronic Materials and Novel Devices (2nd Corrected Ed.), Wiley-VCH, 2005.
7. Francois Leonard, The Physics of Carbon Nanotube Devices, Elsevier, First Indian Print, 2013.
8. An Chen, James Hutchby, Victor Zhimov, George Bourianoff (Eds.), Emerging Nanoelectronic Devices, Wiley, 2015.
9. TeruyaShinjo, Nanomagnetism and Spintronics, Elsevier, 2009.
10. Thomas Heinzel, Mesoscopic Electronics in Solid State Nanostructures, 2nd Ed., Wiley-VCH, 2007
11. Y.BXu and S.M Thompson (Eds), Spintronic Materials and Technology, Taylor & Francis, 2007.

PH 251: GENERAL PHYSICS PRACTICALS

Objectives: Demonstrate and understand various general physics experiments for acquiring fundamental concepts.

(Total of 12 experiments to be done from Section A and B)

Section A (*atleast 6 experiments to be done in this section*)

1. Determination of elastic constants by Cornu's method (elliptical and hyperbolic fringes)

2. Analysis of absorption spectra of liquids using spectrometer

3. Determination of e/k using Ge and Si transistors

5. Anderson Bridge –determination of self and mutual inductance

6. Michelson Interferometer experiments

7. Identification of Fraunhofer lines in solar spectra

8. Verification of Richardson's equation using diode valve

9. Thermal diffusivity of brass

10. e/m of an electron-Thompson's method

11. Charge of an electron-Millikan's method

12. Determination of Fermi energy of Copper

13. Study of variation of resistance of a semiconductor with temperature and determination of band gap

14. Magnetic Susceptibility of a liquid using Quincke's method

15. Ferromagnetic studies using Guoy's method

16. Hall effect in a semiconductor

17. Thermo-emf of bulk samples like Al, Cu. Brass etc.

18. Zeeman effect using Fabry-Perot Interferometer.

Section B (at least 6 experiments to be done from this section)

1. BH curve-anchor ring
2. Study of photoelectric effect and determination of of Planck's constant
3. Determination of Stefan's constant
4. Experiments using Laser:

(a) Laser beam characteristics (b) Diffraction grating (c) Diffraction at different types of slits and apertures (d) refractive index of liquids (e) particle size determination

5. Young's modulus of different materials using strain gauge
6. Determination of magnetic force in a current carrying conductor
7. Optical fibre characteristics – numerical aperture, attenuation and bandwidth of given specimen.
8. Cauchy's constants of liquids and liquid mixtures using hollow prism and spectrometer
9. Surface tension of a liquid using Jaeger's method.
10. Analysis of powder XRD data.
11. Study of stellar spectral classification from low dispersion stellar spectra
12. Study of HR diagram of stars
13. Radioactive material counting statistics
14. Interpretation of UV- visible spectra of materials
15. Electrical characteristics of a solar cell

Course Outcome

(i) To measure and analyze various physical quantities.
(ii) To calculate error in various general physics experiments.
(iii) To develop experimental skills

PH 252 Electronics and Computer Science Practicals
Objectives: Design, construct and verify various electronics circuits and object oriented programing using C++ to solve numerical problems.

Unit I – Electronics Experiments (A total of 12 experiments to be done)

Section A (*atleast 6 experiments to be done*)

1. Single stage CE amplifier –Design and study of frequency response
2. Study of RC Phase shift oscillator circuits using Transistors
3. Construction and study of astable multivibrator and VCO circuits using Transistors
4. Study of OP Amp circuits (a) summing amplifier (b) difference amplifier
5. OP Amp as an integrator and differentiator
6. Characteristics of JFET and MOSFET
7. Characteristics of SCR
8. Design and study of negative feedback amplifier circuits
9. Study of Clipping and Clamping circuits
10. UJT Characteristics and UJT relaxation Oscillator
11. Study of active filters using OP amps (a) low pass (b) high pass (c) band pass for both first order and second order-gain/ roll off determination
12. Wave form generation using OP amp circuits: (a) astable and monostable multivibrators (b) square, triangular and saw-tooth wave generation
13. IC 555 timer experiments (a) monsostable and astable multivibrators (b) VCO
14. D/A convertor circuits using OP Amp 741
15. Differential amplifier circuits using transistors
16. Design of series pass voltage regulators using transistors with load and line regulation (b) O Amp

Section B (atleast 6 experiments to be done)

1. Emitter follower and source follower circuits

2. Weinberg oscillator using OP Amp

3. SR and JK Flip Flops -construction using Logic Gates and study of truth tables

4. Study of the frequency response of a tuned amplifier

5. Study of power amplifier circuits

6. Frequency multiplier using PLL

7 Study of Schmitt trigger circuits using transistors

8. Construction and study of cascade amplifier circuit using transistors.

9.Digital modulation circuits (a) BFSK generation using 555 timer (b) BFSK detector using 555 timer and PLL (c) BPSK generation

10. Shift register and ring counter circuits using flip flops

11. Miscellaneous transistor applications (a) automatic night light with LDR

(a) invertor circuit (transistors as a switch) (c) time delay circuit using SCR

12. BCD to decimal decoder and seven segment display using IC

13. Design of Electronic counters (up and down counters)

Unit II Computer Programming

(*A minimum of 8 experiments to be done, programs should be written in C++ language*)

1. Least square fitting

2. First derivative of tabulated function by difference table

3. Numerical integration (Trapezoidal rule and Simpson method)

4. Solution of algebraic and transcendental equations using Newton-Ralphson method

5. Solution of algebraic equations using bisection method

6. Numerical interpolation using Newton and Lagrangian methods

7. Monte Carlo simulation

8. Evaluation of Bessel and Legendre functions

9. Matrix addition, multiplication, trace, transpose and inverse.

10. Fourier series analysis

11. Study of motion of projectile in a central force field

12. Study of Planetary motion and Kepler's laws

Course Outcome

(i) To design and construct various electronic circuits and its validation.
(ii) To calculate error in various electronics experiments.
(iii) To develop experimental and programming skills

PHN 244: Lab. NANOSCIENCE

Objectives: This course will provide basic ides about the phenomena, physical parameters and characterization techniques relevant to the study of nanostructures materials.

List of experiments - minimum 10 experiments to be done

1. Analysis of given X-ray diffraction pattern of nanocrystalline samples with different crystallite sizes – crystallite size and microstrain.
2. X-ray diffraction-structure evaluation and identification of material.
3. Interpretation of electron diffraction patterns (SAED pattern) of nanocrystalline samples with different sizes.
4. Determination of particle size of given material using He-Ne laser or diode laser
5. Determination of Fermi energy of copper
6. Study of variation of resistance of a semiconductor with temperature
7. Hall effect in a semiconductor
8. Measurement of resistivity of low and high resistivity semiconductors-four probe method
9. Photo current measurement in a semiconductor
10. Measurement of magnetioresistance of semiconductors
11. Determination of thickness of a film by envelope method and calculation of bank using the given transmittance spectrum of the film.
12. Determination of band gap of a semiconductor nanomaterial using UV-visible absorption spectra
13. Preparation of a thin film nanostructured sample using vacuum deposition technique
14. Preparation of a multilayered nanostructured thin film using vacuum deposition technique
15. Synthesis of metal nanoparticles using Turkevich procedure.
16. Synthesis of metal nanoparticle synthesis using Biphasic reduction.
17. Synthesis of CdSe quantum dots and its characterstics.
18. Measurement of absorbance of Au nanoparticles
19. Calculate the concentration of Au nanoparticles using Beer' Law.
20. Demonstrate the working of the self-assembly of nanoparticles on a solid support.
21. Construct a simple nanostructured photovoltaic cell and study its basic characterstics.
22. Distinguish the characteristics of any three dyes and comment on your observations.
23. Any other experiment with equal standards can be included.

Course Outcome

(i) Measure crystallite size and microstrain from XRD analysis
(ii) Interpret the results of experiments commonly employed for characterization og nanomaterials.
(iii) DO and interpret results of various characterization techniques commonly required for understand physics at nanoscale.

(iv) Do some basic preparation/synthesis techniques on nanomaterials/nanostructures