Bose Institute and University of Calcutta

Bose Institute University of Calcutta

Integrated M.Sc. - Ph.D Programme

2017-2019

Physical Sciences

CONTENTS

PROSPECTUS

An integrated M.Sc.-Ph.D. programme (2+4 years) in Physical Sciences is being offered by Bose Institute, Kolkata, in collaboration with University of Calcutta, Kolkata, for the academic session August 2017-2019. The programme was initiated in the year 2012. The website for the programe is http://www.jcbose.ac.in/integrated-phd-physical-sciences

Acharya Jagadish Chandra Bose and Bose Institute:

Acharya Jagadish Chandra Bose (November 30, 1858 – November 23, 1937) was a polymath: a great physicist, biologist, philosopher and dreamer of modern scientific research in India. He pioneered research in radio and microwave optics, made highly significant contributions to plant science, and laid the foundations of experimental science in the Indian subcontinent. He is considered the father of radio science, and is also considered the father of Bengali science fiction. He was the first from the Indian subcontinent to get a US patent, in 1904.

Bose Institute was founded by Acharya Jagadish Chandra Bose in 30th November, 1917 with the purpose of investigating fully "the many and ever opening problems of the nascent science which includes both life and non-life." Bose Institute is one of the earliest modern Institutes of India with a rich legacy of scientific research. The institute is presently celebrating its centenary through various workshops and conferences as well as several outreach programs. A state of the art Unified Academic Campus of the the institute has been inaugurated by the President of India on the 29th June, 2017. The institute website is http://www.jcbose.ac.in

University of Calcutta:

Established on 24 January 1857, the University of Calcutta is one of the most renowned Universities in the Indian subcontinent. Over time it has played a vital role in the development of India's nationhood not only by spreading progressive social ideas and values but also by establishing the ability of Indian researchers to carry out advanced scientific and technological research and rediscover the great philosophical, cultural and literal heritage of the country. The university website is http://www.caluniv.ac.in

Course Offered:

The integrated M.Sc.-Ph.D. programme in Physical Sciences is offered as a combination of a two-year (four semester) Post-Graduate M.Sc. curriculum and a four-year Ph. D. programme. In the M.Sc. curriculum specialization in the following areas centered around the research activities carried out in the Institute are available:

- Astroparticle Physics, Astrophysics and Cosmology
- Nuclear and Particle Physics
- Condensed Matter Physics and Material Science
- Statistical Physics and Complex Systems
- Quantum Computation and Information
- Space Science (Atmospheric Science, Fluid Mechanics and Solar Physics)

Course Objectives:

- To develop human resource with expertise in the broader areas as mentioned above.
- To motivate students to choose a career in basic and applied sciences.

Course Highlights:

- Extensive exposure to theory and experimental methodology of Modern Physics along with the requisite computational techniques.
- Participation in the institutional scientific activities.
- Fellowship:

  During the two years of M.Sc. course all students will be offered a fellowship of Rs. 12000/- per month. The fellowship will be continued in the next semester if and only if a student passes in each module in a semester with 40% marks, scores an aggregate of 60% marks in that semester and attends at least 75 % of the classes in the semester.

  The fellowship during the four years of Ph. D. will be in accordance with the rules of Department of Science & Technology, Govt. of India.

FEE STRUCTURE FOR M.Sc. (Physical Sciences)

The following are the fees to be paid by each student at the time of admission

(1)	Laboratory Caution Money (refundable after completion or dropping out of M.Sc.)	…	Rs.12,000.00
(2)	Library Caution Money (refundable after completion or dropping out of M.Sc.)	…	Rs. 3,000.00

ACADEMIC CALENDAR FOR M.SC. (Physical Sciences)

The academic session for M.Sc. curriculum in the Integrated M.Sc.-Ph.D. programme starts in August. The full session is divided into four semesters of 26 weeks each. The following is the generic academic calendar

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COURSE STRUCTURE FOR M.SC. (Physical Sciences)

SEMESTER 1:			**14 Contact Weeks | Total Credits: 18 | Total Marks: 250**			
Paper	**Group**	**Module**	**Subject**	**Contact Hours**	**Credits**	**Marks**
MPHC 4101	A	CT-MP-I	***Mathematical Physics I***	42	1.5	25
	B	CT-MP-II	***Mathematical Physics II***	42	1.5	25
MPHC 4102	A	CT-CM	***Classical Mechanics***	56	2	40
	B	CT-SR	***Special Relativity***	28	1	10
MPHC 4103	A	CT-MP-III	***Mathematical Physics III***	28	1	15
	B	CT-QM-I	***Quantum Mechanics I***	56	2	35
MPHC 4104	A	CT-SP-I	***Statistical Physics I***	42	1.5	25
	B	CT-ED-I	***Electrodynamics I***	42	1.5	25
MPHC 4151	A	CC-CN-I	***Computation and Numerical I***	56	2	25
	B	CE-GE-I	***General Experiments I***	112	4	25

SEMESTER 2			**14 Contact Weeks | Total Credits 21 | Total Marks: 300**			
Paper	**Group**	**Module**	**Subject**	**Contact Hours**	**Credits**	**Marks**
MPHC 4205	A	CT-QM-II	***Quantum Mechanics II***	42	1.5	25
	B	CT-QM-III	***Quantum Mechanics III***	42	1.5	25
MPHC 4206	A	CT-SP-II	***Statistical Physics II***	42	1.5	25
	B	CT-ED-II	***Electrodynamics II***	42	1.5	25
MPHC 4207	A	CT-EC	***Electronics and Communication***	42	1.5	25
	B	CT-SC	***Semiconductor Physics***	42	1.5	25
MPHC 4252	A	CC-CN-II	***Computation and Numerical II***	56	2	25
	B	CC-IC	***Interfacing & Computer Tools***	56	2	25
MPHC 4253	A	CE-EL	***Electronics Experiments***	84	3	25
	B	CE-COM	***Communication Experiments***	84	3	25
MPHC 4281	---	CV-CV-I	***Comprehensive Viva I***	56	2	50

SEMESTER 3			**14 Contact Weeks | Total Credits: 18 | Total Marks: 250**			
Paper	**Group**	**Module**	**Subject**	**Contact Hours**	**Credits**	**Marks**
MPHC 4309	A	CT-SSP-I	***Solid State Physics I***	42	1.5	25
	B	CT-SSP-II	***Solid State Physics II***	42	1.5	25
MPHC 4310	A	CT-ATM	***Atomic Physics***	35	1.2	20
	B	CT-MOL	***Molecular Physics***	35	1.2	20
	C	CT-LAS	***Laser Physics***	14	0.6	10
MPHC 4311	A	CT-NP	***Nuclear Physics***	42	1.5	25
	B	CT-PP	***Particle Physics***	42	1.5	25
MPHC 4312	A	CT-NLD	***Nonlinear Dynamics***	42	1.5	25
	B	CT-INT	***Instrumentation***	42	1.5	25
MPHC 4354	A	CE-GE-II	***General Experiments II***	84	3	25
	B	CE-GE-III	***General Experiments III***	84	3	25

SEMESTER 4			**20 Contact Weeks | Total Credits: 30 | Total Marks: 200**			
Paper	**Group**	**Module**	**Subject**	**Contact Hours**	**Credits**	**Marks**
MPHS 4401	---	SP-RES	***Research and Dissertation***	760	27	150
MPHC 4482	---	CV-CV-II	***Comprehensive Viva II***	80	3	50

The above course structure is subject to modifications from time to time as decided by the Board of Studies.

EXAMINATION STRUCTURE FOR M.SC. (Physical Sciences)

There shall be four mid-semester examinations and four end-semester examinations in the M.Sc. course in the span of two years.

Evaluation:

The evaluation of the students during the M.Sc. course will be done as under : -

Theory Papers:

Continuous Internal Assessment : 10%
Mid Semester Examination : 20%
End Semester Examination: : 70 %

Experiment/Computation papers:

Continuous Internal Assessment : 20%
Mid Semester Viva : 20%
End Semester Examination : 60%

Comprehensive Viva:

End Semester Examination : 100%

Research and Dissertation:

Mid Semester Viva : 16.67%
Mid Semester Presentation : 16.67%
Final Semester Viva : 33.33%
Final Semester Presentation : 16.67%
Final Semester Report : 16.67%

Credits and Grade Points:

Credits

One credit point corresponds to 28 contact hours in the full semester.

Attendance: In all semesters a candidate attending less than 75% of classes in a given module will receive zero credit for that module. If attendance is equal or more than 75%, the credit earned will be calculated as $C^E = PA * C_i$, where PA is the percentage of attendance.

Grades

A six point credit system has been adopted. Pass grade point is 3.000. If in a module i a candidate secures P_i %, where P_i is at least 40, then the grade point of the candidate is $GP_i = 3.000 + 0.5(P_i - 40)$. In case percentage value of marks involves decimal figures, candidates shall be awarded the next higher integer value if the decimal value (rounded off up to two decimal places) equals or exceeds 0.50. Numerical grade points shall not be calculated in respect of a failed paper. The grading table is as follows.

Percentage of Marks	Grades	Numerical Grade Points	Remarks
80-100	O	5.000-6.000	Outstanding
70-79	A+	4.500-4.999	Excellent
60-69	A	4.000-4.499	Very Good
55-59	B+	3.750-3.999	Good
50-54	B	3.500-3.749	Fair
40-49	C	3.000-3.499	Satisfactory
0-39	F	------	Fail

If the credit in the module i is C_i and the grade point obtained is GP_i, then the Semester Grade Point Average (SGPA) will be given as $SGPA=\sum_{i=1}^{N} C_i^E GP_i / C_S$,where the semester credit is $C_S=\sum_{i=1}^{n} C_i$, and there are total n individual modules in the semester. Similarly if there are N modules in the whole M.Sc. course, then the Cumulative Grade Point Average (CGPA) will be given as $CGPA=\sum_{i=1}^{N} C_i^E GP_i / C_T$, where the total course credit is $C_T=\sum_{i=1}^{N} C_i$. All the GP, SGPA and CGPA are to be rounded up to three decimal places and shown as such.

Examination Regulations:

i. A candidate is required to appear at each and every examination and undergo each and every assessments as described above.

ii. ***Passing Criteria:***

General passing criteria is to obtain 40% in each and every module in all four semesters.

Semesters I, II and III

No candidate shall be permitted to proceed to the next semester if the candidate has either secured less than 40% marks in more than two individual modules, or has remained absent in more than one individual paper in the current semester.

In that case the candidate has to reappear in all the examinations in the same semester in the following year without attending the classes. No opportunity of supplementary examination will be available. A candidate failing to clear a particular semester in the second chance will be dropped from the course.

In case a candidate has secured less than 40% marks in maximum of two modules, or has remained absent in the examination of maximum one paper, the candidate may appear for supplementary examination within six months of the declaration of the semester results. A candidate failing to clear a given module or paper in maximum of two supplementary examinations will be dropped from the course.

Opportunity for reappearance in an examination exists only in the cases as described above. No other voluntary options for reappearance in an examination are available.

Semester IV

A candidate has to obtain at least 40% marks in each module to pass the fourth semester. If the candidate has secured less than 40% marks in any single module or has remained absent in the examination of any single module, the candidate has to reappear in all the examinations in the same semester in the following year without attending the classes. No opportunity of supplementary examination will be available. A candidate failing to clear the fourth semester in the second chance will be dropped from the course.

Opportunity for reappearance in an examination exists only in cases as described above. No other voluntary options for reappearance in an examination are available.

iii. ***Grading the Candidates:***

On the basis of CGPA obtained by a candidate over four semesters, final grade and class shall be awarded as follows:

CGPA	Grade		Class
5.000-6.000	O	Outstanding	1st Class
4.500-4.999	A+	Excellent	1st Class
4.000-4.499	A	Very Good	1st Class
3.750-3.999	B+	Good	2nd Class
3.500-3.749	B	Fair	2nd Class
3.000-3.499	C	Satisfactory	2nd Class
0.000-2.995	F	Fail	Fail

iv. ***M.Sc. Degree:***

On successful completion of the course, the M.Sc. degree will be awarded jointly by Bose Institute and the University of Calcutta.

v. ***Eligibility for entering into the Ph.D. Programme:***

A candidate has to fulfill all of the following criteria to enter into the Ph. D. programme :

1. Pass all modules and obtain 60% marks in aggregate in each of the first three semesters in M.Sc.
2. Pass all modules and obtain 75% marks in aggregate in the 4th semester in M.Sc.
3. Complete the M.Sc. course within two academic years. Any candidate taking more than two academic years to complete the M.Sc. course may be admitted to the Ph.D. course subject to the approval from competent authority.
4. Qualify a national level eligibility test for entering into Ph.D. as recognized by the Department of Science and Technology, Government of India. However for candidates not having cleared such a test an opportunity will be given to clear such a test within one year of obtaining the M.Sc. Degree.

vi. ***Ph.D. Degree:***

The candidates are to get themselves registered for Ph.D. at the University of Calcutta. On successful completion of the doctoral course, the Ph.D. degree will be awarded by the University of Calcutta.

SYLLABUS FOR M.SC. (Physical Sciences)

SEMESTER 1

Paper - MPHC4101

Module: CT-MP-I [Contact Hours: 42 /\ Marks 25]

Mathematical Physics I

1. *Theory of second order linear homogeneous differential equations* :

Singular points – regular and irregular singular points; Frobenius method; Fuch's theorem; Linear independence of solutions – Wronskian, second solution. Sturm-Liouville theory; Hermitian operators; Completeness.

2. *Inhomogeneous differential equations :* Green's functions

3. *Special functions :*

Basic properties (recurrence and orthogonality relations, series expansion) of Bessel, Legendre, Hermite and Laguerre functions.

4. *Integral transforms :*

Fourier and Laplace transforms and their inverse transforms, Bromwich integral [use of partial fractions in calculating inverse Laplace transforms]; Transform of derivative and integral of a function; Solution of differential equations using integral transforms.

Module: CT-MP-II [Contact Hours: 42 /\ Marks 25]

Mathematical Physics II

1. *Complex variables* :

Recapitulation: complex numbers, triangular inequalities, Schwarz inequality, Function of a complex variable – single and multivalued function. Limit and continuity. Differentiation – Cauchy-Riemann equations and their applications. Analytic and Harmonic Functions. Complex integrals. Cauchy's theorem (elementary proof only), converse of Cauchy's theorem, Cauchy integral formula and its corollaries, Series – Taylor and Laurent expansion, classification of singularities, branch point and branch cut, residue theorem and evaluation of some typical integrals using this theorem.

2. *Matrices and Tensors:*

Representation of linear transformations and change of base; Eigenvalues and eigenvectors; Functions of a matrix; Cayley-Hamilton theorem; Commuting matrices with degenerate eigenvalues; Orthonormality of eigenvectors.
4D geometry in arbitrary curvilinear coordinates; transformation of tensors, mathematical operation with tensors (addition, subtraction & multiplication), metric tensors, raising and lowering of indices, unit tensor, Levi civita symbol, invariant volume elements, covariant differentiation, Christoffel symbol, curvature tensor.

Paper - MPHC4102

Module: CT- CM [Contact Hours: 56 /\ Marks 40]

Classical Mechanics

1. *An overview of the Lagrangian formalism :*

Some specific applications of Lagrange's equation; small oscillations, normal modes and frequencies.

2. *Rigid bodies* :

Independent coordinates; orthogonal transformations and rotations (finite and infinitesimal); Euler's theorem, Euler angles; Inertia tensor and principal axis system; Euler's equations; Heavy symmetrical top with precession and nutation.

3. *Hamilton's principle* :

Calculus of variations; Hamilton's principle; Lagrange's equation from Hamilton's principle; Legendre transformation and Hamilton's canonical equations; Canonical equations from a variational principle; Principle of least action.

4. *Canonical transformations :*

Generating functions; examples of canonical transformations; group property; Integral variants of Poincare; Lagrange and Poisson brackets; Infinitesimal canonical transformations; Conservation theorem in Poisson bracket formalism; Jacobi's identity; Angular momentum Poisson bracket relations.

5. *Hamilton-Jacobi theory :*

The Hamilton Jacobi equation for Hamilton's principle function; The harmonic oscillator problem; Hamilton's characteristic function; Action angle variables.

6. *Lagrangian formulation for continuous systems :*

Lagrangian formulation of acoustic field in gases; the Hamiltonian formulation for continuous systems; Canonical equations from a variational principle, Poisson's brackets and canonical field variables.

Module: CT-SR: [Contact Hours: 28 /\ Marks 10]

Special Relativity

Lorentz transformations, four- vectors, tensors, transformation properties, metric tensor, raising and lowering of indices, contraction, symmetric and antisymmetric tensors, four dimensional velocity and acceleration, four-momentum and four-force, covariant equations of motion, relativistic kinematics (decay and elastic scattering), Lagrangian and Hamiltonian of relativistic particles.

Paper- MPHC4103

Module: CT-MP-III [Contact Hours: 28 /\ Marks 15]

Mathematical Physics III

Group Theory

1. *Linear Vector space :*

Axiomatic definition, linear independence, bases, dimensionality, inner product, Gram Schmidt orthogonalization.

2. Group Theory :

Symmetries, representation theory, broad overview of finite and continuous groups, rotation group, the nature of time-reversal and space-inversion operations, point groups and crystal tensors, application to X-ray analysis of structures and molecular vibrations, the Wigner-Eckart theorem, Lie groups and representations, Young tableaux, Dynkin diagrams, SU(2), Gauge invariance, equivalence with angular momentum, Clebsh-Gordan coefficients.

Module: CT-QM-I [Contact Hours: 56 /\ Marks 35]

Quantum Mechanics I

1. *Recapitulation of basic concepts* :

Wave packet, Gaussian wave packet, Fourier transform, spreading of a wave packet, Fourier transforms of delta and sine function, co-ordinate and momentum space: co-ordinate and momentum representation, Parseval's theorem, eigenvalues and eigenvectors: Momentum and parity operators, commutativity and simultaneous eigenfunctions, complete set of eigenfunctions: expansion of wave functions in terms of a complete set, one dimensional problems: square well potential (E>0), delta function, double delta potential, application to molecular inversion, multiple potential well, Kronig-Penney model.

2. *Operator method in quantum mechanics* :

Formulation of quantum mechanics in vector space language, uncertainty principle for two arbitrary operators, one dimensional harmonic oscillator by operator method.

3. *Quantum theory of measurement and time evolution* :

Double Stern-Gerlach experiment for spin ½ systems, Schrodinger, Heisenberg and interaction pictures.

4. *Three dimensional problems* :

Three dimensional problems in Cartesian and spherical polar co-ordinates, 3 d well and Fermi energy, radial equation for a free particle and 3 d harmonic oscillator, eigenvalue of a 3 d harmonic oscillator by series solution.

5. *Angular momentum :*

Angular momentum algebra, raising and lowering operators, matrix representation of j = ½ and j = 1, spin, addition of two angular momenta: Clebsch-Gordan co-efficients, examples.

Paper- MPHC4104

Module: CT-SP-I [Contact Hours: 42 /\ Marks 25]

Statistical Physics I

1. *Introduction :*

Objective of statistical mechanics. Macrostates, microstates, phase space and ensembles. Ergodic hypothesis, postulate of equal a priori probability and equality of ensemble average and time average. Boltzmann's postulate of entropy. Counting the number of microstates in phase space. Entropy of ideal gas: Sackur-Tetrode equation and Gibbs' paradox. Liouville's Theorem.

2. *Canonical Ensemble :*

System in contact with a heat reservoir, expression of entropy, canonical partition function, Helmholtz free energy, fluctuation of internal energy.

3. *Grand Canonical Ensemble :*

System in contact with a particle reservoir, chemical potential, grand canonical partition function and grand potential, fluctuation of particle number. Chemical potential of ideal gas.

4. Classical non-ideal gas :

Mean field theory and Van der Wall's equation of state; Cluster integrals and Mayer-Ursell expansion.

Module: CT-ED-I [Contact Hours: 42 /\ Marks 25]

Electrodynamics I

1. *Electrostatics and Magnetostatics* :

Scalar and vector potentials, gauge transformations, multipole expansion of (i) scalar potential and energy due to a static charge distribution, (ii) vector potential due to a stationary current distribution, electrostatic and magnetostatic energy, Poynting's theorem, Maxwell's stress tensor.

2. *Radiation from time dependent sources of charges and currents* :

Inhomogeneous wave equations and their solutions, Radiation from localized sources and multipole expansion in the radiation zone.

3. *Relativistic electrodynamics:*

Equation of motion in an electromagnetic field, electromagnetic field tensor, covariance of Maxwell's equations, Maxwell's equations as equations of motion, Lorentz transformation law for the electromagnetic fields and the fields due to a point charge in uniform motion, field invariants, covariance of Lorentz force equation and the equation of motion of a charged particle in an electromagnetic field, the generalized momentum, energy-momentum tensor and the conservation laws for the electromagnetic field, relativistic Lagrangian and Hamiltonian of a charged particle in an electromagnetic field.

Paper- MPHC4151

Module: CC-CN-I [Contact Hours: 56 /\ Marks 25]

Computation and Numerical Techniques I

Exposition of the following in a popular programming language:

Constants and variables. Assignment and arithmetic expressions. Logical expressions and control statements, DO loop, array, input and output statements, function subprogram, subroutine.

Processing of text and strings.

Computational Complexity: P, NP and NP Completeness

Case Studies: Genetic Algorithm, Motion under classical force fields, Random walk problem, Kinetic Monte Carlo, Dynamical systems.

Module: CE-GE-I [Contact Hours: 112 /\ Marks 25]

General Experiments I

1. Michelson's Interferometer
2. Planck's Constant by Photoelectric effect / By means of LED characteristics
3. Franck-Hertz experiment
4. Measurement of e/m with Bar magnets/ with He filled tube and Helmoltz's coil
5. Audio oscillators
6. Stefan's Law

SEMESTER 2

Paper- MPHC4205

Module: CT-QM-II [Contact Hours: 42 /\ Marks 25]

Quantum Mechanics II

1. *Approximation Methods :*

Time independent perturbation theory: First and second order corrections to the energy eigenvalues; First order correction to the eigenvector; Degenerate perturbation theory; Application to one-electron system – Relativistic mass correction, Spin-orbit coupling (L-S and j-j), Zeeman effect and Stark effect. Variational method: He atom as example; First order perturbation; Exchange degeneracy; Ritz principle for excited states for Helium atom.

2. *WKB Approximation :*

Quantisation rule, tunnelling through a barrier, qualitative discussion of α-decay.

3. *Time-dependent Perturbation Theory :*

Time dependent perturbation theory, interaction picture; Constant and harmonic perturbations – Fermi's Golden rule; Sudden and adiabatic approximations.

3. *Scattering theory :*

Laboratory and centre of mass frames, differential and total scattering cross-sections, scattering amplitude; Scattering by spherically symmetric potentials; Partial wave analysis and phase shifts; Ramsauer-Townsend effect; Relation between sign of phase shift and attractive or repulsive nature of the potential; Scattering by a rigid sphere and square well; Coulomb scattering; Formal theory of scattering – Green's function in scattering theory; Lippman-Schwinger equation; Born approximation.

Module: CT-QM-III [Contact Hours: 42 /\ Marks 25]

Quantum Mechanics III

1. *Symmetries in quantum mechanics :*

Conservation laws and degeneracy associated with symmetries; Continuous symmetries – space and time translations, rotations; Rotation group, homomorphism between SO(3) and SU(2); Explicit matrix representation of generators for j = 2 and j = 1; Rotation matrices; Irreducible spherical tensor operators, Wigner-Eckart theorem; Discrete symmetries — parity and time reversal.

2. *Identical Particles* :

Meaning of identity and consequences; Symmetric and antisymmetric wavefunctions; Slater determinant; Symmetric and antisymmetric spin wavefunctions of two identical particles; Collisions of identical particles.

3. Relativistic Quantum Mechanics : Klein-Gordon equation, Feynman-Stuckelberg interpretation of negative energy states and concept of antiparticles; Dirac equation, covariant form, adjoint equation; Plane wave solution and momentum space spinors; Spin and magnetic moment of the electron; Non-relativistic reduction; Helicity and chirality; Properties of γ matrices; Charge conjugation; Normalisation and completeness of spinors.

Paper- MPHC4206

Module: CT-SP-II [Contact Hours: 42 /\ Marks 25]

Statistical Physics II

1. *Quantum statistical mechanics :*

Density Matrix; Quantum Liouville theorem; Density matrices for microcanonical, canonical and grand canonical systems; Simple examples of density matrices — one electron in a magnetic field, particle in a box; Identical particles — B-E and F-D distributions.

2. *Ideal Bose and Fermi gas :*

Equation of state; Bose condensation; Equation of state of ideal Fermi gas; Fermi gas at finite T.

3. *Special topics :*

Ising model: partition function for one dimensional case; Chemical equilibrium and Saha ionisation formula. Phase transitions: first order and continuous, critical exponents and scaling relations. Calculation of exponents from Mean Field Theory and Landau's theory, upper critical dimension.

4. Irreversible Thermodynamics :

Flux and affinity. Correlation function of fluctuations. Onsager reciprocity theorem (including proof). Thermoelectric effect.

Module: CT-ED-II [Contact Hours: 42 /\ Marks 25]

Electrodynamics II

1. *Radiation from moving point charges :*

Lienard-Wiechert potentials; Fields due to a charge moving with uniform velocity; Fields due to an accelerated charge; Radiation at low velocity; Larmor's formula and its relativistic generalisation; Radiation when velocity (relativistic) and acceleration are parallel, Bremsstrahlung; Radiation when velocity and acceleration are perpendicular, Synchrotron radiation; Cherenkov radiation (qualitative treatment only). Thomson and Compton scattering.

5. *Radiation reaction :*

Radiation reaction from energy conservation; Problem with Abraham-Lorentz formula; Limitations of CED.

6. Plasma physics :

Definition of plasma; Its occurrence in nature; Dilute and dense plasma; Uniform but time-dependent magnetic field: Magnetic pumping; Static non-uniform magnetic field: Magnetic bottle and loss cone; MHD equations, Magnetic Reynold's number; Pinched plasma; Bennett's relation; Qualitative discussion on sausage and kink instability.

Paper- MPHC4207

Module: CT-EC [Contact Hours: 42 /\ Marks 25]

Electronics and Communication

1. *Analog circuits :*

Comparators, Multivibrators, Waveform generators: Square wave, triangle wave and pulse generators.

2. *Digital MOS circuits :*

NMOS and CMOS gates (AND, NAND and NOT), Dynamic MOS circuits, ratioinverter, two phase inverter; dynamic MOS shift register, static MOS shift registers, four phase shift registers. Memory Devices; Static and dynamic random access memories (SRAM and DRAM)

3. *Transmission line :*

Transmission line equation and solution; Reflection and transmission coefficient; Standing wave and standing wave ratio; Line impedance and admittance; Smith chart.

4. Communication :

Introduction to signals; Concepts of Voice & Data Communication; Transmission lines, Transmission Channels; Modulation & Multiplexing of Analog and Digital Signals; CCITT / ITU Standards of Voice & Data Communication Systems; Pulse Code Modulation (PCM); Digital Multiplexing (PDH&SDH).

Module: CT-SC [Contact Hours: 42 /\ Marks 25]

Semiconductor Physics

1. Carrier concentration in semiconductors, p-n junction band diagram, I-V and C-V Characteristics; basic semiconductor equations, depletion and diffusion capacitance, Reverse Breakdown; Noise; Bipolar Junction Transistors (BJT); Ebers-Moll equation. Frequency response;

2. Metal semiconductor junctions: Schottky barriers; Rectifying and ohmic contacts; Tunnel diode; Uni-junction transistor (UJT); Field Effect Transistor (FET): types, structure, JFET, MESFET, MOSFET: characteristics, threshold voltage.

Paper- MPHC4252

Module: CC-CNT-II [Contact Hours: 56 /\ Marks 25]

Computation and Numerical Techniques II

Numerical analysis: Computer arithmetic and errors in floating point representation of numbers, different numerical methods for (i) finding zeros of a given function (ii) solution of linear simultaneous equations (iii) numerical differentiation and integration (iv) solution of first-order differential equations (v) interpolation and extrapolation (vi) least square fitting. Random number generation, sorting.

Implementation of Numerical algorithms: Descriptive statistics, Solution of linear systems, root finding, interpolation and least square polynomial approximation, Numerical Integration, ODES: Euler and Runge-Kutta, Uses of the random number module.

Module: CE- IC [Contact Hours: 56 /\ Marks 25]

Interfacing and Computer Tools:

Introduction to Open Source Computing Tools: Brief inventory, The Linux Command line Computing Environment Data Visualization and Curve fitting using Gnuplot.

Scientific Computing using Python/Numeric/Scipy/Matplotlib: Language essentials,

Computer Interfacing

Principles of Computer interfaced experiments: Sensors, Sampling, ADC width and delay, DAC limitations, Precision in digitized experiments. Components of the IUAC Phoenix/Expeyes box: Digital I/O, DAC, PWG, Counter, ADC, Amplifiers. Familiarization with the python API. Software and Hardware triggers, Hardware control, Data acquiring and analysis using unipolar and bipolar signals: Fast Vs. Precision experiments, Design / Coding for simple experiments using available thermo/mechanical/audio sensors.

Paper- MPHC4253

Module: CE- EL [Contact Hours: 84 /\ Marks 25]

Electronics Experiments

1. Determination of band gap and reverse saturation current of a p n junction diode
2. Construction of Astable Multi-vibrator and VCO
3. To study UJT Characteristics
4. To study Active Filters (High pass, Low pass, Band pass, Notch)
5. To study T Filters (High and Low pass filter)
6. To study Pi Filters (High and Low pass filter)

Module: CE-COM [Contact Hours: 84 /\ Marks 25]

Communication Experiments

1. Pulse Width Modulation and Demodulation
2. Study of Frequency Modulation and its Demodulation using IC PLL565
3. Pulse Position Modulation and Demodulation
4. Study of Amplitude Shift Keying and Demodulation
5. Study of Frequency Shift keying and Demodulation [IC 8038 Function Generator used]
6. Study of Amplitude Modulation and Demodulation [IC Version 1496]

Paper- MPHC4281

Module: CV-CV-I [Contact Hours: 56 /\ Marks 50]

Comprehensive Viva I

Each student is required to develop an overall understanding of various aspects of physics as well as acquire general knowledge in physics research around the world as much as possible. Comprehensive Viva aims to examine the student's overall understanding and grasp of basic and advanced (as applicable) topics in Physics and Mathematical Physics. The student will be required to answer conceptual questions and solve problems.

SEMESTER 3

Paper- MPHC4309

Module: CT-SSP-I [Contact Hours: 42 /\ Marks 25]

Solid State Physics I

1. *Crystal structure :*

Bravais lattice – primitive vectors, primitive unit cell, conventional unit cell, Wigner-Seitz cell; Symmetry operations and classification of 2- and 3-dimensional Bravais lattices; Crystal structures: basis, crystal class, point group and space group (information only); Common crystal structures: NaCl and CsCl structure, crystals of alkali and noble metals, close-packed structure, cubic ZnS structure; Reciprocal lattice and Brillouin zone; Bragg-Laue formulation of X-ray diffraction by a crystal; Atomic and crystal structure factors; Experimental methods of X-ray diffraction: Laue, rotating crystal and powder method; Electron and neutron diffraction by crystals (qualitative discussion); Intensity of diffraction maxima; Extinctions due to lattice centering.

2. *Band theory of solids :*

Bloch equation; Empty lattice band; Nearly free electron bands; Band gap; Number of states in a band; Tight binding method; Effective mass of an electron in a band: concept of holes; Band structures in copper, GaAs and silicon; Classification of metal, semiconductor and insulator; topology of Fermi-surface; cyclotron resonance – de Haas - van Alphen effect; Boltzmann transport equation – relaxation time approximation, Sommerfeld theory of electrical conductivity.

3. *Lattice dynamics :*

Classical theory of lattice vibration under harmonic approximation; Vibrations of linear monatomic and diatomic lattices, acoustical and optical modes, long wavelength limits; Optical properties of ionic crystal in the infrared region; Adiabatic approximation (qualitative discussion); Normal modes and phonons; Inelastic scattering of neutron by phonon; Lattice heat capacity, models of Debye and Einstein, comparison with electronic heat capacity; Anharmonic effects in crystals — thermal expansion and thermal conductivity; Mossbauer effect.

4. *Dielectric properties of solids :*

Static dielectric constant: electronic and ionic polarisation of molecules, orientational polarisation, static dielectric constant of gases; Lorentz internal field; Static dielectric constants of solids; Complex dielectric constant and dielectric losses, relaxation time; Classical theory of electronic polarisation and optical absorption; Ferroelectricity — dipole theory, case of BaTiO.

Module: CT-SSP-II [Contact Hours: 42 /\ Marks 25]

Solid State Physics II

1. *Magnetic properties of solids :*

Origin of magnetism; Diamagnetism: quantum theory of atomic diamagnetism; Landau diamagnetism (qualitative discussion); Paramagnetism: classical and quantum theory of paramagnetism; case of rare-earth and iron-group ions; quenching of orbital angular momentum; Van-Vleck paramagnetism and Pauli paramagnetism; Ferromagnetism: Curie-Weiss law, temperature dependence of saturated magnetisation, Heisenberg's exchange interaction, ferromagnetic domains; Ferrimagnetism and anti-ferromagnetism.

2. *Magnetic resonances :*

Nuclear magnetic resonances, Bloch equation, longitudinal and transverse relaxation time; Hyperfine field; Electron-spin resonance.

3. *Imperfections in solids and optical properties :*

Frenkel and Schottky defects, defects in growth of crystals; The role of dislocations in plastic deformation and crystal growth; Colour centers and photoconductivity; Luminescence and phosphors; Alloys – order-disorder phenomena, Bragg-Williams theory; Extra specific heat in alloys.

4. *Superconductivity :*

Phenomenological description of superconductivity – occurrence of superconductivity, destruction of superconductivity by magnetic field, Meissner effect; Type-I and type-II superconductors; Heat capacity, energy gap and isotope effect; Outlines of the BCS theory; Giaver tunnelling; Flux quantisation; a.c. and d.c. Josephson effect; Vortex state (qualitative discussions); High Tc superconductors (information only).

Paper- MPHC4310

Module: CT-ATM [Contact Hours: 35 /\ Marks 20]

Atomic Physics

1. *One Electron Atom :*

Introduction: Quantum States; Atomic orbital; Parity of the wave function; Angular and radial distribution functions.

2. *Interaction of radiation with matter :*

Time dependent perturbation: Sinusoidal or constant perturbation; Application of the general equations; Sinusoidal perturbation which couples two discrete states – the resonance phenomenon. Interaction of an atom with electromagnetic wave: The interaction Hamiltonian - Selection rules; Nonresonant excitation – Comparison with the elastically bound electron model; Resonant excitation - Induced absorption and emission.

3. *Fine and Hyperfine structure :*

Solution of Dirac equation in a central field; Relativistic correction to the energy of one electron atom. Fine structure of spectral lines; Selection rules; Lamb shift. Effect of external magnetic field - Strong, moderate and weak field. Hyperfine interaction and isotope shift; Hyperfine splitting of spectral lines; selection rules.

4. *Many electron atom :*

Independent particle model; He atom as an example of central field approximation; Central field approximation for many electron atom; Slater determinant; L-S and j-j coupling; Equivalent and nonequivalent electrons; Energy levels and spectra; Spectroscopic terms; Hunds rule; Lande interval rule; Alkali spectra.

Module: CT-MOL [Contact Hours: 35 /\ Marks 20]

Molecular Physics

5. *Molecular Electronic States :*

Concept of molecular potential, Separation of electronic and nuclear wavefunctions, Born-Oppenheimer approximation, Electronic states of diatomic molecules, Electronic angular momenta, Approximation methods for the calculation of electronic Wave function, The LCAO approach, States for hydrogen molecular ion, Coulomb, Exchange and Overlap integral, Symmetries of electronic wavefunctions; Shapes of molecular orbital; π and σ bond; Term symbol for simple molecules.

6. *Rotation and Vibration of Molecules :*

Solution of nuclear equation; Molecular rotation: Non-rigid rotator, Centrifugal distortion, Symmetric top molecules, Molecular vibrations: Harmonic oscillator and the anharmonic oscillator approximation, Morse potential.

7. *Spectra of Diatomic Molecules :*

Transition matrix elements, Vibration-rotation spectra: Pure vibrational transitions, Pure rotational transitions, Vibration-rotation transitions, Electronic transitions: Structure, Franck-Condon principle, Rotational structure of electronic transitions, Fortrat diagram, Dissociation energy of molecules, Continuous spectra, Raman transitions and Raman spectra.

8. *Vibration of Polyatomic Molecules: Application of Group Theory :* Molecular symmetry; Matrix representation of the symmetry elements of a point group; Reducible and irreducible representations; Character tables for C2v and C3v point groups; Normal coordinates and normal modes; Application of group theory to molecular vibration.

Module: CT-LAS [Contact Hours: 14 /\ Marks 10]

Laser Physics

Basic elements of a laser; Threshold condition; Four-level laser system, CW operation of laser; Critical pumping rate; Population inversion and photon number in the cavity around threshold; Output coupling of laser power. Optical resonators; Cavity modes; Mode selection; Pulsed operation of laser: Q-switching and Mode locking; Experimental technique of Q-switching and mode locking . Different laser systems: Ruby, CO_2 , Dye and Semiconductor diode laser.

Paper- MPHC4311

Module: CT-NP [Contact Hours: 42 /\ Marks 35]

Nuclear Physics

1. *Nuclear Properties* :

Nuclear size, Rutherford scattering, nuclear radius and charge distribution, nuclear form factor, mass and binding energy, angular momentum, parity and symmetry, magnetic dipole moment and electrical quadrupole moment, experimental determination, Rabi's method.

2. *Two-body state* :

Properties of deuteron, Schrodinger equation and its solution for ground state of deuteron, rms radius, spin dependence of nuclear forces, electromagnetic moment and magnetic dipole moment of deuteron and the necessity of tensor forces.

3. *Two-body scattering* :

Experimental n-p scattering data, partial wave analysis and phase shifts, scattering length, magnitude of scattering length and strength of scattering, significance of the sign of scattering length, scattering from molecular hydrogen and determination of singlet and triplet scattering lengths, effective range theory, low energy p-p scattering, nature of nuclear forces: charge independence, charge symmetry and isospin invariance of nuclear forces.

4. *β-decay* :

β emission and electron capture, Fermi's theory of allowed β decay, selection rules for Fermi and Gamow-Teller transitions, parity non-conservation and Wu's experiment.

5. *Nuclear structure*:

Liquid drop model, Bethe-Weizsacker binding energy/mass formula, Fermi model, Shell model and collective model.

6. *Nuclear reactions and Fission* :

Different types of reactions, quantum mechanical theory, resonance scattering and reactions – Breit-Wigner dispersion relation, compound nucleus formation and break-up, statistical theory of nuclear reactions and evaporation probability, optical model, principle of detailed balance, transfer reactions, nuclear fission: experimental features, spontaneous fission, liquid drop model, barrier penetration, statistical model, super-heavy nuclei.

7. *Nuclear Astrophysics* :

(Qualitative ideas only), nucleosynthesis and abundance of elements, neutron star.

Module: CT-PP [Contact Hours: 42 /\ Marks 25]

Particle Physics

Symmetries and conservation laws, Hadron classification by isospin and hypercharge, SU(2) and SU(3): Groups, algebras and generators, Young tableaux rules for SU(2) and SU(3), quarks, colour, elementary ideas about electroweak interaction and the Standard Model.

Paper- MPHC4312

Module: CT-NLD [Contact Hours: 42 /\ Marks 25]

Nonlinear Dynamics

Why Nonlinear Dynamics --The basic differences of Nonlinear Systems with Linear ones--

Flows and Maps, Fixed Point Analysis in 1-D Systems, Fixed point analysis and Qualitative features of Phase Portraits in 2-D systems, Limit Cycles, Generalization of ideas in higher dimensions, Bifurcations-- 1-D systems, Bifurcations-- 2-D systems -- mainly local ones with some notions of Global Bifurcations, Hamiltonian systems- integrability and non-integrability-- onset of chaos in nearly integrable systems, Poincare Section and Maps along with Stroboscopic Maps , 1-D and 2-D Maps -- Logistic, Standard and Baker's Maps -- Chaos and Liapunov Exponents, Ideas of strange attractors and chaos – Nonlinear Oscillators, Fractals and Fractal dimensions.

Module: CT-INT [Contact Hours: 42 /\ Marks 25]

Instrumentation

1. *Experimental design:*

Scintillation detectors; Solid state detectors (Si and HPGe). Measurement of energy and time using electronic signals from the detectors and associated instrumentation, Signal processing; Multi channel analyzer; Time of flight technique; Coincidence measurements true-to-chance ratio.

2. *Error analysis and hypothesis testing* :

Propagation of errors; Plotting of graphs, Distribution, Least square fit, Criteria for goodness of fit ($\chi 2$ -testing).

Paper- MPHC4353

Module: CE-GE-II [Contact Hours: 84 /\ Marks 25]

General Experiments II

Hall Effect I
Hall Effect II
Resistivity measurement using four-probe
Dielectric constant as a function of frequency for different solids
Dielectric constant and Curie temperature of ferromagnetic ceramics
Study of optical absorption and optical band gap determination of semiconductors
Determination of precise lattice parameter and crystallite size of materials by X-Ray powder diffractometer.

Module: CE-GE-III [Contact Hours: 84 /\ Marks 25]

General Experiments III

Iodine absorption spectra
Laser: Parametric down conversion
Detection of single photon
Single photon interference
Two photon interference and/or quantum eraser
Experimental Plasma Physics: Determination of basic parameters of plasma using Plasma discharge tube.
Determination of energy peaks of gamma rays from radioactive sources using Sodium Iodide detector.

SEMESTER 4

Paper- MPHS4401

Module: SP-RES [Contact Hours: 760 /\ Marks 150]

Research and Dissertation

Each student is required to undertake a research project on an advanced topic to be chosen in consultation with a supervisor. The topic will be usually centered around the research activities carried out in the institute. Apart from advanced learning it is expected that each project shall have a research component. The progress of the student will be examined in the mid-semester and in the end-semester examinations. At the end of the project the students have to submit a detailed project report (dissertation) and deliver a seminar in support of their work. Submission of the dissertation has to be done ten days before (excluding) the seminar date. 20% marks will be deducted from the project report component of the marking scheme for each day of delay in submission of the report.

The broad area of research will be considered as the area of specialization in the M.Sc. course.

Paper- MPHC4482

Module: CV-CV-II [Contact Hours: 80 /\ Marks 50]

Comprehensive Viva II

Each student is required to develop an overall understanding of various aspects of physics as well as acquire general knowledge in physics research around the world as much as possible. Comprehensive Viva aims to examine the student's overall understanding and grasp of basic and advanced (as applicable) topics in Physics and Mathematical Physics. The student will be required to answer conceptual questions and solve problems.

Reference Books (Core Courses)

(Only a few are suggested here. Make your own search)

Mathematical Methods

1. G. Arfken: Mathematical Methods for Physicists
2. J. Mathews and R.L. Walker : Mathematical Methods of Physics
3. P. Dennery and A. Krzywicki: Mathematics for Physicists
4. R.V. Churchill and J.W. Brown: Complex variables and Applications
5. M.R. Spiegel: Theory and Problems of Complex Variables
6. W.W. Bell: Special Functions for Scientists and Engineers
7. A.W. Joshi: Matrices and Tensors in Physics
8. A.W. Joshi: Elements of Group Theory for Physicists
9. M. Tinkham: Group Theory and Quantum Mechanics
10. S.L. Ross: Differential Equations

Classical and Relativistic Mechanics

1. H. Goldstein: Classical Mechanics
2. K.C. Gupta: Classical Mechanics of Particles and Rigid Bodies
3. S.N. Biswas: Classical Mechanics
4. N.C. Rana and P.S. Joag: Classical Mechanics
5. A.P. French: Special Relativity
6. R. Resnick : Introduction to Special Relativity

Quantum Mechanics I

1. S. Gasiorowicz : Quantum Physics
2. P.M. Mathews and K. Venkatesan: A Text Book of Quantum Mechanics
3. E. Merzbacher: Quantum Mechanics
4. J.J. Sakurai : Modern Quantum Mechanics
5. R. Eisberg and R. Resnick : Quantum Physics for Atoms, Molecules, Solid, Nuclei and Particles
6. S. Fluegge : Practical Quantum Mechanics

Electrodynamics

1. J.D. Jackson: Classical Electrodynamics
2. W.K.H. Panofsky and M. Phillips: Classical Electricity and Magnetism
3. J.R.Reitz, F.J. Milford and R.W. Christy: Foundations of Electromagnetic theory
4. D.J. Griffiths: Introduction to Electrodynamics
5. J.B. Marion : Classical Electromagnetic Radiation

Statistical Mechanics

1. F. Reif: Fundamentals of Statistical and Thermal Physics
2. R.K. Pathria: Statistical Mechanics

3. K. Huang: Statistical Mechanics
4. F. Mandl: Statistical Physics
5. H.B. Callen: Thermodynamics and an Introduction to Thermostatics
6. H.E. Stanley: Introduction to Phase Transitions and Critical Phenomena
7. D. Mattis: Theory of Magnetism vol. II
8. J.M. Yeomans: Statistical Mechanics of Phase Transitions

Computation and Numerical Techniques

1. V. Rajaraman: Computer Programming in Fortran IV
2. V. Rajaraman: Computer Oriented Numerical Methods
3. J.M. McCulloch and M.G. Salvadori: Numerical Methods in Fortran
4. Harvey Gould, Jan Tobochnik and Wolfgang Christian: An Introduction to Computer Simulation Methods: Applications to Physical Systems, Third edition, Addison-Wesley (2006).
5. WH Press, SA Teukolsky, WT Vetterling, and BP Flannery (2007). Numerical recipes: The art of scientific computing, 3'rd ed. Cambridge University Press.

Quantum Mechanics II and III

1. L.I. Schiff: Quantum Mechanics
2. J.J. Sakurai: Modern Quantum Mechanics
3. P.M. Mathews and K. Venkatesan: A Text Book of Quantum Mechanics
4. E. Merzbacher: Quantum Mechanics
5. Messiah: Quantum Mechanics, Vol. II
6. J.D. Bjorken and S.D. Drell: Relativistic Quantum Mechanics
7. F. Halzen and A.D. Martin: Quarks and Leptons
8. W. Greiner: Relativistic Quantum Mechanics
9. A. Lahiri and P.B. Pal: A First Book of Quantum Field Theory
10. M. Tinkham: Group Theory and Quantum Mechanics
11. R. Eisberg and R. Resnick : Quantum Physics for Atoms, Molecules, Solid, Nuclei and Particles
12. S. Fluegge : Practical Quantum Mechanics

Electronics and Instrumentation

1. J.D. Ryder: Network, Lines and Fields
2. J. Millman and C. Halkias: Integrated Electronics
3. J.D. Ryder: Electronic Fundamental and Applications
4. J. Kennedy: Electronic Communication Systems
5. J. Millman and A. Grabel: Microelectronics
6. B.G. Streetman, S. Banerjee: Solid State Electronic Devices
7. G.F. Knoll: Radiation, Detection and Measurement
8. Sedra and Smith: Microelectronic Devices
9. Taub and Schilling: Digital Integrated Electronics
10. S.Y. Liao: Microwave Devices and Circuits
11. H.J. Reich: Microwave Principles
12. P. Bhattacharyya: Semiconductor Optoelectronic Devices
13. S.M. Sze: Physics of Semiconductor Devices
14. Boylestad and Nashelski: Electronic Devices and Circuit Theory
15. Horowitz and Hill : The Art of Electronics

Communication

1. Samuel Y. Liao: Microwave Devices and Circuits
2. Herbert J. Reich: Microwave Principles
3. K.C. Gupta: Microwaves
4. M.L. Sisodia and G.S. Raghubanshi: Microwave Circuits and Passive Device
5. N. Mercuvitz: Waveguide Handbook
6. S.M. Sze: Physics of Semiconductor Devices
7. R.E. Collins: Foundations of Microwave Engineering
8. J.D. Ryder: Network Lines and Fields
9. Royal Signals: Handbook of Line Communication
10. W. Frazer; Telecommunications
11. J.D.Kraus: Antenna

Solid State Physics

1. N.W. Ashcroft and N.D. Mermin: Solid State Physics
2. J.R. Christman: Fundamentals of Solid State Physics
3. A.J. Dekker: Solid State Physics
4. C. Kittel: Introduction to Solid State Physics
5. H. Ibach and H. Luth: Solid State Physics: An Introduction to Theory and Experiment
6. J.P. Srivastava: Elements of Solid State Physics
7. J.P. McKelvey: Solid State and Semiconductor Physics
8. D. Pines: Elementary Excitations in Solids
9. S. Raimes: Many Electron Theory
10. O. Madelung: Introduction to Solid State Theory
11. N.H. March and M. Parrinello: Collective Effects in Solids and Liquids
12. J.M. Ziman: Principles of the Theory of Solids
13. C. Kittel: Quantum Theory of Solids
14. M. Sachs: Solid State Theory
15. A.O.E. Animalu: Intermediate Quantum Theory of Crystalline Solids

Atomic, Molecular and Laser Physics

1. B.H. Bransden and C.J. Joachain: Physics of Atoms and Molecules
2. C. Cohen-Tannoudji, B. Dier, and F. Laloe: Quantum Mechanics vol. 1 and 2
3. R. Shankar: Principles of Quantum Mechanics
4. C.B. Banwell: Fundamentals of Molecular Spectroscopy
5. G.M. Barrow: Molecular Spectroscopy
6. K. Thyagarajan and A.K. Ghatak: Lasers, Theory and Applications
7. O. Svelto: Principles of Lasers
8. B.H. Eyring, J. Walter and G.E. Kimball: Quantum Chemistry
9. W. Demtroder: Molecular Physics
10. H. Herzberg: Spectra of Diatomic Molecules
11. J.D. Graybeal: Molecular Spectroscopy
12. M.C. Gupta: Atomic and Molecular Spectroscopy
13. B.B. Laud: Lasers and Non-linear Optics

14. A. Thorne, U. Litzen and J. Johnson: Spectrophysics
15. M. Sargent, M.O. Scully and W.E. Lamb: Laser Physics
16. S. Stenholm: Foundations of Laser Spectroscopy
17. P. Meystre: Atom Optics
18. H. Metcalf and P. Straten: Laser Cooling and Trapping
19. P. Meystre and M. Sargent III: Elements of Quantum Optics
20. R. Loudon: Elements of Quantum Optics

Nuclear and Particle Physics

1. K.S. Krane : Introductory Nuclear Physics
2. J.S. Lilley : Nuclear Physics
3. M.K. Pal: Theory of Nuclear Structure
4. R.R. Roy and B.P. Nigam: Nuclear Physics
5. S.N. Ghoshal: Atomic and Nuclear Physics (Vol. 2)
6. D.H. Perkins: Introduction to High Energy Physics
7. D.J. Griffiths: Introduction to Elementary Particles
8. W.E. Burcham and M. Jobes: Nuclear and particle Physics
9. M.A. Preston and R.K. Bhaduri: Structure of the Nucleus
10. W. Greiner and J.A. Maruhn: Nuclear Models
11. R.D. Evans : The Atomic Nucleus
12. R. Bhaduri : Models of Nucleons
13. J.M. Blatt and V.F. Weisskopf : Theoretical Nuclear Physics
14. J.D. Walecka : Theoretical Nuclear and Subnuclear Physics

Nonlinear Dynamics

1. S. Strogatz: Nonlinear Dynamics and Chaos
2. E. Ott: Chaos in Dynamical Systems
3. Jordan and Smith: Differential Equations and Nonlinear Dynamics
4. Alligood, Sauer, Yorke: Chaos: An introduction to dynamical systems
5. F. Reif: Statistical and Thermal Physics
6. J.K. Bhattacharjee: Statistical Physics
7. J.K. Bhattacharjee and S. Bhattacharyya : Nonlinear Dynamics

Reference Books (Advanced Topics)

(Only a few are suggested here. Make your own search)

Quantum Field Theory

1. M. Peskin and F. Schroeder: Quantum Field Theory
2. J.D. Bjorken and S.D. Drell: Relativistic Quantum Fields
3. D. Bailin and A. Love: Introduction to Gauge Field Theory
4. A. Lahiri and P.B. Pal: A First Book of Quantum Field Theory
5. F. Mandl and G. Shaw: Quantum Field Theory
6. P. Ramond: Field Theory: A Modern Primer
7. C. Itzykson and J.B. Zuber: Quantum Field Theory

Materials Physics

1. C. Kittel: Introduction to Solid State Physics
2. R. Zallen: The Physics of Amorphous Solids
3. N.F. Mott and E.A. Davies: Electronic Processes in Non-crystalline Materials
4. C.N.R. Rao and B. Raveau: Colossal Magnetoresistance, Charge Density and Related Properties of Manganese oxides
5. J.M. Yeomans: Statistical Mechanics of Phase Transitions
6. R.E. Prange and S.M. Girvin (editors): The Quantum Hall Effect
7. H.P. Klug and L.E. Alexander: X-ray Diffraction Procedures

Nuclear Reactions and Nuclear Astrophysics

1. G.R. Satchler: Introduction to Nuclear Reactions
2. K.S. Krane: Introductory Nuclear Physics
3. R.R.Roy and B.P. Nigam: Nuclear Physics
4. J.L. Basdevant, J Rich and M. Spiro: Fundamentals in Nuclear Physics
5. C Iliadis: Nuclear Physics of Stars
6. B.E.J. Pagel: Nucleosynthesis and Chemical Evolution of Galaxies
7. G.F. Knoll: Radiation Detection Measurement

Particle Physics

1. F. Halzen and A.D. Martin: Quarks and Leptons
2. J. Donoghue, E. Golowich and B. Holstein: Dynamics of the Standard Model
3. T.-P. Cheng and L.-F. Li: Gauge Theories in Particle Physics
4. E. Leader and E. Predazzi: An Introduction to Gauge Theories and Modern Particle Physics
5. F.E. Close: An Introduction to Quarks and Partons

Solid State Electronics

1. S.M. Sze: Physics of Semiconductor Devices
2. A. Ghatak and K. Thyagarajan: Optical Electronics
3. J. Millman and A. Grabel: Microelectronics
4. R.S. Gaonkar: Microprocessor Architecture, Progamming and Application with 8085/8086
5. John H. Davies: Physics of Low Dimensional Semiconductors
6. J.H. Fendler: Nanoparticles and Nanostructured Films: Preparation, Characterization and Applications
7. B.G. Streetman and S. Banerjee: Solid State Electronic Devices

Astrophysics and Cosmology

1. T. Padmanabhan: Theoretical Astrophysics, vols. 1-3
2. S. Weinberg: Gravitation and Cosmology
3. M. Rowan-Robinson: Cosmology
4. E.W. Kolb and M.S. Turner: The Early Universe
5. J.V. Narlikar: Introduction to Cosmology
6. T.T. Arny: Explorations, An Introduction to Astronomy
7. M. Zeilik and E.V.P. Smith: Introductory Astronomy and Astrophysics
8. D. Clayton: Introduction to Stellar Evolution and Nucleosynthesis
9. A. Liddle: An Introduction to Modern Cosmology
10. J.B. Hartle: Gravity
11. V. Mukhanov: Physical Foundations of Cosmology

General Theory of Relativity

1. J.V. Narlikar: Lectures on General Relativity and Cosmology
2. S. Weinberg: Gravitation and Cosmology
3. P.A.M. Dirac: General Theory of Relativity
4. L.D. Landau and E.M. Lifshitz: The Classical Theory of Fields
5. C.W. Misner, K.S. Thorne and J.A. Wheeler: Gravitation
6. R.M. Wald: General Theory of Relativity
7. A. Raychaudhuri, S. Banerjee and A. Banerjee: General Theory of Relativity

Many Body Theory

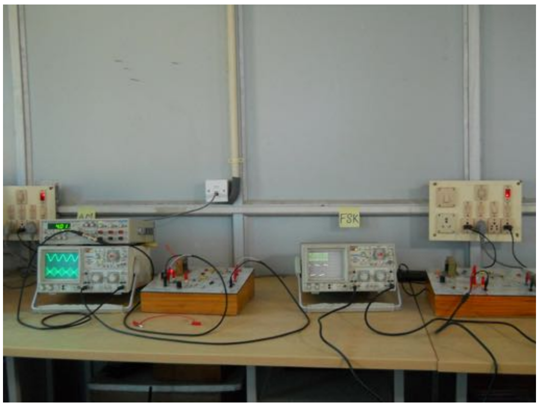
1. S. Raimes: Many Electron Theory
2. Fetter and Walecka: Quantum Theory of Many Particle System
3. G.D. Mahan: Many Particle Physics
4. Negele and Orland: Quantum Many Particle System
5. A.A. Abrikosov et al. : Methods of Quantum Field Theory in Statistical Physics

Physics of Liquid Crystals

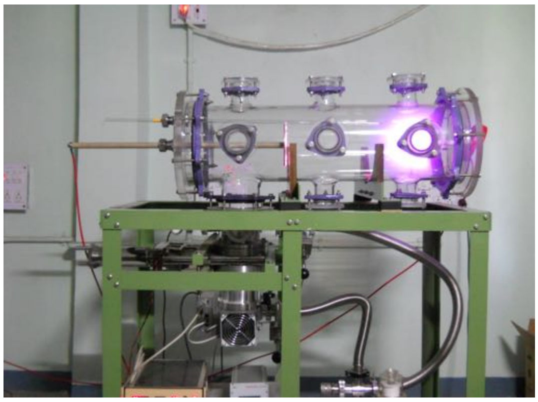
1. E.B. Priestley, P.J. Wojtowich and P. Sheng: Introduction to Liquid Crystals
2. P.G. de Gennes: Physics of Liquid Crystal
3. S. Chandrasekhar: Liquid Crystals
4. P.J. Collings and M. Hand: Introduction to Liquid Crystals

FACILITIES AVAILABLE

The following are some of the facilities available to students.



Laboratory on communications



Plasma Physics Laboratory

Space Science Laboratory

Cosmic Ray Laboratory

Library

Raman Spectroscopy Laboratory