JSS MAHAVIDYAPEETHA

JSS College of Arts, Commerce & Science (Autonomous)

Ooty Road, Mysuru-25

PG Department of Physics

(Autonomous under University of Mysore, Re-accredited by NAAC with 'A' Grade
Recognised by UGC as "College with Potential for Excellence")

M.Sc. Physics

Course Structure and Syllabus

Under

Choice Based Credit Scheme (CBCS)

&

Continuous Assessment Grading Pattern (CAGP)

2022-23 (With PO,PSO and Co's)

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Details of Courses offered and associated credits

Paper Code	Paper	HC/SC/EL/OE	Credits L	T	P	Total
I Semester						
PHA 120	Classical Mechanics	HC 1	3	-	-	03
PHA 130	Mathematical Methods of Physics 1	HC 2	3	-	-	03
PHA 140	Mathematical Methods of Physics 2	HC 3	3	-	-	03
PHA 150	Classical Electrodynamics & Plasma Physics	HC 4	3	-	-	03
PHA 160	Computer Lab CL-A	HC 5	-	-	2	02
PHA 220	Electronics Lab	SC 1	-	-	4	04
						18
II Semester						
PHB 070	Continuum Mechanics and Relativity	HC 6	3	-	-	03
PHB 080	Thermal Physics	HC 7	3	-	-	03
PHB 090	Quantum Mechanics 1	HC 8	3	-	-	03
PHB 100	Spectroscopy and Fourier Optics	HC 9	3	-	-	03
PHB 110	Computer Lab CL-B	HC 10	-	-	2	02
PHB 210	Optics Lab	SC 2	-	-	4	04
						18
III Semester						
PHC 050	Quantum Mechanics 2	HC 11	3	-	-	03
PHC 060	Condensed Matter Physics	HC 12	3	-	-	03
PHC 070	Nuclear and Particle Physics	HC 13	3	-	-	03
PHC 080/090	Condensed Matter Physics Lab / Nuclear and Particle Physics Lab	HC 14	-	-	4	04
Students are permitted to choose any one of the following (special paper) and corresponding practical coupled to the special paper						
PHC 240	Solid State Physics 1	SC 3	3	-	-	03
PHC 250	Solid State Physics Lab 1	SC 4	-	-	2	02
PHC 260	Nuclear Physics 1	SC 3	3	-	-	03
PHC 270	Nuclear Physics Lab 1	SC 4	-	-	2	02
PHY 306	Theoretical Physics 1	SC 3	3	-	-	03
PHY 315	Theoretical Physics Lab 1	SC 4	-	-	2	02
Students from other departments can register for any one of the following						
PHY-321/322	Modern Physics/Energy Science	OE	3	1	-	04
						22

Paper Code	Paper	HC/SC/EL/OE	L	T	P	Total
IV Semester						
PHD 090/080	Nuclear and Particle Physics Lab/ Condensed Matter Physics Lab	HC 15	-	-	4	04
A student has to register for one particular discipline in confirmation with the corresponding SC (special paper) opted in III semester						
PHD 250	Solid State Physics 2	SC 5	3	-	-	03
PHD 260	Solid State Physics 3	SC 6	3	-	-	03
PHD 240	Solid State Physics Lab 2	SC 7	-	-	2	02
PHD 300	Nuclear Physics 2	SC 5	3	-	-	03
PHD 310	Nuclear Physics 3	SC 6	3	-	-	03
PHD 320	Nuclear Physics Lab 2	SC 7	-	-	2	02
PHY-405	Theoretical Physics 2	SC 5	3	-	-	03
PHY-406	Theoretical Physics 3	SC 6	3	-	-	03
PHY-425	Theoretical Physics Lab 2	SC 7	-	-	2	02
Students are permitted to choose any one of the following (Elective papers 1)						
PHD 270	Accelerator Physics	SC 8	2	-	-	02
PHY-408	Liquid Crystals		2	-	-	02
PHY-409	Atmospheric Physics		2	-	-	02
PHY-410	Numerical Methods		2	-	-	02
Students are permitted to choose any one of the following (Elective papers 2)						
PHY-411	Nuclear Spectroscopy Methods	SC 9	3	1	-	04
PHY-412	Modern Optics					
PHD 280	Electronics					
PHY-414	Minor Project		04			
18						

Semester	HC	SC	OE	Total
I Semester	14	4		18
II Semester	14	4		18
III Semester	13	5	04	22
IV Semester	04	14		18
Total	45	27	04	76

HC: Hard Core; **SC:** Soft Core; **OE:** Open Elective; **EL:** Elective; **EC:** Extra Credit;

Scheme of Assessment

1. First Theory and Practical Internal Assessment tests (for C1) will be conducted after 8th week of the semester comprising 50% of the syllabus.
2. Second Theory and Practical Internal Assessment tests (for C2) will be conducted in the 16th week of the semester comprising remaining 50% of the syllabus.
3. The Theory C1 and C2 Internal Assessment tests evaluation will be an aggregate of written test, assignments, seminar by the corresponding Course teacher/teachers.
4. Practical Internal Assessment tests C1 and C2 will be assessed based on the performance of the student in the given Lab experiment, Record writing and viva by the corresponding Course teacher/teachers.
5. A student will be eligible for C3 semester end examination, if he/she has scored a minimum of 30% which is the sum total of C1test and C2 test.
6. C3 semester end examination for theory Courses (papers) will be conducted in 18th week of the Semester. Three sets of question papers will be set by both internal and external Examiners, who were chosen from the panel of examiners approved by the Board of Studies for each Course. The Board of Examination convened well before the C3 semester end examination will scrutinise and approve the question papers sets and submit the same to Controller of Examination.. From each of the sets, one question paper is randomly chosen by Chief Controller of Examination.
7. C3 semester end Laboratory examination for practical Courses will be conducted conveniently before or after C3 semester end examination for theory Courses. The Laboratory examination will be conducted by both internal and external examiners.
8. Overall grade will be based on marks scored in C1, C2 and C3 examination

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The details of the allotment of marks for evaluation of the theory and practical question papers of C1, C2 and C3 examinations were also prepared on the recommendations and approval of Board of Studies. The pattern of evaluation is provided below:

Theory Examination : C1+C2+C3=100 Marks

Theory	Unit 1	Unit 2	Unit 3	Problems from the three units	Average Score	Assignment	Seminar	Total Marks
C1	10	10	10	-	10	5	-	15
C2	10	10	10	-	10	-	5	15
C3	18	18	18	16	--	-	-	70

Practical Examination: C1+C2+C3=100 Marks

Practical	Experiment	Record	Viva	Total Marks
C1	7	5	3	15
C2	7	5	3	15
C3	50	-	20	70

Programme Outcomes:

PO1. Identify, formulate and analyze complex problems using first principles.
PO2. A research oriented learning to develop analytical problem-solving approaches.
PO3. Awareness of ethical issues and regulatory considerations.
PO4. Understand the basic concepts, fundamental principles and the scientific Theories.
PO5. Acquire skills in handling scientific instruments, planning and performing in laboratory experiments.
PO6. Think creatively in explaining solutions to the problems.
PO7. Realize developments in science subject and interdisciplinary approach.
PO8. Develop scientific outlook towards all aspects of life.
PO9. Effective influence, which inspires in new scientific theories and inventions.
PO10. To Imbibe ethical, moral and social values in personal and social life and develop Positive attitude that leads to successful life.

PROGRAMME SPECIFIC OUTCOMES:

PSO1. Acquire substantial knowledge in Physics, basic knowledge in Mathematics and computer science
PSO2. Specialisation in Solid State Physics/Nuclear Physics provides special expertise.
PSO4. Provide hands-on research experience in a specific field of Physics, through the supervised project.
PSO5. Familiarise with contemporary research within various fields of Physics.
PSO6. Provides the candidate knowledge with general competence and analytical skills needed in research, education, industry, consultancy and public administration.
PSO7. Develop interdisciplinary approach.
PSO8. Critically assess and evaluate research methods and results.
PSO9. Understands the role of Physics in society and ethical problems.
PSO10. To avail Global research opportunities.

Syllabus for the 4-Semester M.Sc., (Physics)
Choice Based Credit Scheme (CBCS)

PHA 120: Classical Mechanics

Course Outcome:

Students who have completed this course should be able to

CO1. Solve the Newton equations for simple configurations
CO2. Use conservation to solve dynamics problems.
CO3. Represent the equations of motion for complicated mechanical systems
CO4. Derive and solve the equations of motions for systems subject to the Principle of Least Action
CO5. Calculate conserved quantities from symmetries
CO6. Acquire a deep knowledge of the Lagrangean and Hamiltonian formalism
CO7. Understand theory of small oscillations

Mechanics of a system of particles: Conservation of linear and angular momenta in the absence of (net) external forces and torques using centre of mass. The energy equation and the total potential energy of a system of particles using scalar potential (**Goldstein H).**
The Lagrangean method: Constraints and their classifications. Generalized coordinates. Virtual displacement, D'Alembert's principle and Lagrangean equations of the second kind. Examples of (1) single particle in Cartesian, spherical polar and cylindrical polar coordinate systems, (2) Atwood's machine, (3) a bead sliding on a rotating wire in a force-free space and (4) Simple pendulum. Derivation of Lagrange equations from Hamilton principle **(Goldstein H).**
Central forces: Reduction of two particle equations of motion to the equivalent one-body problem, reduced mass of the system. Conservation theorems (First integrals of the motion). Equations of motion for the orbit, classification of orbits, conditions for closed orbits. The Kepler problem (inverse-square law of force) (**Aruldas G,Goldstein H, Srinivasa Rao K.N**). **[16 hours]**

Hamilton's equations: Generalised momenta. Hamilton's equations. Examples - simple harmonic oscillator, charged particle moving in an electromagnetic field. Hamiltonian for a free particle in different coordinates. Cyclic coordinates. Physical significance of the Hamiltonian function. Derivation of Hamilton's equations from a variational principle **(Goldstein H)**.
Canonical transformations: Definition, Generating functions (Four basic types). Examples of Canonical transformations. The harmonic Oscillator. Infinitesimal contact transformation.Poisson brackets; properties of Poisson brackets, angular momentum and Poisson bracket relations. Equation of motion in the Poisson bracket notation. The Hamilton-Jacobi equation; the example of the harmonic oscillator treated by the Hamilton-Jacobi method **(Goldstein H).** **[16 hours]**

Mechanics of rigid bodies: Degrees of freedom of a free rigid body. Angular momentum and kinetic energy of rigid body. Moment of inertia tensor, principal moments of inertia, products of inertia, the inertia tensor. Euler equations of motion for a rigid body. Torque free motion of a rigid body. Precession of earth's axis of rotation, Euler angles, angular velocity of a rigid body **(Goldstein H).**
Small oscillations of mechanical system: Introduction, types of equilibria, Quadratic forms of kinetic and potential energies of a system in equilibrium. General theory of small oscillations, secular equation and eigenvalue equation. Small oscillations in normal coordinates and normal modes, examples of two coupled oscillators. Vibrations of a linear triatomic molecule **(Goldstein H).** **[16 hours]**

Total work load **48 hours**
References:

1. Goldstein H., Poole C. and Safko J., Classical mechanics, 3rd Edn., Pearson Education, New Delhi. 2002
2. Upadhaya J.C., Classical mechanics, Himalaya Publishing House, Mumbai. 2006.
3. Srinivasa Rao K.N., Classical mechanics, Universities Press, Hyderabad. 2003.
4. Takwale R.G. and Puranik S., Introduction to classical mechanics, Tata McGraw, New Delhi, 1991.
5. Landau L.D. and Lifshitz E.M., Classical mechanics, 4th Edn., Pergamon Press, 1985.
6. Aruldas G., Classical Mechanics, PHI Learning Private Limited, New Delhi

PHA 130: Mathematical Methods of Physics 1

Course Outcome:

Upon completion of the course students should be

CO1. Familiar with mathematical methods for solving advanced problems in physics.
CO2. Familiar with Tensors, algebra of tensors and Tensor Calculus and its applications in applied sciences and engineering;
CO3. Able to solve abstract mathematical problems, recognize real-world problems and to formulate mathematical models for such problems.
CO4. Familiar with Hermite and Laguerre polynomials solutions
CO5. Familiar with generating function of the polynomials
CO6. Able to Use Legendre polynomials, associated Legendre polynomials in Physics
CO7. Able to Use Bessel functions, Spherical harmonics in Physics

Curvilinear coordinates and Tensors: Curvilinear coordinates in the Euclidean 3-space, Orthogonal curvilinear coordinates. Differential vector operators; Grad, divergence, curl and Laplacian in arbitrary curvilinear coordinates. Circular cylindrical coordinates, spherical polar coordinates **(Arfken &Weber).**

Tensors: Tensors of rank r as a r-linear form in base vectors. Transformation rules for base vectors and tensor components. Tensor algebra, contraction, Raising and lowering of indices, Associated tensors, quotient rule. Mention of pseudo tensor, dual tensor and non-cartesian tensor. Metric tensor,Covariant and contravariant components of the metric tensor, Christoffel symbols. Tensor derivative operators, Covariant differentiation. The contracted Christoffel symbol **(Arfken &Weber).** **[16 hours]**

Differential equations, Hermite function and Laguerre functions: Differential equations: Partial differential equations, Separation of variables - Helmholtz equations in Cartesian, circular cylindrical coordinates Spherical polar coordinates. Regular and irregular singular points of a second order ordinary differential equation. Series solution-Frobenius power series method, Examples of Harmonic oscillator and Bessel's equation. Linear dependence and independence of solutions-Wronskian. Non-homogeneous equations-Green's function, examples **(Arfken &Weber).**
Hermite functions: Hermite`s differential equation and its Solution, Hermite polynomials, Generating functions, Recurrence relations, Rodrigues representation, Orthogonality **(Arfken &Weber).**
Laguerre functions: Laguerre differential equation and its solution, Laguerrepolynomials, Generating function, Recurrence relations, Rodrigues representation, Orthogonality.Associated Laguerre functions: Definition, Generating function, Recurrence relations and Orthogonalit **(Arfken &Weber).** **[16 hours]**

Special functions: Sturm - Liouville theory - Self adjoint ODE's, Hermitian operators, completeness of eigenfunction, Green's function—eigenfunction expansion (**Arfken &Weber).**

Bessel functions: Bessel functions of the first kind J_v(x), Bessel differential equation, generating function for J_v(x), Integrals for J_o(x) and J_v(x), recurrence formulae for J_v(x), orthogonal properties of Bessel polynomials**(Arfken &Weber).**

Legendre functions: Legendre differential equation, Legendre polynomials, generating functions, recurrence formulae, Rodrigues representation, Orthogonality. Associated Legendre polynomials; The differential equation, Orthogonality relation **(Arfken &Weber).**

Spherical harmonics: Definition and Orthogonality **(Arfken &Weber).** **[16 hours]**

Total work load **48 hours**

References:

1. Arfken G.B. and Weber H.J., Mathematical methods for physicists, 6th Edn., Academic Press, New York (Prism Books, Bangalore, India), 1995.
2. Harris E.G., Introduction to modern theoretical physics, Vol. 1, John Wiley, New York, 1975.
3. Srinivasa Rao K.N,, The rotation and Lorentz groups and their representations for physicists, Wiley Eastern, New Delhi, 2003.
4. Gupta B.D., Mathematical physics, 4th Edn, 2011.
5. Bali N. P., Engineering Mathematics, Laxmi Publications, New Delhi
6. Dass H. K., Higher Engineering Mathematics, S. Chand, New Delhi
7. Chattopadhay P. K., Mathematical Physics, New Age International.

PHA 140: Mathematical Methods of Physics 2

Course Outcome:

Upon completion of the course students should be able to

CO1. Explain the concepts of Linear vector space.
CO2. Express conditions for transformations.
CO3. Explain matrix representation of a linear transformation, Matrix representations
CO4. Explain concepts of eigenvalues and eigenvectors of a matrix.
CO5. Use matrices and determinants to solve sets of simultaneous linear equations
CO6. Understand the concepts of inner product, orthogonality and orthnormality
CO7. Recognize real-world problems and formulation of mathematical models of such problems.
CO8. Understand linear representations of groups and Rotation groups and applications in Physics
CO9. Apply Fourier transforms and Integral equations in Physics

Linear vector space: Linear vector space - Definition. Linear dependence and independence of vectors. Dimension. Basis. Change of basis. Subspace. Isomorphism of vector spaces. Linear operators. Matrix representative of a linear operator in a given basis. Effect of change of basis. Invariant subspace. Eigenvalues and eigenvectors. Characteristic equation. The Schur canonical form. Diagonalization of a normal matrix. Schur's theorm **(Arfken &Weber).** **[16 hours]**

Linear representations of groups: Groups of regular matrices; the general linear groups *GL (n, C)*and *GL (n, R)*. The special linear groups *SL (n, C)*and *SL(n, R).* The unitary groups *U (n)*and *SU(n).* The orthogonal groups *O(n, C),O (n, R),SO(n, C)*and *SO(n, R).* Homogeneous Lorentz group(**Arfken &Weber).**
Rotation group: The matrix exponential function-Definition and properties. Rotation matrix in terms of axis and angle. Eigenvalues of a rotation matrix. Euler resolution of a rotation. Definition of a representation. Equivalence. Reducible and irreducible representations. Schur's lemma. Construction of the $D^{1/2}$and D^{1}representation of *SO (3)*by exponentiation. Mention of the D^{j} irreps *SO (3***(Srinivasa Rao K.N).** **[16 hours]**

Fourier transforms and Integral equations: General properties, completeness, use of Fourier series. Applications of Fourier series **(Arfken &Weber).**

Integral transforms; Development of Fourier Integral, Fourier transform - inversion theorem, Fourier transform of derivatives, convolution theorem. Momentum representation (**Arfken &Weber).**

Integral equations: Definitions, transformation of a differential equation into an integral equation, Integral transforms, generating functions, Abel's equation, Neumann series, separable kernels, Numerical solution, non-homogeneous integral equations **(Arfken &Weber).** **[16 hours]**

Total work load **48 hours**

References:

1. Shankar R., Principles of quantum mechanics, 2nd Edn., Plenum Press, New York, 1984.
2. Srinivasa Rao K.N., The rotation and Lorentz groups and their representations for Physicists, Wiley Eastern, New Delhi, 1988.
3. Arfken G.B. and Weber H.J., Mathematical methods for Physicists, 5th. Edn., Academic Press, New York, 2001.
4. Gupta B.D., Mathematical Physics, 4th Edn. (Page no. 8.48–8.83, 8.16-8.48) 2011
5. Bali N. P., Engineering Mathematics, Laxmi Publications, New Delhi
6. Dass H. K., Higher Engineering Mathematics, S. Chand Publications, New Delhi
7. Charlie Harper, Introduction to Mathematical Physics, PHI Publications, 2008.

PHA 150: Classical Electrodynamics, Plasma Physics and Optics

Course Outcome:

Students who have completed this course should

CO1. Have theoretical foundations of electromagnetic phenomena.
CO2. Be able to solve the Maxwell equations for simple configurations.
CO3. Formulate and solve electromagnetic problems with the help of electrodynamic potentials and super potentials
CO4. make a detailed account for gauge transformations and their use
CO5. Learn the techniques of deriving and evaluating formulae for the electromagnetic fields from general charge and current distributions
CO6. calculate the electromagnetic radiation from radiating systems, formulate and solve electrodynamics problems, covariant form in 4 dimensional space-time
CO7. Formulate self-consistent models for the interaction between matter and em fields,
CO8. Covariant formulation of electrodynamics, Lagrange formalism
CO8. Apply the concept of Sspecial theory of relativity for relativistic electrodynamics

Electric multipole moments: The electric dipole and multipole moments of a system of charges. Multipole expansion of the scalar potential of an arbitrary charge distribution **(Griffiths D.J).**

Potential formulation: Maxwell equations in terms of electromagnetic potentials. Gauge transformations. The Lorentz, Coulomb and radiation gauges **(Griffiths D.J).**

Fields of moving charges and radiation: The retarded potentials. The Lienard-Wiechert potentials. Fields due to an arbitrarily moving point charge; the special case of a charge moving with constant velocity **(Griffiths D.J).**

Radiating systems: Radiation from an oscillating dipole. Power radiated by a point charges - Larmor formula. Lienard's generalisation of Larmor formula. Energy loss in bremsstrahlung and linear accelerators. Radiation reaction - Abraham-Lorentz formula **(Griffiths D.J)** **[16 hours].**

Relativistic electrodynamics: Charge and fields as observed in different frames. Covariant formulation of electrodynamics; Electromagnetic field tensor, Transformation of fields, Field due to a point charge in uniform motion. Lagrangian formulation of the motion of charged particle in an electromagnetic field **(Griffiths D.J).**

Plasma Physics: Quasineutrality of a plasma, plasma behaviour in magnetic fields, Plasma as a conducting fluid. Magnetohydrodynamics; magnetic confinement, Pinch effect, instabilities, Plasma waves. **(Laud B. B.).**
[16 hours]

Electromagnetic waves: Monochromatic plane waves - velocity, phase and polarization. Propagation of plane electromagnetic waves in (1) conducting media and (2) ionised gases. Reflection and refraction of electromagnetic waves; Fresnel formulae for parallel and perpendicular components. Brewster`s law. Normal and anomalous dispersion; Clausius-Mossotti relation **(Born M. and Wolf E).**

Interference: General theory of interference of two monochromatic waves. Two beam and Multiple beam interference with a plane-parallel plate. Fabry-Perot interferometer; etalon construction, resolving power and its application. Interference filters **(Born M. and Wolf E).**

Diffraction: Integral theorem of Helmholtz and Kirchhoff. Fresnel-Kirchhoff diffraction formula; conditions for Fraunhofer and Fresnel diffraction. Fraunhofer diffraction due to a circular aperture. **(Born M. and Wolf E)**
[16 hours]

Total work load **48 hours**

References:

1. Griffiths D.J., Introduction to Electrodynamics, 5th Edn., Prentice-Hall of India, New Delhi, 2006.
2. Jackson J.D., Classical Electrodynamics, 2nd Edn., Wiley-Eastern Ltd, India, 1998.
3. Born M. and Wolf E., Principles of Optics, 6th Edn., Pergamon Press, Oxford, 1980.
4. Matveev A.N., Optics, Mir Publishers, Moscow, 1988.
5. Laud B.B., Electromagnetics, Wiley Eastern Limited, India, 2000.
6. Hecht E., Optics, Addison-Wesley, 2002.
7. Lipson S.G., Lipson H. & Tannhauser D.S., Optical physics, Cambridge University Press, USA, 1995.
8. Ajoy Ghatak, Optics, Tata McGraw – Hill, New Delhi
9. Gupta A. B. Modern Optics, Books and Allied (P) Ltd, Kolkata
10. Sen S .N., Plasma Physics, Pragathi Prakasan

PHA 160: Computer Lab CL-A

Course Outcome:

Students who have completed this course should

CO1. Learn scientific typesetting with LaTeX program.
CO2. Plot the functions and data with Gnuplot program,
CO3. Solve problems with Octave program

- Linux operating system basics (4 sessions) :
  Login procedure; creating, deleting directories; copy, delete, renaming files; absolute and relative paths; Permissions—setting, changing; Using text editor.
- Scientific text processing with LATEX.
  Typeset text using text effects, special symbols, lists, table, mathematics and including figures in documents.
- Using the plotting program GNUPLOT (2 sessions) :
  Plotting commands; To plot data from an experiment and applying least-squares fit to the data points. Including a plot in a LATEX file.
- Using the mathematics package OCTAVE (2 sessions), To compute functions, matrices, eigenvalues, inverse, roots.

Total work load: 1 day(s) per week × 4 hours × 16 weeks = **64 hours**

PHA 220: Electronics Lab

Course Outcome:

Students who have completed this course should

CO1. Maintain digital and analog devices and circuits.
CO2. Analyze components associated with digital and analog electronic systems.
CO3. Demonstrate proficiency in the use of electronic equipment and devices.
CO4. Assist in the design, operation, and troubleshooting of electronic systems.
CO5. Analyse electronics devices and circuits using computer simulations.
CO6. Realise electronic circuits using electronic devices and mathematical concepts.
CO7. Accept professional and ethical responsibilities of the engineering technology

Any ten of the following experiments:

1. Regulated power supply.
2. Active filters : low pass (single pole).
3. Active filters : high pass (double pole).
4. Voltage follower.
5. Colpitts' oscillator.
6. Opamp as an integrator and differentiator.
7. Opamp as a summing and log amplifier.
8. Opamp as an inverting and non-inverting amplifier.
9. Coder and encoder.
10. Half adder and full adder.
11. Boolean algebra-Logic gates.
12. Opamp astable multivibrator.

Total work load: 2 day(s) per week × 4 hours × 16 weeks = **128 hours**

PHB 070: Continuum Mechanics and Relativity

Course Outcome:

After the completion of the course, student will be familiar with

CO1. Internal response of materials to external loading
CO2. Development of physical intuition for the behaviour of solids and fluids
CO3. Unique connections between solid and fluid mechanics.
CO4. The non-existence ether through Michelson-Morley experiments
CO5. Minkowski space-time
CO6. The true nature of Newtonian mechanics and Lorentz Transformations
CO7. The concept of constant relative motion of different bodies in different frames
CO8. The calculation of proper time, dilated time, proper length and contracted length
CO9. Principles of the special theory of relativity, Covariant form of Newton laws
CO10. Einstein field equations, their underlying mathematical structure and solutions
CO11. Lagrangean formulation of General Relativity.
CO12. Derivation of testable physical consequences of General Relativity

Continuum mechanics of solid media: Small deformations of an elastic solid; the strain tensor. The stress tensor. Equations of equilibrium. The symmetry of the stress tensor. The generalised Hooke`s law for a homogeneous elastic medium; the elastic modulus tensor. Navier equations of motion for a homogeneous isotropic medium. **(Landau L.D. and Lifshitz)**

Fluid mechanics: Equation of continuity. Flow of a viscous fluid; Navier-Stokes equation and its solution for the case of flow through a cylindrical pipe. The Poiseuille formula **(Landau L.D. and Lifshitz).** **[16 hours]**

Minkowski space-time: Real coordinates in Minkowski space-time. Definition of 4-tensors. The Minkowski scalar product and the Minkowski metric η_{ij} = diag (1 -1 -1 -1). Orthogonality of 4-vectors. Raising and lowering of 4-tensor indices. Time like, null and space like vectors and world-lines. The light-cone at an event **(Griffiths).**

Relativistic mechanics of a material particle: The proper-time interval $d\tau$ along the world - line of a material particle. The instantaneous (inertial) rest-frame of a material particle; Components of 4-velocity, 4-acceleration and 4-momentum vector, statement of second law of Newton. Determination of the fourth component F_4 of the 4-force along the world-line of the particle. Motion of a particle under the conservative 3-force field and the energy integral. The rest energy and the relativistic kinetic energy of a particle. **[16 hours]**

Einstein's equations: The Principle of Equivalence and general covariance. Inertial mass, gravitational mass, Eötvös experiment. Gravitation as space-time curvature. Einstein Gravitational field equations and its Newtonian limits.

The Schwarzschild metric: Heuristic derivation of the Schwarzschild line element. Motion of particles and light rays in the Schwarzschild field. Explanation of the (1) perihelion advance of planet Mercury, (2) gravitational red shift and (3) gravitational bending of light. A brief discussion of the Schwarzschild singularity and the Schwarzschild black hole. **[16 hours]**

Total work load **48 hours**

References:

1. Landau L.D. and Lifshitz E.M., Fluid Mechanics, Pergamon Press, 1987.
2. Landau L.D. and Lifshitz E.M., Theory of Elasticity, Pergamon Press, 1987.
3. Synge J.L., Relativity: The Special Theory, North-Holland, 1972.
4. Landau L.D. and Lifshitz E.M., The Classical Theory of Fields, 4th Edn., (Sections 1 to 6, 16 to 18, 23 to 25, 26 to 35), Pergamon Press, Oxford, 1985.
5. Wald R.M., General relativity, The University of Chicago Press, Chicago, 1984.
6. Schutz B.F., A first course in general relativity, Cambridge University Press, Cambridge, 1985.
7. Bergman P., Introduction to theory of relativity, Prentice-Hall of India, 1969.
8. Rindler R., Relativity: Special, general and cosmological, Oxford University Press, 2006.
9. Narlikar J. V., An introduction to Cosmology, Cambridge Publications
10. Somnath Datta, Introduction to Special theory of Relativity, Allied Publishers, India, 1998
11. Griffiths D. J. Introduction to Electrodynamics, Pearson Publications, 2013.

PHB 080: Thermal Physics

Course Outcome:

After the completion of the course, Student will be familiar with

CO1. Basic concepts of Thermodynamics
CO2. Formulation of the first law of thermodynamics for a closed systems
CO3. Mode of heat transfer, the amount of heat energy transferred and conservation of mass and energy equations.
CO4. Second law of thermodynamics; thermal efficiency & coefficient of performance.
CO5. concept of ensemble, phase space & conservation of phase-space density(Liouville's theorem)
CO6. Solution to statistical mechanics problems for simple non-interacting systems,
CO7. Phase transitions, Statistical equilibrium,. Entropy and probability
CO10. Microcanonical ensemble, Partition function, Gibbs paradox, canonical ensemble
CO11. Quantum statistical mechanics. Symmetry of wave functions.
CO12. Quantum distribution functions (BE and FD), Applications of Quantum Statistics

Thermodynamics Preliminaries: Zeroth law of thermodynamics, vander Walls equation of state second law of thermodynamics **(Huang K., Laud B.B, Satya Prakash).**

Entropy: Change in entropy for reversible an irreversible process, entropy and second law of thermodynamics, thermodynamic functions and Maxwell's relations ***TdS*** equations, heat capacities equations, third law of thermodynamics. Irreversible thermodynamics Onsager's reciprocal relation **(Huang K., Laud B.B, Satya Prakash).**

Phase equilibria; Equilibrium conditions. Classification of phase transitions; phase diagrams; Clausius-Clapeyron equation, applications. Thermoelectric phenomenon, Peltier effect, Seebeck effect, Thompson effect. Systems far from equilibrium **(Huang K., Laud B.B, Satya Prakash).** **[16 hours]**

Classical Statistical Mechanics: Probability, phase space, division of phase space, ensembles, density distribution in phase space, ergodic hypotheses, Liouville theorem. Statistical equilibrium, postulate of equal *a priori* probability, general expression for probability, Stirlings formula, the most probable distribution, Maxwell Boltzmann distribution law, law of equipartition of energy. Entropy and probability.
Microcanonical ensemble, connection between statistical and thermodynamic quantities, Partition function of system of particles, Gibbs paradox, canonical ensemble, perfect monoatmic gas in canonical ensemble, grand canonical ensemble. Vibrational partition function of diatomic molecules (Einstein relations), Rotational partition function of diatomic molecule **(Huang K., Laud B.B, Satya Prakash).** **[16 hours]**

Quantum Statistical Mechanics: The postulates of quantum statistical mechanics. Symmetry of wave functions. The Liouville theorem in quantum statistical mechanics; condition for statistical equilibrium; Ensembles in quantum mechanics; the quantum distribution functions (BE and FD), the Boltzmann limit of Boson and Fermion gases, the derivation of the corresponding distribution functions.

Applications of Quantum Statistics: Equation of state of an ideal Fermi gas (derivation not expected), Application of Fermi-Dirac statistics to the theory of free electrons in metals, degeneracy. Application of Bose statistics to the photon gas, derivation of Planck's law, comments on the rest mass of photons. Thermodynamics of Black body radiation. Bose-Einstein condensation **(Huang, Laud, Satya Prakash).** **[16 hours]**

Total work load **48 hours**

References:

1. Agarwal B.K. and Eisner M., Statistical mechanics, New Age International Publishers, 2000.
2. Roy S.K., Thermal physics and statistical mechanics, New Age International Pub., 2000.
3. Huang K., Statistical mechanics, Wiley-Eastern, 1975.
4. Laud B.B., Fundamentals of statistical mechanics, New Age International Pub.,2000.
5. Schroeder D.V., An introduction to thermal physics, Pearson Education New Delhi, 2008.
6. Salinas S.R.A., Introduction to statistical physics, Springer, 2004.
7. Mark W Zemansky Heat and Thermodynamics, McGraw – Hill
8. Gupta A. B and Roy H. B., Thermal Physics Books and Allied (P) Ltd, Kolkata
9. Satya Prakash, Statistical Mechanics, Kedarnath Ramnath, 2017.
10. Mike Glazer, J.S. Wark, Statistical Mechanics: A Survival Guide, Oxford Publications, 2001.

PHB 090: Quantum Mechanics 1

Course Outcome:

After the completion of the course Student will be familiar with

CO1. The Basic concepts and mathematical foundations of quantum mechanics

CO2. Solutions to the Schrödinger equation for simple potentials.

CO3. The effect of symmetries in quantum mechanics

CO4. The significance of wave function, normalization, uncertaintyPrinciple

CO5. The Physical significance of eigen functions and eigen vectors

CO6. Formalism; Hilbert space,, Dirac notation, concepts of Dynamical variables and operators

CO7. General Uncertainty relation. Matrix representation of wave functions & operators.

CO8. The Schrödinger equation and time evolution of a system.

CO9. The Schrödinger picture and Heisenberg picture

CO10. Schrodinger equation in three dimensions, Hydrogen atom.

The wave function and uncertainty Principle: Wave particle duality, interpretation of the wave function, wave functions for particles having definite momentum, wave packet, Gaussian wave packet. Heisenberg uncertainty principle.

Time independent Schrodinger equation, conservation of probability, expectation values and operators, the Ehrenfest theorem, Time dependent Schrodinger equation, stationary states. Energy quantisation. Properties of energy eigenfunction, general solutions of time dependent Schrodinger equation for a time independent potential. Schrodinger equation in momentum space **(Bransden & Joachain).** **[16 hours]**

Formalism: Hilbert space. The state of a system, Dirac notation. Dynamical variables and operators – Hermitian operators, adjoint operator, projection operators. Inverse and unitary operators. Expansion in eigenfunctions - eigenvalue and eigenfunction of an operator. Commutator algebra. General Uncertainty relation. Unitary transformation, Representation in discrete basis; Matrix representation of wave functions and operators. Change of representation and Unitary transformations. Matrix representation of eigenvalue problem. Representation in continuous bases. The Schrödinger equation and time evolution of a system.
The Schrödinger picture and Heisenberg picture.

Schrodinger equation in one dimension: The free particle, the potential step, potential barrier, infinite square well, finite square well, the linear harmonic oscillator (Algebraic and Analytic method), the periodic potential **[Bransden and Joachain, Nouredine Zettili].** **[16 hours]**

Angular Momentum: Orbital angular momentum; Orbital angular momentum and spatial rotations, eigenvalues and eigenfunctions of $\mathbf{L}^2$ and L_z. Particle on a sphere and the rigid rotator. General angular momentum. The spectrum of $\mathbf{J}^2$ and J_z. Matrix representation of angular momentum operators, spin angular momentum, spin one-half, total angular momentum. Addition of angular momenta - CG Coefficients.

Schrodinger equation in three dimensions: Separation of the Schrodinger equation in Cartesian coordinates - the free particle. Central potential. Separation of the Schrodinger equation in spherical polar coordinates; the Hydrogenic atom and its solutions **(Bransden & Joachain).** **[16 hours]**

Total work load **48 hours**

References:

1. Nouredine Zettili, Quantum Mechanics, WILEY Publications, U K 2009
2. Griffiths D.J., Introduction to quantum mechanics, Prentice-Hall, USA, 1994.
3. Bransden & Joachain, 2004, II edition, Pearson Low Price Edition
4. Sakurai J.J. and Tuan S.F. (Editor), Modern quantum mechanics, AddisonWesley, India, 1999.
5. Shankar R., Principles of quantum mechanics, 2nd Edn., Plenum Press, New York, 1984.
6. Schiff L.I., Quantum mechanics, 3rd. Edn., McGraw-Hill, Kogakusha Ltd., New Delhi, 1968.
7. Aruldas G., Quantum Mechanics, PHI, New Delhi
8. Mathews P. M. and Venkatesan K., Quantum mechanics, Tata - McGraw-Hill, New Delhi
9. Verma H. C., Quantum Physics, Surya Publications, Ghaziabad
10. Merzbacher E., Quantum Mechanics, III edition, Wiley publication.

PHB 100: Spectroscopy and Fourier Optics

Course Outcome:

After completing this course, the student will be able to

CO1. Explain the applications of spectroscopic methods for qualitative & quantitative analysis.
CO2. Compare and contrast atomic and molecular spectra.
CO3. Understand the molecular absorption & scatter from particulate matter in atomic absorption spectroscopy
CO4. Recognise the effect of changing the slit width on qualitative & quantitative analysis.
CO5. Explain the selection rule for infrared-active transitions
CO6. design a non-dispersive infrared spectrophotometer
CO7. Understand the Fourier Transform infrared spectroscopy
CO8. understand Raman spectroscopy
CO9. Elements of Nonlinear Optics

Atomic spectroscopy:vector model of atom- orbital magnetic moment , Larmor precession, electron spin, coupling of orbital and spin angular momenta. Spectroscpic terms and their notations, spin-orbit interaction, quantum mechanical relativistic correction. Fine structure of hydrogen, Lamb shift. L-S and J-J coupling. Lande interval rule, selection rules.

Zeeman effect, Examples 1. ${}^2D_{3/2}$ - ${}^2P_{1/2}$ **2)** ${}^2D_{5/2}$ - ${}^2P_{3/2}$ **3)** ${}^3P$ - ${}^2S$.

Anomalous Zeeman effect, Lande-g factor, Paschen-Back effect – spin-orbit correction. Stark effect – weak field effects and strong field effects. Hyperfine structure of spectral lines. Nuclear spin and hyperfine splitting, intensity ratio and determination of nuclear spin. Breadth of spectral lines, natural breadth. Doppler Effect and external effect **(Rajkumar).** **[16 hours]**

Nuclear magnetic resonance: Quantum mechanical expression for the resonance condition. Relaxation Mechanisms; Expression for spin lattice relaxation. Chemical shift; spin-spin interaction, example of ethyl alcohol. Fourier transform technique in NMR. FTNMR spectrometer and experimental procedure. NMR in medicine.

Microwave spectroscopy: The classification of molecules. The rotational spectra of rigid diatomic rotator, the spectra of non-rigid diatomic rotator, example of HF. Microwave oven.

Infrared spectroscopy: The Born-Oppenheimer approximation. Vibrational energy of diatomic molecule. Anharmonic oscillator. Diatomic vibrating rotator, example of the CO molecule. The vibrations of polyatomic molecules; skeletal and group frequencies. Experimental technique in FTIR.

Raman spectroscopy: The quantum theory of Raman effect. Pure rotational Raman spectraof linear molecules and symmetric top molecules. Vibrational Raman spectra. Rotational finestructure. Instrumentation technique in Raman spectroscopy **(Banwell C.N. & McCash E.M and Aruldas).** **[16 hours]**

Fourier optics: Spatial frequency filter; effect of a thin lens on an incident field distribution. Lens as a Fourier transforming element. Application to phase contrast microscopy. **(Hecht)**

Propagation of light in an anisotropic medium: Structure of a plane electromagnetic wave in an anisotropic medium. Dielectric tensor. Fresnel's formulae for the light propagation in crystals. Ellipsoid of wave normals and ray normals. Normal surface and ray surface. Optical classification of crystals. Light propagation in uniaxial and biaxial crystals. Refraction in crystals. **(Born M. and Wolf E.)**

Elements of Nonlinear Optics: Second harmonic generation, optical rectification and phase matching; third harmonic generation **(Lipson, Srivatsava).** **[16 hours]**

Total work load **48 hours**

References:

1. Tralli N. and Pomilla P.R., Atomic theory, McGraw-Hill, New York, 1999.
2. Banwell C.N. and McCash E.M., Fundamentals of Molecular Spectroscopy, 4th Edn., Tata McGraw-Hill, New Delhi, 1995.
3. Mahan B.H., University Chemistry, 3rd Edn. (Chapters 3, 10, 11 and 12), Narosa, New Delhi, 1975.
4. Hecht E., Optics, Addison-Wesley, 2002.
5. Lipson S.G., Lipson H. and Tannhauser D.S., Optical physics, Cambridge University Press, USA, 1995.
6. Rajkumar, Atomic and molecular spectra:Laser, Kedarnath Ramanath Publications, Meerut.
7. Born M. and Wolf E., Principles of optics, 6th Edn., Pergamon Press, Oxford, 1980
8. Srivatsava, P K Optics, CBS Publisher & Distributors I Ediition, 2011

PHB 110: Computer Lab CL-B

Course Outcome:

After completing this course the student will

CO1. Learn Computer Programming,

CO2. Have Hands on experience with C programming language and its syntax,

CO3. Apply C techniques for physics problem solving and data analysis.

CO4. Learn PERL scripting language

Programming in C

- Check whether given number is odd or even.
- Find the largest and smallest number in the input set.
- Compute the Fibonacci sequence.
- Check whether the input number is prime or not.
- Compute the roots of a quadratic equation.
- Generate Pascal's triangle.
- To add two m X n matrices.
- To find the sum and average of a data stored in a file.
- Linear least-squares fitting to data in a file.
- To find the trajectory of a projectile shot with an initial velocity at an angle. Also, find the maximum height travelled and distance travelled. Write the trajectory data to a file specified and plot using Gnuplot.

Programming in Perl

- Searching for a pattern in a string.
- Counting the number of characters, words and lines in a given file.
- Sorting strings.
- Check whether the input number is prime or not.
- Compute the roots of a quadratic equation.
- Linear least squares fitting to data in a file.

Total work load : 1 day(s) per week × 4 hours × 16 weeks = **64 hours**

PHB 220: Optics Lab

Course Outcome:

After completing this course the student will

CO1. Have hands on experience of experiments using spectrometer

CO2. Use the principles of superposition to explain interference, diffraction and polarisation

CO3. Describe the operation of optical devices, including, polarisers and interferometers.

CO4. Solve problems in optics by selecting the appropriate equations & performing numerical or analytical calculations.

CO5. Follow instructions to perform experiments & document their results, using correct procedures and protocols.

CO6. Analyse, interpret and communicate results from laboratory experiments, orally or in a written laboratory report.

Any ten of the following experiments:

1. Verification of the Brewster law of polarisation.
2. Verification of Fresnel laws of reflection from a plane dielectric surface.
3. Determination of the inversion temperature of the copper-iron thermocouple.
4. Birefringence of mica by using the Babinet compensator.
5. Birefringence of mica by using the quarter-wave plate.
6. Experiments with the Michelson interferometer.
7. Determination of the refractive index of air by Jamin interferometer.
8. Determination of the size of lycopodium spores by the method of diffraction haloes.
9. Determination of wavelength by using the Fabry-Perot etalon.
10. Dispersion of the birefringence of quartz.
11. The Franck-Hertz experiment.
12. Experiments with the laser.
13. Determination of the Stokes vector of a partially polarised light beam
14. Determination of the modes of vibration of a fixed-free bar.

Total work load : 2 day(s) per week × 4 hours × 16 weeks = **128 hours**

PHC 050: Quantum Mechanics 2

Course Outcome:

After completing this course the student will be able to

CO1. Understand the effect of symmetries in quantum mechanics
CO2. Understand the significance of wave function, normalization, uncertainty principle, Physical significance of eigenfunctions and eigenvectors
CO3. Time-independent perturbation theory: Non degenerate Perturbation Theory
CO4. Degenerate Perturbation Theory; Fine Structure of Hydrogen, Zeeman Effect.
CO5. The Variational Principle: Theory, the Ground State of Helium.
CO6. WKB Approximation: The Classical Region, Tunneling; connection formulae, α- decay
CO7. The time-dependent perturbation theory
CO8. Adiabatic approximation and scattering phenomena
CO9. Have a basic understanding of relativistic effects in quantum mechanics.
CO10. Mathematical foundations of quantum mechanics & Schrödinger equation for simple cases.
CO11. Relativistic quantum mechanics using Klein-Gordon equation & Dirac equation

The time-independent perturbation theory: Non degenerate Perturbation Theory; first and second order perturbation, Perturbed Harmonic Oscillator. Degenerate Perturbation Theory; Fine Structure of Hydrogen, The Zeeman Effect.

The Variational Principle: Theory, the Ground State of Helium.

WKB Approximation: Classical Region, Tunneling; connection formulae, α-particle decay **(Griffiths).[16 hours]**

Time-dependent perturbation theory: Time dependent perturbation theory; general features, constant and periodic perturbations. Two-Level Systems; Emission and Absorption of Radiations, Spontaneous Emission, Fermi golden rule, Rabi Oscillations**.**

Adiabatic approximation - The Adiabatic Theorem, Berry's Phase. Sudden approximation.

Scattering: Introduction, scattering cross section, scattering by a spherically symmetric potential. Partial Wave Analysis, phase shifts. Optical theorem, Lippmann- Schwinger equation. Born Approximation, Rutherford scattering **(Griffiths D J)**. **[16 hours]**

Relativistic quantum mechanics: Klein-Gordon equation: free particle, stationary state solutions, continuity equation. The Dirac equation; free-particle, stationary state solutions, continuity equation. Covariant formulation; Covariant form of Dirac equation, Lorentz invariance of the Dirac equation, Plane wave solutions of the Dirac equation -non-relativistic limit. Spin and helicity operators. Normalization of the solutions. Brief discussion of the hydrogen atom according to Dirac theory, Non-relativistic limit of Dirac equation. Negative energy states - Hole theory **(Sakurai J J).** **[16 hours]**

Total work load **48 hours**

References:

1. Bransden and Joachain, II edition, Pearson Low Price Edition
2. Sakurai J.J. and Tuan S.F. (Editor), Modern Quantum Mechanics, Addison Wesley, India, 1999.
3. Shankar R., Principles of Quantum Mechanics, 2nd Edn., Plenum Press, New York, 1984.
4. Schiff L.I., Quantum mechanics, 3rd. Edn., McGraw-Hill, Kogakusha Ltd., New Delhi, 1968.
5. Griffiths D.J., Introduction to Quantum mechanics, Prentice-Hall, USA, 1994.
6. Sakurai J.J., Advanced quantum mechanics, Addison-Wesley, Harlow, England, 1999.
7. Griffiths D., Introduction to Elementary particles, John Wiley and Sons, New York, 1987.
8. Gasiorowicz S., Elementary Particle Physics, John-Wiley, New York, 1966.
9. Muirhead H., The Physics of Elementary Particles, Pergamon Press, London, 1965.

PHC 060: Condensed Matter Physics

Course Outcome:

After completing this course, the student will be able to

CO1. Understand the principles of Condensed Matter Physics, Mathematical descriptions of physical phenomena.
CO2. Understand the principles of crystal structure of elements Instrumentation for crystal studies
CO3. Evaluation of crystals data and their suitability for single crystal structure analysis.
CO4. Crystal growth techniques
CO5. Liquid crystals; Classification and structures
CO6. Understand the Structural, Magnetic, Electrical and Semiconductor Properties
CO7. Theoretical and practical experience in the Condensed Matter Physics

X-ray crystallography: Crystalline state. Reference axes, equation of a plane, Miller indices. External symmetry of crystals; symmetry operations. Two and three dimensional point groups. Lattices; two dimensional lattices, choice of unit cell. **(Buerger, p12–20, 23–45).**
Three-dimensional lattices; crystal systems and Bravais lattices.Screw and glide operations. Space groups; Examples of space groups. Diffraction of X rays by crystals; Laue equations. Reciprocal lattice. [**Sherwood, p272–288**]. Bragg equation. Equivalence of Laue and Bragg equations. Significance of structure of solid for applications (**Ladd and Palmer,p55–66, p114-121)**.

Atomic scattering factor (qualitative).

Electron and neutron diffraction: Basic principles. Differences between electron, neutron and X-ray diffractions, applications (qualitative). **(Vainshtein, p 336 – 357).**

Crystal growth techniques: General methods of crystl growth.Czochralski, Kyropoulus, Stockbarger-Bridgman. Zone refining techniques**(Rose et al p 146 – 154).** **[16 hours]**

Disordered materials: Amorphous solids. Aperiodic materials.
Liquid crystals: Introduction, Classification and their applications. Morphology. The smectic (A-H), nematic and cholesteric phases. Birefringence, texture and X-ray studies**.** Orientational order and its determination for nematic liquid crystals (**DeGennes P.G. and Prost J, Gray and Goodby)**

Crystal lattice dynamics: Vibration of an infinite one-dimensional monoatomic lattice, First Brillouin Zone. Group velocity. Finite lattice and boundary conditions. Vibrations of a linear diatomic lattice; optical and acoustical branches, dispersion relations**. (Wahab, p288–305).**

Magnetic properties of solids: Diamagnetism and its origin. Expression for diamagnetic susceptibility. Paramagnetism; Quantum theory of paramagnetism, Brillouin function. Ferromagnetism; Curie-Weiss law, Spontaneous magnetisation and its variation with temperature. Ferromagnetic domains. Antiferromagnetism. Two sub-lattice model. Susceptibility below and above Neel's temperature.**(Dekker, p446–490).** **[16 hours]**

Superconductivity: Experimental facts. Type I and type II superconductors. Phenomenalogical theory. London equations. Meissner effect. High frequency behaviour. Thermodynamics of superconductors; Entropy and Specific heat. Qualitative ideas of the theory of superconductivity.**(Kittel, p333–364).**

Semiconductors: Elemental and compound Semiconductors [Streetman, p61–95].Crystal structure and bonding. Expressions for carrier concentrations. Fermi energy, electrical conductivity and energy gap in intrinsic semiconductors. Extrinsic Semiconductors; impurity states and ionization energy of donors. Carrier concentrations and their temperature variation **(Mckelvey, p256–277).** **[16 hours]**

Total work load **48 hours**

References:

1. Stout G.H. and Jensen L.H., X-ray structure determination, MacMillan, USA, 1989.
2. Ladd M.F.C. and Palmer R.A., Structure determination by X-ray crystallography, Plenum Press, USA, 2003.
3. Buerger M.J., Elementary crystallography, Academic Press, London.
4. Dekker A.J., Solid state physics, Prentice Hall, 1985.
5. Kittel C., Introduction to solid state physics, 7th Edn., John Wiley, New York, 1996.
6. Mckelvey J.P., Solid state and semiconductor physics, 2nd Edn., Harper and Row, USA, 1966.
7. Streetman B.G., Solid state electronic devices, 2nd Edn., Prentice-Hall of India, New Delhi, 1983.
8. DeGennes P.G. and Prost J.,The physics of liquid crystals, 2nd Edn., Clarendon Press, Oxford, 1998.
9. Wahab M.A., Solid state physics, Narosa Publishing House, New Delhi, 1999.
10. Azaroff L.V., Introduction to solids, McGraw-Hill Inc, USA, 1960.

11. Sherwood D., Crystals, X-rays and proteins, Longman, UK, 1976.
12. Rose R.M., Shepard L.A. and Wulff J., The structure and properties of materials Vol. 4, Electronic properties, Wiley Eastern, 1965.
13. Vainshtein B.K., Modern crystallography, Vol. I, Springer-Verlag, Germany, 1981.
14. Pillai S.O., Solid state physics, New Age International Publications, 2002.

PHC 070: Nuclear and Particle Physics

Course Outcome:

After completing this course the student will be able to

CO1. Understand the relation between the standard model and QCD.
CO2. Understanding strong interactions with many-body physics.
CO3. Quantitatively estimates for nuclear phenomena
CO4. Understand the Standard Model
CO5. Familiarise with theoretical and experiments used in particle physics.
CO6. Stabilise the nucleus, nuclear forces, interactions and models,.
CO7. Critically assess a range of applications of nuclear technology.
CO8. Develop Theoretical & practical experience in the scattering experiments & gamma-ray spectroscopy.

Properties of the Nucleus: Nuclear radius; determination by mirror nuclei, Mesic X-rays and electron scattering methods. Nuclear moments; spin, magnetic dipole moment. Relation between J and μ on the basis of single particle model. Determination of nuclear magnetic moment by Molecular beam experiment. Electric quadrupole moment – reduced Electric quadrupole moment **.**

Nuclear Models: Liquid drop model; Weissacker's formula and its application to (1) stability of isobars and (2) fission process. Shell model; Infinite square well potential, Magic numbers. Fermi gas model; well depth, level density and nuclear evaporation.

Nuclear reactions: Q-values, threshold energy. Reactions induced by proton, deuteron and particles. Photodisintegration **(Krane & Tayal)**. **[16 hours]**

Nuclear decay modes: Beta decay; Beta ray spectrum, Pauli neutrino hypothesis, mass of the neutrino from beta ray spectral shape, Fermi theory of beta decay, Kurie plot, ft- values and forbidden transitions. Methods of excitation of nuclei; Nuclear isomerism, Mossbauer effect (qualitative only), Auger effect.

Interaction of nuclear radiation with matter: Energy loss due to ionization for proton -like charged particles, Bethe-Bloch formula, Range energy relations. Ionisation and Radiation loss of fast electrons (Bremsstrahlung - qualitative only). Interaction of gamma and X-rays with matter. Detectors; Brief description of NaI (Tl) gamma ray spectrometer. Boron triflouride counter**.**

Nuclear reactors: Condition for controlled chain reactions, slowing down of neutrons, logarithmic decrement in energy. Homogeneous spherical reactor; critical size, effect of reflectors. Breeder reactor(Qualitative discussion) **(Krane & Tayal)**. **[16 hours]**

Nuclear forces and elementary particles: General features of nuclear force; spin dependence, charge independence, exchange character, saturation other features. Meson theory of nuclear forces; Yukawa's theory. Properties of pi mesons; charge, mass, spin, isospin and parity, decay modes, meson resonances.

Particle interactions and families: Conservation laws; classification of fundamental forces and elementary particles. Associated particle production, Gellmann-Nishijima scheme, strange particles. CP violations in Kaon decay. Symmetries; Eight-fold way symmetry, quarks and gluons. Elementary ideas of the Standard model **(Griffiths D J).** **[16 hours]**

Total work load **48 hours**

References

1. Tayal D.C., Nuclear Physics, Himalaya Publishing House, New Delhi, 2012 (Unit 1. Chapter Page 6-14. Page 30- 35, 40-49. Chapter 9. Page 355-369. Chapter 10. Page 401-411.)
2. Krane K.S., Introductory nuclear physics, Wiley, New York, 1987. (Unit 1. Chapter 16 page 605-610.)
3. Ghoshal S.N., Nuclear physics, S.Chand and Company, Delhi, 1994. (Unit 2: Chapter 5 page 137-155, Chapter 6 page 187-204, 222, 262, Chapter 13, page 647-651, chapter 15, page717-721.)
4. Wong S.S.M., Introductory nuclear physics, Prentice Hall of India, Delhi, 1998.
5. Khanna M.P., Introduction to particle physics, Prentice Hall of India, Delhi, 2008.
6. Kapoor S.S. and Ramamoorthy V., Nuclear radiation detectors, Wiley Eastern, Bangalore,2007

PHC 240: Solid State Physics 1

Course Outcome:

After completing this course the student will

CO1. Understand the Dielectrics properties of Solids;
CO2. Understand Physics of Ferroelectric Properties of Solids
CO3. Quantitatively estimate the Magnetic properties of solids
CO4. Compute the magnetic relaxation time
CO5. Understand BCS theory of Superconductors
CO6. Understand the fundamentals of nanomaterials
CO7. Understand the elastic properties of solids

Dielectric properties of solids: Macroscopic description of static dielectric constant, the static electronic and ionic polarisabilities of molecules, orientation polarization. Local electric field at an atom; Lorentz field, field of dipoles inside cavity. The static dielectric constant of solids; Clausius- Mossotti relation. Complex dielectric constant. Polarization catastrophe. Dielectric losses and Debye relaxation time. Classical theory of electronic polarization and optical absorption.

Ferroelectricity: Basic properties and classification of ferroelectric materials. The dipole theory of ferroelectricity, objections against the dipole theory. Ionic displacements and behavior of Barium titanate above the Curie temperature. Theory of spontaneous polarization of Barium titanate. Thermodynamics of ferroelectric transitions. Landau theory of phase transitions, Dielectric constant near the Curie point. Ferroelectric domain **(Dekker and Kittel).** **[16 hours]**

Magnetic properties: Definition of magnetization and susceptibility. Hund`s rule; calculation of L, S and J for 3d and 4f shells. Setting up of Hamiltonian for an atom in an external magnetic field; explanation of diamagnetism, Van Vleck Paramagnetism and quantum theory of paramagnetism **(Ashcroft & Mermin).** Interpretation of the Weiss field in terms of exchange integral **(Dekker p473-474,).** Calculation of the singlet triplet splitting, spin Hamiltonian and Heisenberg model **(Ashcroft and Mermin).**

Zero-temperature properties: Ground state of the Heisenberg ferromagnet. First excitation of one dimensional ferromagnetism at zero-temperature; spin waves, anti-ferromagnetism. Low-temperature behaviour of ferromagnets; Bloch's $T^{3/2}$ law **(Ashcroft and Mermin, Kittel).**

Magnetic resonance: Phenomenological description, Relaxation mechanisms, Derivation of Casimir Durpe relation. Nuclear Magnetic moments, condition for resonance absorption, setting up of Bloch's equations, solutions for steady state and weak RF field. Expression for power absorption, change of inductance near resonance. Dipolar line width in a rigid lattice **(Dekker p498-512).** **[16 hours]**

Band theory of solids: Statement and proof of Bloch theorem; periodic potentials in solids. Reciprocal lattice, periodic boundary conditions, density of states. Construction of Brillouin zones for a square lattice. Nearly free electron model and solution at the boundary. Energy gap using nearly free electron model. Tightly bound electron approximation, application to SC , BCC and FCC lattices **(Dekker**).

Superconductivity: BCS theory; Cooper pairs, Energy gap, Meissner effect. Flux quantization. Theory for DC and AC bias; Josephson tunnelling, Josephson junction. High $T_c$superconductors **(Ibach and Luth).**

Elastic constants of crystals: Elastic strains and stresses. Elastic compliance and stiffness constants, applications to cubic crystals and isotropic solids. Elastic waves and experimental determination of elastic constants **(Kittel, R S Krishnan, R J Asero]** **[16 hours]**

Total work load **48 hours**

References:

1. Dekker A.J., Solid state physics, Prentice Hall, 1985.
2. Kittel C., Introduction to solid state physics, 7th Edn., John Wiley, New York, 1996.
3. Ashcroft N.W. and Mermin N.D., Solid State Physics, Saunders College Publishing, 1996.
4. Ibach H. and Luth H., Solid State Physics Narosa, New Delhi, 1996.
5. Pillai S.O., Solid state physics, New Age International Publications, 2002.
6. Wahab M.A., Solid state physics, Narosa Publishing House, New Delhi, 1999.
7. R S Krishnan, Progress in Crystal Physics, Vol 1, Central Art Presst, Chennai
8. R J Asero, Mechanics of Solids and Mateials, Uni. Of Caifornia,

PHC 260: Nuclear Physics 1

Course Outcome:

After completing this course the student will

CO1. Conceptualise the Nuclear Detectors, Nuclear Pulse techniques and Nuclear models

CO2. Develop Theoretical and practical experience in the scattering experiments and gamma-ray spectroscopy.

CO3. Learn High-energy nuclear physics, the behaviour of nuclear matter under extreme conditions.

CO4. Learn Low-energy nuclear physics, structure & dynamics of nuclei, nuclear reactions and their probabilities;

CO5. Understand development of sensors, detectors, and larger complex Nuclear instruments

Nuclear detectors: Scintillation processes in inorganic crystals (NaI(Tl)). Semiconductor detector -Diffused junction, Surface barrier and Lithium drifted detectors. Relation between applied voltage and depletion layer thickness in junction detectors, Hyper pure germanium detectors, Cerenkov detectors.

Nuclear pulse techniques: Preamplifier circuits; charge sensitive and voltage sensitive preamplifiers.
Linear pulse amplifiers; Linearity, stability, pulse shaping, pulse stretching.
Operational amplifiers; analog to digital converters. Scalars, Schmidt trigger as a pulse discriminator, Single channel analyser; Integral and differential discriminators.
Multichannel Analysers, memory devices and online data processing. **[16 hours]**

Shell model: Motion in a mean potential, Square well and simple harmonic oscillator potential well, spin orbit interaction and Magic numbers. Extreme single particle model, Ground state properties of nuclei based on shell model. Nordhiem's Rules.

Collective model: Evidences for collective motion. Nuclear rotational motion; Rotational energy spectrum and nuclear wave functions for even-even nuclei. Odd- A nuclei energy spectrum and wave function.

Nilsson model: Nilsson diagrams.

Many body self-consistent models: Hartree-Fock model. **(Hans H.S)** **[16 hours]**

Timing spectroscopy: Coincidence and anti-coincidence circuits. Delay circuits. Time to amplitude conversion; start-stop and overlap converters.

Gamma ray spectroscopy: Life time measurements. Gamma-gamma, beta-gamma angular correlation studies. Angular distribution of gamma rays from oriented nuclei. Polarization of gamma rays. **[16 hours]**

Total work load **48 hours**

References:

1. Mermier P. and Sheldon E., Physics of the nuclei and particles, Vol. 1 and 2, Academic Press, New York 1970.
2. Segre E., Nuclei and particles, Benjamin Inc, New York, 1977.
3. Arya A.P., Fundamentals of nuclear physics, Allyn and Bacon, USA, 1968.
4. Blatt J.M. and Weisskopf V.F., Theoretical nuclear physics, Wiley and Sons, New York, 1991.
5. Siegbahn K., The alpha, beta and gamma ray spectroscopy: Vol. 1 and 2, North Holland, Amsterdam, 1965.
6. Price J.W., Nuclear radiation detectors, McGraw Hill, New York, 1965.
7. Kapoor S.S. and Ramamoorthy V., Nuclear radiation detectors, Wiley Eastern, Bangalore, 1993.
8. Kowalski E., Nuclear electronics, Springer Verlag, Berlin,1970.
9. Leo W.R.,Techniques for nuclear and particle physics experiments, Springer Verlag, 1992.
10. Roy R.R. and Nigam B.P., Nuclear physics, New Age International, New Delhi, 1986.
11. Hans H.S., Nuclear physics—Experimental and theoretical, New Age International Publishers, 2001.
12. Tayal D.C., Nuclear Physics, Himalaya Publishing House, New Delhi, 2012

PHY-306: Theoretical Physics 1

Course Outcome:

After completing this course the student will

CO1. Tackle a wide range of topics using powerful analytical tools including formal methods in classical and quantum physics

CO2. Clearly communicate information & conclusions in written and verbal form of the ideas in Theoretical Physics

CO3. Evaluate complex problems & formulate solutions, indentifying the role of theory, hypothesis and experiment in the scientific method

CO4. Apply computation to solve the problems in theoretical physics

CO5. Plan, carry out and report theoretical physics based investigation

CO6. Apply classical and quantum theoretical techniques in research

General theory of relativity: Tensor Calculus and Riemannian geometry: Covariant Differentiation, Parallel Transport, Geodesies, The Curvature Tensor.

Riemannian geometry: Riemannian space, The determinant of $g_{\mu\nu}$. Metrical Densities, The Connection of a Riemannian Space: Christoffel Symbols, Geodesies in a Riemannian Space, The Curvature of a Riemannian Space: The Riemann Tensor. **[16 hours]**

Gravitational field: The Principle of Equivalence, The Field Equations of General Relativity, Metrics with Spherical Symmetry, The Schwarzschild Solution. Geodesies in the Schwarzschild Space, Advance of the Perihelion of a Planet, The Deflection of Light Rays, Red Shift of SpectralLines, The Schwarzschild Sphere. Gravitational Collapse. Black Holes. **[16 hours]**

Quantum field theory-1: Classical and quantum fields: Particles and fields, Discrete and continuous mechanical systems, Classical scalar fields, Maxwell fields Quantum Theory of Radiation: Creation, annihilation, and number operators, Quantized radiation field, Fock states, Emission and absorption of photons by atoms, Rayleigh scattering, Thomson scattering, and the Raman effect. **[16 hours]**

Total work load **48 hours**

References:

1. Papapetrov A., Lectures on general relativity, D. Reidel Publishing Company, USA, 1974.
2. Dirac P.A.M., The general theory of relativity, John Wiley and Sons, New York, 1975.
3. Adler R., Bazin M. and Schiffer M., Introduction to general relativity, McGraw-Hill Kogakusha, Ltd. New Delhi, 1965.
4. Hartle J.B., Gravity: An introduction to Einstein's general relativity, Benjamin-Cummings Pub. Co., USA, 2002.
5. Sakurai J.J., Advanced quantum mechanics, Addison-Wesley, Harlow, England, First ISE Reprint, 1999.
6. Griffiths D., Introduction to elementary particles, John Wiley and Sons, New York, 1987.
7. Gasiorowicz S., Elementary particle physics, John-Wiley, New York, 1966.
8. Muirhead H., The physics of elementary particles, Pergamon Press, London, 1965.

Open Elective Papers

Paper to be offered to Non-Physics Postgraduate students

PHY-321: Modern Physics

Course Outcome:

After completing this course the student will

CO1. Apply basic principles and laws of electricity and magnetism

CO2. Solve Problems involving the fundamental principles of physics

CO3. Apply Mathematical techniques for quantitative solutions to problems

CO4. Understand the fundamentals of Condensed Matter, Nuclear and Quantum Physics

Nuclear physics: A brief overview of nuclear physics. Nuclear reactions, a brief description of nuclear models. Interactions of X-rays and γ-rays with matter, slowing down and absorption of neutrons. Fundamental particles, classification of fundamental particles, fundamental forces, conservation laws in particle physics, a brief outline of the quark model.

Nuclear power: Nuclear fission, fission chain reaction, self sustaining reaction, uncontrolled reaction, nuclear bomb. Nuclear reactors, different types of reactors and reactors in India. Nuclear waste management. Nuclear fusion, fusion reactions in the atmosphere. Radiation effects; dosage calculation. Nuclear energy; applications and disadvantages. **[16 hours]**

Condensed matter physics: Amorphous and crystalline state of matter. Crystal systems. Liquid crystals. X-ray diffraction; Bragg equation. Structure of NaCl. FTIR; Experiment analysis. NMR; Experiment and analysis. Electrical conductivity of metals and semiconductor. Magnetic materials; para,ferro, ferri and anti-magnetism. Dielectrics—para, ferro, pyro and piezo properties. Symmetry in physics. **[16 hours]**

Quantum physics: Qualitative discussion. Molecules, atoms, nucleus, nucleons, quarks and gluons. Particle physics (qualitative). Stern-Gerlach experiment and consequences. Uncertainty relation. Hydrogen atom. Positron annihilation. Laser trapping and cooling. Ion traps. Electromagnetic, strong, weak and Gravitational forces. Big Bang theory, String theory. LHC experiment, consequences. Higgs Boson. **[16 hours]**

Tutorial **[32 hours]**

References:

1. Ghoshal S.N., Atomic and nuclear physics, Vol.2., S. Chand and Company, Delhi, 1994.
2. Evans R.D., Atomic nucleus, Tata Mc Grow Hill, New Delhi, 1976.
3. Penrose R., Road to Reality, Vintage Books, 2007.
4. Ladd M.F.C. and Palmer R.A., Structure determination by X-ray crystallography, Plenum Press, USA, 2003.
5. De Gennes P.G. and Prost J., The physics of liquid crystals, 2nd Edn., Clarendon Press, Oxford, 1998.
6. Myer R., Kennard E.H. and Lauritsern T., Introduction to modern physics, 5th Edn., McGraw- Hill, New York, 1955.
7. Halliday D., Resnick R. and Merryl J., Fundamentals of physics, Extended 3rd Edn., John Wiley, New York, 1988.

PHY-322: Energy Science

Course Outcome:

After completing this course the student will

CO1. Learn the need for renewable energy in the growing world
CO2. Understand the conservation of renewable energy resources
CO3. Understand the proper utilisation of renewable energy resources
CO4. Understand the physics of renewable energy resources
CO5. Learn the technology behind the biogas and biomass production

Renewable energy resources: Forms of Energy, Basics of Thermodynamics: Heat capacity, Heat transfer mechanism, entropy, First and second law of thermodynamics Carnot Cycle, Rankin cycle. Fossil fuels, time scale of fossil fuels. Solar energy: Sun as the source of energy and its energy transport to the earth, Extraterrestrial and terrestrial solar radiations, Measurement techniques of solar radiations using Pyranometer and Pyrheliometer. **[16 hours]**

Materials and solar cell technology : Single, poly and amorphous silicon, GaAs, CdS, fabrication of single and polycrystalline silicon solar cells, amorphous silicon solar cells, photovoltaic systems and technical problems. Wind Energy Origin and classification of winds, Aerodynamics of windmill: Maximum power and Forces on the Blades and thrust on turbines; Wind data collection and field estimation of wind energy, Site selection, Basic components of wind mill, Types of wind mill, Wind energy farm, Hybrid wind energy systems: The present Indian Scenario. **[16 hours]**

Biomass energy and biogas technology: Nature of Biomass as a fuel, Biomass energy conversion processes, Direct combustion: heat of combustion, combustion with improved Chulha and cyclone furnace; Dry chemical conversion processes: pyrolysis, gasification, types of gasification. Importance of biogas technology, anaerobic decomposition of biodegradable materials, Factors affecting Bio-digestion, Types of biogas plants, Applications of biogas. **[16 hours]**

Tutorial **[32 hours]**

References:

1. Peter A., Advances in energy systems and technology, Academic Press, USA, 1986.
2. Neville C.R., Solar energy conversion: The solar cell, Elsevier North-Holland, 1978.
3. Dixon A.E. and Leslie J.D., Solar energy conversion, Pergamon Press, New York, 1979.
4. Ravindranath N.H., Biomass, energy and environment, Oxford University Press, 1995.
5. Cushion E., Whiteman A. and Dieterle G., World Bank Report, 2009.

PHC 080: Condensed Matter Physics Lab

Course Outcome:

After completing this course the student will

CO1. Independently collect single crystal XRD data and evaluate the crystal structure,
CO2. Analyse Diffraction data and their suitability for single crystal structure.
CO3. Independently work on raw diffraction data and Solve and refine crystal data
CO4. Understand the properties of Condensed Materials such as Structural, Magnetic, Electrical and Semiconducting Properties
CO5. Acquire theoretical and practical experience in the Condensed Matter Physics

Any eight of the following experiments:

1. Determination of the paramagnetic susceptibility of the given salt by Quincke's method
2. Study of mercury spectrum by superimposing it on brass spectrum
3. Sodium spectrum analysis by using Edser-Butler fringes
4. Temperature coefficient of resistance of a thermistor
5. Analysis of the powder X-ray photograph of a simple cubic crystal
6. Thermionic work function of a metal (Richardson-Dushmann formula)
7. Energy gap of a semiconductor
8. Frank Hertz experiment
9. Measurement of magneto resistance of semiconductors
10. Stefan's Constant of Radiation

11. Thermal Conductivity of Poor Conductor
12. Di-electric constant of a Non polar liquid
13. Dipole moment of an organic Molecule
14. High Resistance by Leakage

Total work load : 2 day(s) per week × 4 hours × 16 weeks = **128 hours**

PHC 090: Nuclear and Particle Physics Lab

Course Outcome:

After completing this course the student will

CO1. Be familiar with theoretical concepts & experimental techniques of Nuclear & particle physics,.
CO2. Be able to make quantitative estimates of phenomena in elementary particles
CO3. Understand stability of the nucleus, nuclear forces, interactions & models, Critically assess a range of applications of nuclear technology.
CO4. Acquire Theoretical & practical experience in the scattering experiments and gamma-ray spectroscopy.
CO5. Be able to realise the Nuclear Electronic circuits

Any eight of the following experiments:

1. Half-life of Indium-116 measurement.
2. Energy Resolution of a NaI(Tl) scintillation spectrometer.
3. Compton scattering—determination of the rest energy of an electron.
4. Beta absorption coefficient measurement.
5. Dekatron as a counter of signals.
6. Gamma-ray absorption coefficient measurement.
7. End-point energy of Beta particles by half thickness measurement.
8. Common Source amplifier.
9. Astable multivibrator using timer IC 555.
10. Dead time of the G.M. counter.

Total work load : 2 day(s) per week × 4 hours × 16 weeks =**128 hours**

Reference: 1. Varier K. M., Antony Joseph and Pradyumman P. P., Advanced experimental techniques in Modern Physics, Pragati Prakashan, 2011

PHC 250: Solid State Physics Lab 1

For those who have opted for ***Solid State Physics Specialisation***

Course Outcome:

After completing this course the student will

CO1. Be able to make quantitative estimates for phenomena in solid state physics.
CO2. Describe thermal & vibrational properties of solids,
CO3. Compute band structures using the tight-binding approximation
CO4. Compute trajectories in real and reciprocal space, Characterize magnetism
CO5. Characterize intrinsic and doped semiconductors
CO6. Describe superconductivity
CO7. Understand the mechanism and working of semiconductor devices.

Any five of the following experiments:

1. Optical rotatory dispersion of a uniaxial crystal.
2. Birefringence of quartz using spectrometer.
3. Paramagnetic susceptibility by Gouy balance method.
4. Fermi energy of copper.
5. Cell parameter(s) from an X-ray powder diffractogram.
6. Verification of Langmuir-Child's law.
7. Curie temperature of a ferroelectric material.
8. Dielectric constant and its temperature variation.
9. Determination of the polarisabilities of the molecules of an uniaxial crystal using spectrometer.
10. Determination of Stefan's constant using Photo Cell
11. Calibration of Si Diode

12. Measurement of Electrical and Thermal Conductivity of Copper
13. Verification of Curie-Weiss law
14. BH Curve in a ferromagnetic Material

Total work load : 1 day(s) per week × 4 hours × 16 weeks = **64 hours**

PHC 270: Nuclear Physics Lab 1

*For those who have opted for **Nuclear Physics Specialisation***

Course Outcome:

After completing this course the student will

CO1. Be familiar with Nuclear Detectors, Pulse techniques, nuclear models, timing spectroscopy and nuclear technology.

CO2. Be familiar with Theoretical & practical experience in the scattering experiments and gamma-ray spectroscopy.

CO3. Learn Instrumentation, development of sensors, detectors, & larger complex instruments.

CO4. Familiarise in Fundamentals of reactor theory and nuclear decay mechanisms

CO5. Learn Accelerator physics, research and development for the next generation of particle accelerators.

Any five of the following experiments:

1. Cockroft-Walton voltage multiplier.
2. Coincidence circuit.
3. Linear amplifier.
4. Transistorised binary circuit.
5. Pulse shaping circuits.
6. Linear Gate.
7. Randomocity of radioactive decay.
8. Nomogram method : Measurement of endpoint energy of beta rays.
9. Study of linearity of the NaI(Tl) gamma ray spectrometer.
10. Determination of the energy of an unknown gamma ray source.

Total work load : 1 day(s) per week × 4 hours × 16 weeks = **64 hours**

PHY-315: Theoretical Physics Lab 1

*For those who have opted for **Theoretical Physics Specialisation***

Course Outcome:

After completing this course the student will

CO1. Tackle a wide range of topics using powerful analytical tools including formal methods in classical and quantum physics

CO2. Clearly communicate information and conclusions in written and verbal formats on ideas in Theoretical Physics

CO3. Evaluate complex problems and formulate solutions, indentifying the role of theory,hypothesis and experiment in the scientific method

CO4. Apply computation to solve the problems in theoretical physics

CO5. Plan, carry out and report theoretical physics based investigation

CO6. Apply classical and quantum theoretical techniques in research

Any five of the following experiments:

1. Calculation of Christoffel symbols.
2. Geodesics and curvature calculations.
3. Exterior Schwarzschild metric calculations.
4. Robertson-Walker metric calculations.
5. Lagrangian and Hamiltonian, Euler Lagrange equations for Schroedinger field.
6. Lagrangian for Maxwell's field and The field equations.
7. Symmetries of the Lagrangian and Constants of motion.
8. Operator algebra-BCH formula.
9. Relativistic kinematics-1: Relations between center of momentum and laboratory frames.
10. Relativistic kinematics-2: Non-relativistic limit of relativistic kinematics.

Total work load : 1 day(s) per week × 4 hours × 16 weeks = **64 hours**

PHD 250: Solid State Physics 2

Course Outcome:

After completing this course the student will

CO1. Gain an overall idea about X-ray diffraction method Solid State Physics
CO2. Get the understanding about X-ray diffraction (XRD) by Crystals.
CO3. Understand the Physical phenomena and significance of XRD
CO4. Be able to make quantitative estimates for structural phenomena of solids.
CO5. Describe thermal and vibrational properties of solids
CO6. Understand the concepts of Dislocations, Imperfections and Defects in Solids
CO7. Appreciate the Luminescent effects and colour centres in ionic crystals

X-ray diffraction by crystals: The reciprocal lattice. Ewald sphere and construction. Scattering by an electron and atom; Atomic scattering factor. Anomalous scattering. Fourier analysis and inversion of Fourier series; Physical significance. Geometrical structure factor of the unit cell. Absent reflections and space groups.**(Sherwood, P290 – 358).**

Experimental techniques: Brief introduction to Laue, Powder and single crystal methods. Use of Synchrotron radiation for structure studies. Weissenberg and precession methods. Cell parameter and space group determination. Molecular weight determination. **(Stout and Jensen,p 90–211).** **[16hours]**

Structure analysis: Low angle scattering. Reduction of intensities to structure amplitudes. Various corrections. Absolute scale factor and temperature factor from statistical methods. Statistical method for finding the presence of center of symmetry Fourier analysis of electron density. Patterson synthesis. Harker sections and lines. Heavy atom methods. Direct methods for phase determination. The inequality relations. Difference Patterson synthesis and error Fourier synthesis. Figure of merit. Cyclic Fourier refinement, Difference Fourier synthesis. Refinement of structures: The least squares method. Accuracy of the parameters. Bond lengths and angles. **(Sherwood, Ladd and Palmer)**

SAXS; Particle Size study of Fibre structure **[16 hours]**

Imperfections in solids: Different types of imperfections. Schottky and Frenkel defects; expression for energy for the formation of Frenkel and Schottky defects. Diffusion in metals; Kirkendall effect. Ionic conductivity in pure and doped halides. Photoconductivity **(Kittel).**

Dislocations: Buerger's Vector. Expression for strain in edge and screw dislocations **(Wahab and Kittel).**

Synthesis and Device fabrication of Nanomaterials: Nanomaterials**.** Bottom-Up approach; Sol-gel synthesis, hydrothermal growth, thin-film growth, physical vapor deposition, chemical vapor deposition. Top- Down Approach; Ball milling, Microfabrification, Lithography, Ion-beam lithography**(Ramachandra rao and Shubra singh, p129-142).**

Luminescence: Excitation and Emission. Franck-Condon principle. Decay mechanisms;Temperature dependent and independent decays. Thermoluminescence and glow curve. Gudden-Pohl effect **(Dekker).** **[16 hours]**
Total work load **48 hours**

References:

1. Stout G.H. and Jensen L.H., X-ray structure determination, MacMillan, USA, 1989.
2. Ladd M.F.C. and Palmer R.A., Structure determination by X-ray crystallography, Plenum Press, USA, 2003.
3. Sherwood D., Crystals, X-rays and proteins, Longman, London, 1976.
4. Wahab M.A., Solid state physics, Narosa Publishing House, New Delhi, 1999.
5. Azaroff L.V., Introduction to solids, McGraw-Hill Inc, USA, 1960.
6. Weertman J. and Weertmann J.R., Elementary dislocation theory, McMillan, USA, 1964.
7. Pillai S.O., Solid state physics, New Age International Publications, 2002.

PHD 260: Solid State Physics 3

Course Outcome:

After completing this course the student will

CO1. Have overall idea about properties of Solids.
CO2. Be provided with the understanding about free electron theory of metals
CO3. Understand the properties of impurity semiconductors.
CO4. Learn Semiconductor phenomena; Hall effect, Magneto-resistance phenomenon
CO5. Be able to make quantitative estimates of semiconducting phenomena of solids.
CO6. Describe the effect of excess carriers in semiconducting solids
CO7. Understand the mechanism and working of semiconductor devices.

Free electron theory of metals: Boltzmann transport equation, Sommerfeld's theory of electrical conductivity, mean free path in metals, dependence of resistivity on temperature and impurities. Matthiessens rule. Electron-phonon collisions. Electrical conductivity of metals at high frequencies. Plasma frequency. Transparency of alkali metals to UV radiation. Anomalous skin effect. Plasmons. Field enhanced emission, Schottky effect. Hall effect and magnetoresistance in metals. Cyclotron frequency **(Kittel & Pillai).** Thermal conductivity of insulators; Umklapp processes **(Dekker, p275-292)**. **[16 hours]**

Impurity semiconductors: A brief discussion on Elemental and Compound Semiconductors and their properties. Carrier concentrations; effect of temperature and impurity density. Electrical neutrality condition. Fermi energy; Variation with temperature and impurity density, when the Boltzmann approximation is valid,. Effect of impurity density at very low temperatures. Mobility of current carriers; effect of temperature and impurity. Electrical conductivity; effect of temperature, impurity density and the energy band gap.

Hall effect in semiconductors; Expression for Hall co-efficient,
Magneto-resistance phenomenon (qualitative) **(M A Wahab).**
Cyclotron resonance;Cyclotron resonance in Si and Ge semiconductors. Effective mass tensor. Variation of cyclotron resonance frequency with orientation of the crystal in the magnetic field **(Mckelvey, p270–300).**
[16 hours]

Excess carriers in semiconductors: Generation and recombination rates. Continuity equations; Einstein equations, Expression for the diffusion length of electrons and holes **(Mckelvey, p320–335).**
High field transport in semiconductors; electron temperature. Gunn effect, Expression for drift velocity. Superlattice Phenomenon **(Roy, p29–39).**

Semiconductor devices: The pn junction; space charge region, effect of the applied field on barrier potential, barrier thickness and contact field. Transition capacitance. Current density for excess carriers. Characteristics and applications of phototransistors, JFET, SCR and UJT**(Mckelvey, p390–441).** **[16 hours]**

Total work load **48 hours**

References:

1. Dekker A.J., Solid state physics, Prentice Hall, 1985.
2. Mckelvey J.P., Solid state and semiconductor physics, 2nd Edn., Harper and Row, USA, 1966.
3. Roy D.K., Physics of semiconductor devices, University Press, Hyderabad, 1992.
4. Schur M., Physics of semiconductor devices, Prentice-Hall of India, New Delhi, 1999.
5. Wilson J. and Hawkes J.F.B., Optoelectronics—An introduction, 2nd Edn., Prentice-Hall of India, New Delhi, 1996.
6. Streetman B.G., Solid state electronic devices, 2nd Edn., Prentice-Hall of India, New Delhi, 1983.
7. Omar M.A., Elementary solid state physics, Addison Wesley, New Delhi, 2000.
8. Wahab M.A., Solid state physics, Narosa Publishing House, New Delhi, 1999.
9. Pillai S. O. Solid State Physics, ew Age International Publications, New Delhi.

PHD 300: Nuclear Physics 2

Course Outcome:

After completing this course the student will

CO1. Understand the phenomenon of nuclear fission and its application in energy production.
CO2. Gain an overview on the neutron physics and nuclear reactor theory.
CO3. Develop the understanding of quantum theory beta decay.
CO4. Learn about the multipole transition involving gamma decay and internal conversion.

Nuclear fission: Nuclear fission, Mass-energy distribution of fission fragments. Statistical model of fission.

Reactor theory-1: Neutron and its interaction with matter-collision kinematics, differential elastic scattering cross sections, isotropic scattering, the criticality condition for a reactor. Neutron transport equation using elementary diffusion theory. One group critical equation, critical size on the basis of Fermi age theory.
[16 hours]

Reactor theory-2: Reactors; One group theory, spherical and cylindrical homogeneous reactor. Effective multiplication factor. Reflector reactors: effects of reflector. One group method of a homogeneous reactor with reflector. reflector savings. Infinite multiplication factor, critical size and critical mass.
Heterogeneous reactor system; calculation of thermal utilization factor. Fast Breeder reactor, Evaluation of Buckling using one group model. **[16 hours]**

Beta decay: Classification of beta interactions. Matrix elements. Fermi and Gamow-Teller selection rules for allowed beta decay. The non conservation of parity in beta decay. Wu et al experiment. The universal Fermi interaction.

Gamma decay: Electromagnetic interactions with nuclei. Multipole transitions. Transition probabilities in nuclear matter. Weisskopf's estimates. Structure effects. Selection rules. Internal conversion Photo disintegration of deuteron and radiative capture of neutron by proton. **[16 hours]**

Total work load **48 hours**

References:

1. Glasstone S.& Edlund M.C., Elements of nuclear reactor theory, D. Van Nostrand Co., USA, 9th Print, 1963.
2. Garg S., Ahmed F. and Kothari I.S., Physics of nuclear reactors, Tata McGraw-Hill, New Delhi, 1986.
3. Roy R.R. and Nigam B.P., Nuclear physics, New Age International, New Delhi, 1986.
4. Hans H.S., Nuclear physics—Experimental and theoretical, New Age International Publishers, 2001.
5. Ghoshal S.N., Nuclear physics, Vol. 2., S.Chand and Company, Delhi, 1994. Chapter 15, page 714-730.

PHD 310: Nuclear Physics 3

Course Outcome:

After completing this course the student will

CO1. Know about the two particle nuclear bound system like deuteron.
CO2. Learn the theory of nucleon-nucleon scattering processes.
CO3. Get an understanding of plane wave theory of nuclear reactions.
CO4. Acquire knowledge on optical model and heavy ion physics.

Two particle systems: Deuteron; Schrodinger equation for a two nucleon system, Theory of the ground state of the deuteron under central and non central forces, Excited states of the deuteron. Rarita-Schwinger relations. Deuteron magnetic and Quadrupole moments.

Nucleon-nucleon scattering processes: Theory of s-wave scattering of neutrons by free protons and experimental results. Wigner's formula for n-p scattering. Theory of scattering of slow neutrons by bound protons (Ortho and Para hydrogen) and experimental results. Effective range theory for n-p scattering.
S wave theory of proton-proton scattering. Mott's modification of Rutherford's formula. Pion-nucleon scattering experimental results, (3/2, 3/2) resonance. **[16 hours]**

Nuclear reactions-1: Plane wave theory of direct reactions. Born approximation (Plane wave); Butler's theory. Cross section for nuclear scattering and reactions. Shadow scattering, Breit-Wigner resonance formulae.

Nuclear reactions-2: Bohr's independence hypothesis. The compound nucleus (CN) reactions, decay rates of CN, Statistical theory of nuclear reactions. Evaporation probability and cross sections for specific reactions.
[16 hours]

Optical model: Giant resonances, Kapur-Pearls' dispersion formula for potential scattering. Direct reactions: Kinematics of stripping and pickup reactions. Theory of stripping and pickup reactions. Inverse reactions.

Heavy ion physics: Special features of heavy ion Physics. Remote heavy ion electromagnetic interactions. Coulomb excitations. Close encounters.

Heavy ion scattering. Grazing interactions. Particle transfer. Direct and head on collisions, compound nucleus and quasi molecule formation. **[16 hours]**

Total work load **48 hours**

References:

1. Roy R.R. and Nigam B.P., Nuclear physics—Theory and experiment, New Age International Ltd, New Delhi, 1986.
2. Hans H.S., Nuclear physics—Experimental and theoretical, New Age International Publishers 2001.
3. Sachtler G.R., Nuclear reactions, Addison Wesley, New York, 1983.
4. Mermier P. and Sheldon E., Physics of nuclei and particles, Vol. 2 Academic Press, USA, 1971.
5. Jackson D.F., Nuclear reactions, Chapman and Hall, London, 1975
6. Mermier P. and Sheldon E., Physics of nuclei and particles, Vol. 3 Academic Press, USA, 1971.

PHY-405: Theoretical Physics 2

Course Outcome:

After completing this course the student will

CO1. Tackle a wide range of topics using powerful analytical tools including formal methods in classical and quantum physics

CO2. Clearly communicate information and conclusions in written and verbal formats on ideas in Theoretical Physics

CO3. Evaluate complex problems and formulate solutions, indentifying the role of theory, hypothesis and experiment in the scientific method

CO4. Apply computation to solve the problems in theoretical physics

CO5. Plan, carry out and report theoretical physics based investigation

CO6. Apply classical and quantum theoretical techniques in research

Relativistic quantum mechanics: Probability conservation in relativistic quantum mechanics, The Dirac equation, Conserved current, Representation independence, large and small components, approximate Hamiltonian for an electrostatic problem, free particle solutions, Relativistic covariance, Space inversion, Bilinear covariants and their properties, Klein's paradox, Hole theory and charge conjugation. **[16 hours]**

Quantization of the Dirac field: Second quantization, positron operators and positron spinors, Electromagnetic and Yukawa couplings. Weak interactions and parity nonconservation: Classification of interactions, parity and hyperon decay, Fermi theory of beta decay, the two-component neutrino. Pion decay and the CPT theorem. **[16 hours]**

Covariant perturbation theory: Natural units and dimensions, S-matrix expansion in the Interaction representation. Unitarity, First order processes: Matrix element for electron scattering. Cross section for Mott scattering. Helicity change and spin projection operator. Pair annihilation, pair creation, hyperon decay. S - matrix for two photon annihilation, electron propagator, Matrix element for Compton scattering, Feynman rules. Cross section for two photon annihilation. **[16 hours]**

Total work load **48hours**

References:

1. Sakurai J.J., Advanced quantum mechanics, Addison-Wesley, Harlow, England, First ISE Reprint, 1999.
2. Griffiths D., Introduction to elementary particles, John Wiley and Sons, New York, 1987.
3. Gasiorowicz S., Elementary particle physics, John-Wiley, New York, 1966.
4. Muirhead H., The physics of elementary particles, Pergamon Press, London, 1965.

PHY-406: Theoretical Physics 3

Course Outcome:

After completing this course the student will

CO1. Tackle a wide range of topics using powerful analytical tools including formal methods in classical and quantum physics

CO2. Clearly communicate information and conclusions in written and verbal formats on ideas in Theoretical Physics

CO3. Evaluate complex problems and formulate solutions, indentifying the role of theory, hypothesis and experiment in the scientific method

CO4. Apply computation to solve the problems in theoretical physics

CO5. Plan, carry out and report theoretical physics based investigation

CO6. Apply classical and quantum theoretical techniques in research

Angular momentum theory and applications: Angular momentum: Transformations under rotations. Coupling of three and four angular momenta. Racah coefficients, Wigner 9j symbols, applications. Wigner-Eckart theorem. Projection theorem. j-j and L-S coupling. Angular momentum in nuclear reactions, Spherical tensors. Evaluation of matrix elements between coupled angular momentum states. Vector spherical harmonics. Gradient theorem (without proof). Multipole radiation. **[16 hours]**

Spin density matrix: Spin and helicity in a relativistic process. Effect of Lorentz and discrete transformations on helicity states. Wick and Wigner rotations, pure rotation, pure boost, parity, time reversal and charge conjugation. The spin density matrix (ρ), general properties, multipole parameters, combined systems, Diagonalization of ρ. Oriented and non-oriented systems, Polarized and aligned systems, Spherical tensor basis and SU(N) basis. **[16 hours]**

Relativistic density matrix: Helicity multipole parameters and their transformation laws. Helicity amplitudes for elastic reactions and their symmetry properties. Polarization in scattering of spin ½ particles, Final state density matrix. Observables of a reaction, reactions involving polarized beam and polarized targets. **[16 hours]**

Total work load **48 hours**

References:

1. Sakurai J.J. and Tuan S.F. (Editor), Modern quantum mechanics, AddisonWesley, India, 1999.
2. Leader E., Spin in particle physics, Cambridge University Press, London, 2001.
3. Rose M.E., Elementary theory of angular momentum, John Wiley and Sons, USA, 1957.
4. Blum K., Density matrix theory and applications, Plenum Press, New York, 1981.

Elective Papers 1

PHD 270: Accelerator Physics

Course Outcome:

After completing this course the student will

CO1. Know about different types of ion sources and their working.
CO2. Learn ion optics and focussing.
CO3. Know about different particle accelerators.
CO4. Get theory behind electron accelerator.

Ion sources: Brief introduction to ion sources for positive and negative ions. Ion production. Semi classical treatment of ionization, Townsend theory-comparison of theory and experiment for ion production. Examples of ion sources-properties of ion sources. Insulation at high voltages-Spark voltage. Paschen's law for gas breakdown.
Ion optics and focussing: Focussing properties of linear fields. Electrostatic and magnetic lenses. **[16 hours]**
Particle accelerators: Introduction, development of accelerators. Direct-voltage accelerators: Cockroft-Walton generator, Van de Graff generator, Tandem accelerators, Pelletron. Resonance accelerators: Cyclotron - fixed and variable energy, principles and longitudinal dynamics of the uniform field cyclotron. Linear accelerators. **[16 hours]**
Electron accelerators: Betatron; Beam focusing and Betatron Oscillation. Microtron. Synchronous accelerators; Principle of phase stability, Mathematical theory for Principle of phase stability. Electron synchrotron. Proton synchrotron.
Alternating gradient machines; Alternating gradient principle, AG proton synchrotron. **[16 hours]**

Total work load **48 hours**

References:

1. Townsend P.D., Kelly J.C. and Hartley N.E.W., Ion implantation, sputtering and their applications, Academic Press, London, 1976.
2. Humphrey S. Jr., Principles of charged particle acceleration, John Wiley, 1986.
3. Arya A.P., Fundamentals of nuclear physics, Allyn and Bacon, USA, 1968.
4. Ghoshal S.N., Atomic and nuclear physics, Vol. 2, S.Chand and Company, Delhi, 1994.
5. Varier K.M., Joseph A. and Pradyumnan P.P., Advanced experimental techniques in modern physics, Pragathi Prakashan, Meerut, 2006.

PHY-408: Liquid Crystals

Course Outcome:

After completing this course the student will

CO1. Be familiars with the fundamentals of anisotropic fluids.
CO2. Understand the principles of Long and short range order in nematics.
CO3. Learn static distortion in nematics, defects and textures in nematics
CO4. Know about Dynamical properties of liquid crystals and nematics.
CO5. Study Optical properties of Cholesterics.

Anisotropic fluids: Main Types and properties: Introduction. The building blocks. Small organic molecules. Long helical rods. Associated structures. Nematics and Cholesterics. Nematics proper. Static pretransitional effects above T_{N-1}^{i}. The cholesterics. A distorted form of the nematic phase. Smectic. Smectic A. Smectic B. Smectic C. Other mesomorphic phases. Exotic smectics; long range order in a system of long rods. Lyotropic systems. Remarkable features of liquid crystals. Applications of liquid crystals. [**De Gennes and Prost**] **[16 hours]**

Long and short range order in nematics: Definition of an order parameter. Microscopic approach. Order parameter from optical method, from diamagnetic anisotropy. Mean field theory with S2 interaction (Maier-Saupe).

Static distortion in nematics: Long range distortions, distortion free energy. Magnetic field effects—Molecular diamagnetism, Magnetic coherence length.

Defects and textures in nematics: Observations. Black filaments. Schlieren structures. Types of defects (qualitative discussion only).

Smectics: Continuum description of smectics A and C, Mean field description of S_A-N transition.
[**De Gennes and Prost**] **[16 hours]**

Dynamical properties of nematics: Experiments measuring the Leslie coefficients-Laminar flow under a strong orienting field, Attenuation of ultrasonic shear waves, Laminar flow in the absence of external fields. Convective instabilities under electric fields. Basic electrical parameters, Experimental observations at low frequencies, The Helfrich interpretation. Extension to higher frequencies (qualitative).

Cholesterics: Optical properties of an ideal helix—The planar texture, Bragg reflection, Transmission properties at arbitrary wavelengths (normal incidence), The Mauguin limit, Rotatory Power. Agents influencing the pitch—Physicochemical factors, External fields (qualitative). Textures in cholesterics. [**De Gennes and Prost**]
[16 hours]

Total work load **48 hours**

References:

1. De Gennes P.G. and Prost J., The physics of liquid crystals, 2nd Edn., Clarendon Press, Oxford, 1998.
2. Chandrashekhar S., Liquid crystals, Cambridge University Press, 1977.
3. Gray G.W., Molecular structure and the properties of liquid crystals, Academic Press, 1962.
4. Maier G., Sackmann E. and Grabmanier I.G., Applications of liquid crystals, Springer Verlag, 1975.
5. Gray G.W. and Goodby J.W., Smectic liquid crystals (Textures and structures), Leanard Hill, London, 1984.

PHY-409: Atmospheric Physics

Course Outcome:

After completing this course the student will

CO1. Understand the composition of atmosphere and its different layers.
CO2. Get on the thermodynamics of the atmosphere.
CO3. Learn on terrestrial radiations and its effects on atmosphere.
CO4. Understand on aerosols, clouds and atmospheric radioactivity.
CO5. Understand working of atmospheric electricity.

Atmospheric composition: Energy in the atmosphere, heating of the atmosphere, motions in the atmosphere. Variations in atmospheric composition, Structure on the basis of composition. Thermal structure of the atmosphere.

Thermodynamics: Entropy of dry air, vertical motion of saturated air, tephigram, potential energy of an air column.

Dynamics: Escape of hydrogen, photodissociation of oxygen, photo chemical processes. Equations of motion, the geostrophic approximation, cyclostrophic motion. **[16 hours]**

Terrestrial and extra terrestrial radiation: General features of direct, diffuse and global radiation-attenuation of direct solar radiation-Rayleigh and Mie scattering. Angstrom turbidity formula for all aerosols. Direct transmittance due to continuum attenuation, diffuse spectral irradiance due to Rayleigh and aerosol scattering.

Aerosols: Production and properties of aerosols. Aerosol optical depth, Beer's law - Sun Photometer. Optical filters.

Clouds: Microphysics of clouds, Macro characterization of clouds. Radiative transfer in clouds and aerosols.
[16 hours]

Atmospheric radioactivity: Background Radiation, Radioactivity in Atmosphere, Radon, Properties of radon, Origin of radon, Radon entry into the atmosphere: Diffusion, Advection and Convection. Health Effects: Dose.

Atmospheric electricity: The generation of an ion, The mobility of ions, Ion size, recombination of ions. Ions in an electric field, Ionizing agencies, radioactivity. The conductivity of the atmosphere and its origin, Measurement of conductivity of the atmosphere near the ground. Relationship between ions and conductivity. The current voltage characteristics in a gas under conditions of volume ionization. **[16 hours]**

Total work load **48 hours**

References:

1. Salby M.L., Fundamentals of atmospheric physics, Academic Press, USA, 2006.
2. Houghton J., The physics of the atmosphere, Cambridge University Press, 2002.
3. Siddhartha K., Atmosphere, weather and climate, Kisalaya Publications, 2000.
4. Lutgens F.K. and Tarbuk E.K., The atmosphere: An introduction to meteorology, Prentice Hall USA, 1986.
5. Holton, J.R., Dynamic meteorology, 3rd edition, Academic Press, USA, 1992.
6. Keshvamurthy R.N. and Shankar Rao M., The physics of monsoons, Allied Publishers, 1992.
7. Iqbal M., An introduction to solar radiation, Academic Press, USA, 1983.
8. Wilkening M., Radon in the environment, Elsevier Science Publishers, The Netherlands, 1990.
9. Israel H., Atmospheric electricity-Vol II, Israel Program for Scientific Translations, Jerusalem. 1973.

PHY-410: Numerical Methods

Course Outcome:

After completing this course the student will

CO1. Understand Computer arithmetic in solving the problems.

CO2. Learn Iterative methods like Bisection method, Newton-Raphson method, Secant method.

CO3. Solve Linear algebraic equations by numerical techniques like the Gausselimination method.

CO4. Learn numerical Interpolations, Least-squares approximation of functions.

CO5. Learn different techniques of Numerical integration

CO6. Solve Numerical solution of differential equations

Computer arithmetic: Integers; Floating point representation of numbers; Arithmetic operations with normalisation; Errors in representation; Commonly used number types and their limits like max. and min. integer, float, double precision, long, etc.

Iterative methods: Bisection method, Newton-Raphson method, Secant method, the method of successive approximations. Solution of a polynomial equation. **[16 hours]**

Linear algebraic equations: The Gauss elimination method, LU decomposition method, Gauss-Jordon method, An introduction to the solution of simultaneous non-linear equations.

Interpolations: Introduction, Newton interpolation formulae, extrapolation, Lagrange interpolation. spline interpolation.

Least-squares approximation of functions: Introduction, linear regression, algorithm for linear regression. Polynomial regression, fitting exponential and trigonometric functions. **[16 hours]**

Numerical integration. Trapezoidal method, Simpson rule. Errors in integration formulae (Romberg method). Algorithms for integration of a tabulated function. Algorithms for integrating a known function. Gaussian quadrature formulae.

Numerical solution of differential equations: Euler method, Runge - Kutta methods, Runge - Kutta 4th order formulae, predictor - corrector method. comparison of predictor-corrector and Runge- Kutta methods.
[16 hours]

Total work load **48 hours**

References:

1. Atkinson K.E., An introduction to numerical analysis, John Wiley and Sons, USA, 1988.
2. Press W.H., Flannery B.P., Teukolsky S.A. and Vetterling W.T., Numerical recipes in C, Cambridge University Press, UK, 1989.
3. Krishnamurthy E.V. and Sen S.K, Numerical algorithms, Affiliated East West Press Pvt. Ltd., India, 1993.
4. Rajaraman V., Computer oriented numerical methods, Prentice Hall of India Pvt. Ltd., India,m 2001.

Elective Papers 2

PHY-411: Nuclear Spectroscopy Methods

Course Outcome:

After completing this course the student will

CO1. Understand Ion implantation and backscattering spectroscopy

CO2. Study Compton scattering

CO3. Know about Positron annihilation spectroscopy

CO4. Understand Experimental methods of positron annihilation spectroscopy

Ion implantation and backscattering spectroscopy: Ion implantation, Implantation technique, Ion beam diffusion, Thermal annealing and sputtering, Analysis techniques. Backscattering, Energy loss and straggling. Kinematics factor, differential scattering cross sections, depth scale, backscattering yield, instrumentation. Application to elemental and compound targets. Axial and planar half angles. Estimates of minimum yield. Lattice location of impurities, alignment procedures. Ion induced X-rays. Application of ion implantation. **[16 hours]**

Compton scattering: Compton scattering from free electrons. Effects of external potential. Klein-Nishina cross sections for polarized and unpolarized radiation. Compton profiles, momentum distributions and impulse Compton profiles. Calculation of Compton profiles for electron models. Relativistic profile corrections: experimentation. Discussion of methodology including sources, detectors and geometry. Data accumulation, analysis and multiple scattering corrections. Discussion of experimental results for some simple metals, ionic and covalent crystals. **[16 hours]**

Positron annihilation spectroscopy: The positron and its discovery, Positronium, its characteristics, formation. Spur model and Ore gap model of positronium formation. Quenching and enhancement. Theory of 2-gamma and 3-gamma annihilations. Positron and positronium states in solids: trapping of positrons. Two state trapping model.

Experimental methods of positron annihilation spectroscopy: Positron lifetime techniques (PLT), Angular Correlation of Annihilation Radiation (ACAR), Doppler broadening (DB) and Coincidence DB. Methods of data analysis: PLT and ACAR. Experimental results of some metals and defected materials. Interpretation of the experimental results. PAS in the study of polymers. Multiparameter techniques. A brief mention of slow positron beams. **[16 hours]**

Tutorial **[32 hours]**

References:

1. Townsend P.D., Kelly J.C. and Hartley N.E.W., Ion implantation, sputtering and their applications, Academic Press, London, 1976.
2. ChuW.K., Mayer J.W. and Nicholate Mar A.O., Backscattering spectroscopy, Academic Press, New York, 1978.
3. Mayer J.W. and Rimini B. (Eds.), Ion beam handbook for material analysis, Academic Press, 1977.
4. Williams B. (Ed.), Compton scattering, McGraw-Hill, New York, 1977.
5. Hautojarvi P. (Ed.), Positrons in solids, Springer Verlag, New York, 1979.
6. Fava R.A. (Ed.), Methods of experimental physics, Academic Press, New York, 1980.
7. Schradev D.M. and Jean Y.C., Positron and positronium chemistry, Elsevier Science Publication, Amsterdam, 1988.
8. Jayaram B., Mass spectrometry–Theory and applications, Plenum Press, New York, 1966.

PHY-412: Modern Optics

Course Outcome:

After completing this course the student will

CO1. Understand the phenomenon of polarization of light using quantum mechanics
CO2. Familiar with Non linear Optics
CO3. Understand Pancharatnam phase inQuantum features of radiation field.
CO4. Learn the concept of Radiation Field Quantization.
CO5. Understand Squeezed states of light.

Polarization of light: Pure states and mixed states. Density operator, properties and equation of motion. Polarization of light, states of polarized light, Jones matrices, Jones formalism, Stokes parameters, Poincar´e sphere, Mueller matrices and Mueller formalism, Mueller matrices and their characterization, Few illustrative examples; comparison of Jones and Mueller formalisms. Pancharatnam phase, dynamical phase, cyclic evolution of polarization state on Poincar´e sphere; Applications of the concept of Pancharatnam phase. **[16 hours]**

Quantum features of radiation field: Planck's law of radiation and Einstein coefficients, Thermal equilibrium, Semi-classical theory of two level atoms, quantum theory of B coefficient, Optical resonance, damping, Theory of chaotic light, coherence, temporal, spatial, mutual coherence, line broadening, natural and Doppler width, collision broadening. **[16 hours]**

Quantized radiation field: Quantization of radiation field, States of radiation field; Fock states and phase eigenstates; Interaction of radiation with matter, theory of spontaneous emission; Coherent states and their properties, BCH formula, P, Q and Wigner distribution functions, Squeezed states of light and their properties; applications. Correlation functions, Brown-Twiss correlations. **[16 hours]**

Tutorial **[32 hours]**

References:

1. Loudon R., The quantum theory of light, Clarendon Press, Oxford, 1973.
2. Mandel L. and Wolf E., Optical coherence and quantum optics, Cambridge University Press, 1995.
3. Louisell W.H., Quantum statistical properties of radiation, John Wiley and Sons, New York, 1973.
4. Blum K., Density matrix theory and applications, Plenum Press, New York, 1981.
5. Pancharatnam S., Collected works, Oxford University Press, 1975.

PHD 280: Electronics

Course Outcome:

After completing this course the student will

CO1. Learn analyzing digital and analog devices and circuits.
CO2. Analyze components associated with digital and analog electronic systems.
CO3. Demonstrate proficiency in the use of electronic equipment and devices.
CO4. Assist in the design, operation, and troubleshooting of electronic systems.
CO5. Analyze electronics devices and circuits using computer simulations.
CO6. Solve electronic devices and systems using mathematical concepts.

BJT AC Analysis: Amplification in AC domain. BJT transistor modeling, common emitter voltage divider bias configuration. Emitter follower configuration. Darlington connection. Hybrid equivalent model, Approximate Hybrid equivalent circuit ; Voltage divider configuration, Complete hybrid equivalent model.
Feedback and Oscillator Circuit: Feedback concept, Feedback connections types, Practical feedback circuits. Feedback amplifier; Phase and frequency considerations. Oscillator operation, Phase - shift Oscillator, Wien-bridge Oscillator, Crystal Oscillator—BJT version.
FET amplifiers: JFET small signal model, Biasing of FET, Common drain, common gate configurations, FET amplifier and its frequency response. MOSFET – types and E – MOSFET Voltage divider configurations **(Boylestad and Nashelsky)** **[16 hours]**

Operational amplifiers: Concepts of differential amplifier, Ideal op-amp, op-amp parameters, ideal voltage transfer curve, open loop and closed op-amp configurations, inverting amplifier, non inverting amplifier, limitations of open loop op-amp configurations.
Operational amplifier applications: Summing, scaling and averaging amplifiers, voltage to current converter with grounded load, current to voltage converter, integrator, differentiator,. V to I and I to V converters, Log and antilog amplifiers, Wave form generators, phase shift oscillator, Wein bridge oscillator. Non-linear circuit applications: Crossing detectors, 555 timer as a mono-stable and astable multivibrators, Active Filters—First and second order Low pass and High pass filters, Butterworth filters **(Gaekwad R.A)** **[16 hours]**
Digital electronics: Boolean Laws and Theorems, addition and subtraction based on 1's and 2's complements, Families of gates, RS and JK flip-flops, The Master-Slave JK Flip-Flop, D and T flipflops. Karnaugh maps for 3 and 4 variables, Decoders-BCD decoders, Encoders.
Combinational logic circuits: Shift registers-series, series in-series out and parallel in parallel out. Half and full adders, Registers, Counters - Binary Ripple Counters, Synchronous Binary counters, Counters based on Shift Registers, Synchronous counters, Synchronous Mod-6 Counter using clocked JK Flip-Flops. Synchronous Mod-6 Counter using clocked D, T, or SR Flip-Flops. Memory cells, memory registers **16 hours]**

Tutorial **[32 hours]**

References:

1. Boylestad R.L. and Nashelsky L., Electronic devices and circuit theory, 4th Edn., Pearson Education, 2006.
2. Bell D.A., Operational amplifiers and linear circuits, 2nd Edn., Pearson Education, 2004.
3. Gayakwad R.A., Operational amplifiers and linear integrated circuits, Prentice-Hall of India, New Delhi, 1993.
4. Malvino A.P. and Leach D.P., Digital principles and applications, 4th Edn., Tata McGraw Hill, 1988.
5. Arivazhagan S. and Salivahananan S., Digital circuits and design, Vikash Publishing House Pvt. Ltd.New Delhi, 2001.
6. Op-amps and linear integrated circuits, ramakanth A Gaekwad, 3rd edition,Pearson education Asia, 2002
7. Linear ICs and applications Uday A Bakshi & Atul P Godse, Technical Publications
8. Linear integrated Circuits, Roy & Choudary
9. Digital fundamentals, Thomos L Floyd

PHY-414: Minor Project

Course Outcome:

After completing this course the student will have

CO1. Hands on experience to various experimental Techniques
CO2. Research exposure to Physics experiments.
CO3. Knowledge on construction of electronic circuits for various application.
CO4. Data analysis techniques and plotting of experimental results.

PHD 090: Nuclear and Particle Physics Lab

*For those who have completed **Condensed Matter Physics Lab PHY311***

Course Outcome:

After completing this course the student will

CO1. Be familiar with theoretical concepts & experimental techniques of Nuclear &particle Physics,.
CO2. Be able to make quantitative estimates of phenomena in elementary particles
CO3. Understand stability of the nucleus, nuclear forces, interactions and nuclear models; critically assess applications of nuclear technology.
CO4. Acquire Theoretical and practical experience in the scattering experiments and gamma-ray spectroscopy.
CO5. Be able to realise the Nuclear Electronic circuits

*For those who have completed **Condensed Matter Physics Lab PHY311***

Any eight of the following experiments:

1. Half-life of Indium-116 measurement.
2. Energy Resolution of a NaI(TI) scintillation spectrometer.
3. Compton scattering determination of the rest energy of an electron.
4. Beta absorption coefficient measurement.
5. Dekatron as a counter of signals.
6. Gamma-ray absorption coefficient measurement.
7. End-point energy of beta particles by half thickness measurement.
8. Common source amplifier.
9. Astable multivibrator using timer IC 555.
10. Dead time of the G.M. counter.

Total work load : 2 day(s) per week × 4 hours × 16 weeks = **128 hours**

PHD 080: Condensed Matter Physics Lab

*For those who have completed **Nuclear Physics Lab PHY 312***

Course Outcome:

After completing this course the student will

CO1. Independently collect single crystal XRD data and evaluate the crystal structure,
CO2. Analyse Diffraction data and their suitability for single crystal structure.
CO3. Independently work on raw diffraction data and Solve and refine crystal data
CO4. Understand the properties of Condensed Materials such as Structural, Magnetic, Electrical and Semiconducting Properties.
CO5. Acquire theoretical and practical experience in the Condensed Matter Physics

Any eight of the following experiments :

1. Determination of the paramagnetic susceptibility of the given salt by Quincke's method.
2. Study of mercury spectrum by superimposing it on brass spectrum.
3. Sodium spectrum analysis by using Edser-Butler fringes.
4. Temperature coefficient of resistance of a thermistor.
5. Analysis of the powder X-ray photograph of a simple cubic crystal.
6. Thermionic work function of a metal (Richardson-Dushmann formula).
7. Energy gap of semiconductor.
8. Determination of Stefan's constant.
9. Frank Hertz experiment
10. Magnetic hysteresis.
11. Measurement of magneto resistance of semiconductors.

Total work load : 2 day(s) per week × 4 hours × 16 weeks = **128 hours**

PHD 240: Solid State Physics Lab 2

*For those who opted for **Solid State Physics Specialisation***

Course Outcome:

After completing this course the student will

CO1. Be able to make quantitative estimates for phenomena in solid state physics.
CO2. Describe characteristics of thermal and vibrational properties of solids, Compute Band structures
CO3. Compute trajectories in real and reciprocal space, Characterize magnetism
CO4. Characterize intrinsic and doped semiconductors
CO5. Describe superconductivity
CO6. Understand the mechanism and working of semiconductor devices.

Any five of the following experiments:

1. Photovoltaic cell.
2. Photoconductive cell.
3. Hall effect in semiconductors.
4. Determination of the energy gap of semiconductors by four-probe method.
5. Temperature variation of the junction voltage of a p-n diode.
6. Temperature variation of the reverse saturation current in a p-n diode.
7. Depletion capacitance of a junction diode.
8. Determination of material constant of an intrinsic semiconductor.
9. Schottky effect.
10. Ionic conductivity of an alkali halide crystal.
11. Dielectric constant and its temperature variation.
12. Ultrasonic velocity and elastic constants of a solid.
13. Determination of Curie temperature of a magnetic material
14. Magnetic field variation along with axis of the solenoid
15. Magnetic Hysteresis
16. Thermal Diffusivity of Brass
17. Temperature co-efficient of resistance of copper

Total work load: 1 day(s) per week × 4 hours × 16 weeks = **64 hours**

PHD 250: Nuclear Physics Lab 2

For those who opted for ***Nuclear Physics Lab Specialisation***

Course Outcome:

After completing this course the student will

CO1. Be familiar with Concepts of Nuclear Detectors, Pulse techniques, nuclear models, timing spectroscopy and nuclear technology.

CO2. Be familiar with Theoretical and practical experience in the scattering experiments and gamma-ray spectroscopy.

CO3. Learn Instrumentation, development of sensors, detectors, and larger complex instruments.

CO4. Familiarise in Fundamentals of reactor theory and nuclear decay mechanisms

CO5. Learn Accelerator physics, research and development for the next generation of particle accelerators.

Any five of the following experiments:

1. Schmitt trigger.
2. Variable delay line.
3. Pulse recorder.
4. Display devices.
5. Feather analysis: End-point energy of beta rays measurement.
6. Z dependence of external Bremsstrahlung radiation.
7. Fermi-Kurie plot : Determination of the end-point energy of beta rays using a plastic scintillation detector.
8. Determination of the resolving time of a coincidence circuit.
9. Determination of source strength by gamma-gamma coincidence.
10. Determination of source strength by beta-gamma coincidence.
11. Multichannel analyser : Study of the variation of energy resolution as a function of gamma ray energies.
12. Verification of Mosley's law
13. Beta ray absorption studies – relation between —and end point energy.
14. Absorption coefficient of Al using Sr-90 and Y-90 beta sources.

Total work load : 1 day(s) per week × 4 hours × 16 weeks = **64 hours**

PHY-425: Theoretical Physics Lab 2

*For those who opted **Theoretical Physics Lab Specialisation***

Course Outcome:

After completing this course the student will

CO1. Tackle a wide range of topics using powerful analytical tools including formal methods in classical and quantum physics

CO2. Clearly communicate information and conclusions in written and verbal formats on ideas in Theoretical Physics

CO3. Evaluate complex problems and formulate solutions, indentifying the role of theory, hypothesis and experiment in the scientific method

CO4. Apply computation to solve the problems in theoretical physics

CO5. Plan, carry out and report theoretical physics based investigation

CO6. Apply classical and quantum theoretical techniques in research

Any five of the following experiments:

1. Density matrix description of polarization of light.
2. Double scattering of spin-1/2 particles on spin-zero targets.
3. Second order QED processes (Compton scattering).
4. Evolution of matrix elements between coupled angular momentum states.
5. Dirac matrix representations.
6. Algebra of Dirac matrices.
7. Electron-proton scattering, Rosenbluth formula.
8. Relativistic kinematics-3: Study of decay and production processes.
9. Feynman diagrams and calculations.
10. Energy matrix calculation.

Total work load : 1 day(s) per week × 4 hours × 16 weeks = **64 hours**

JSS MAHAVIDHYAPEETHA

JSS COLLEGE OF ARTS COMMERCE & SCIENCE

(Autonomous) Ooty road, Mysore – 25

II and IV Semester Examination May / June 2018

M.Sc PHYSICS Question Paper Pattern

Time:3 Hours **Answer all the questions** **Max. Marks: 70**

SECTION A

1. (a)
(b)
(c) **18 Marks**

OR

2. (a)
(b)
(c) **18 Marks**

SECTION B

3. (a)
(b)
(c) **18 Marks**

OR

4. (a)
(b)
(c) **18 Marks**

SECTION C

5. (a)
(b)
(c) **18 Marks**

OR

6. (a)
(b)
(c) **18 Marks**

SECTION D - (Problems only)

7. **5 Marks**

OR

8. **5 Marks**

9. **6 Marks**

OR

10. **6 Marks**

11. **5 Marks**

OR

12. **5 Marks**