CENTRAL UNIVERSITY OF RAJASTHAN

Department of Physics

Syllabus
for
M. Sc. Physics
Effective from academic session 2011-2013

Central University of Rajasthan
City Road, Madanganj-Kishangarh-305802
Ajmer District

M. Sc. Physics- Detailed Syllabus

PREAMBLE

Physics is one of the oldest academic disciplines. Not only it is fundamental and foremost to all basic natural sciences, it has been significant and influential through advances in its understanding that have translated into new technologies. The story of physics has been one of people who thought outside the box. From Galileo and Newton in the 1600s to Einstein and Feynman in the 20th century, the progress of science in answering fundamental questions about the Nature is rooted in a different way of approaching things — a scientific way to test the validity of a physical theory, using a methodical approach to compare the implications of the theory in question with the associated conclusions drawn from experiments and observations conducted to test it.

The M.Sc. Physics course is a rigorous study program at post graduate level covering both depth and breadth of all relevant areas, and providing substantial research training. It is designed to impart a thorough knowledge of the fundamental principles of the several branches of physics, as mathematically and experimentally demonstrated; and also to execute with their own hands various experiments to have hands-on experience with the tools and methods of physics, not simply with the concepts. The program aims to train future generations of physicists with specialization in one of the frontier areas of research, that is, either in High Energy Physics, or Condensed Matter Physics, or Astrophysics and Cosmology.

The M.Sc. Physics is a post graduate Four Semester Course spanning over two years duration.

ELIGIBILITY:

A candidate who has secured more than 50% or CGPA of 3.0 in the UGC Seven Point scale [45% or CGPA 2.5 in the UGC Seven Point Scale for SC/ST] or equivalent in the Bachelor degree in Science with Physics as Major Subject.

ADMISSIONS:

The admission to this program is based on the results of an entrance examination CUCET (to be conducted jointly by Central Universities) at various centers in India. 15% weightage will be given for the performances of the students at senior secondary level and 85% weightage is for the performance at the entrance examination.

Syllabus of M.Sc. Physics

The details of the courses with code, title and the credits assigned are given below.

Abbreviations Used

Course Category

CCC: Compulsory Core Course
ECC: Elective Core Course
OEC: Open Elective Course
SC: Supportive Course
STP: Summer Training Programme
PRJ: Project Work

Contact Hours
L: Lecture
T: Tutorial
P: Practical or Other
Relative Weights
IA: Internal Assessment (Attendance/Classroom Participation/Quiz/Home Assignment etc.)
ST: Sessional Test
EoSE: End of Semester Examination

First Semester

S. No.	Subject Code	Course Title	Course Category	Credit	Contact Hours Per week			EoSE Duration (Hrs.)		Relative Weights %		
					L	T	P	Thy	P	IA	STs	EoSE
1.	PHY 101	Classical Mechanics	CCC	**4**	3	1	0	3	0	20	30	50
2.	PHY 102	Quantum Mechanics	CCC	**4**	3	1	0	3	0	20	30	50
3.	PHY 103	Classical Electrodynamics	CCC	**4**	3	1	0	3	0	20	30	50
4.	PHY 104	Mathematical Methods in Physics	CCC	**4**	3	1	0	3	0	20	30	50
5.	PHY 105	Physics Lab –I (Ten Experiments)	CCC	**3**	0	0	6	0	4	20	30	50
6.	PHY 106	Computational Physics Lab-I	CCC	**3**	0	0	6	0	4	20	30	50
7.	PHY 107	Dynamics of Communication Skills	SC	**2**	0	0	3	0	1	50		50
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Second Semester

S. No.	Subject Code	Course Title	Course Category	Credit	Contact Hours Per week			EoSE Duration (Hrs.)		Relative Weights %		
					L	T	P	Thy	P	IA	STs	EoSE
1.	PHY 201	Statistical Mechanics	CCC	**4**	3	1	0	3	0	20	30	50
2.	PHY 202	Atomic and Molecular Physics	CCC	**4**	3	1	0	3	0	20	30	50
3.	PHY 203	Advance Quantum Mechanics	CCC	**4**	3	1	0	3	0	20	30	50
4.	PHY 204	Elective -1	OEC/ ECC	**4**	3	1	0	3	0	20	30	50
5.	PHY 205	Physics Lab –II (Ten Experiments)	CCC	**3**	0	0	6	0	4	20	30	50
6.	PHY 206	Computational Physics Lab-II	CCC	**3**	0	0	6	0	4	20	30	50
7.	PHY 207	Summer Training Programme (Min. 3 weeks after II Semester EOSE)	STP	**2**	0	0	20	0	1	50	0	50
				24								

Third Semester

S. No.	Subject Code	Course Title	Course Category	Credit	Contact Hours Per week			EoSE Duration (Hrs.)		Relative Weights %		
					L	T	P	Thy	P	IA	STs	EoSE
1.	PHY 301	Relativistic Quantum Mechanics and Particle Physics	CCC	**4**	3	1	0	3	0	20	30	50
2.	PHY 302	Nuclear Physics	CCC	**4**	3	1	0	3	0	20	30	50
3.	PHY 303	Solid State Physics	CCC	**4**	3	1	0	3	0	20	30	50
4.	PHY 304	Elective-2	ECC	**4**	3	1	0	3	0	20	30	50
5.	PHY 305	Elective-3	ECC	**4**	3	1	0	3	0	20	30	50
6.	PHY 306	Physics Lab –III (Ten Experiments)	CCC	**4**	0	0	8	0	4	20	30	50
				24								

Fourth Semester

S. No.	Subject Code	Course Title	Course Category	Credit	Contact Hours Per week			EoSE Duration (Hrs.)		Relative Weights %		
					L	T	P	Thy	P	IA	STs	EoSE
1.	PHY 401	Elective-4	ECC	**4**	3	1	0	3	0	20	30	50
2.	PHY 402	Elective-5	ECC	**4**	3	1	0	3	0	20	30	50
3.	PHY 403	Elective-6	ECC	**4**	3	1	0	3	0	20	30	50
4.	PHY 404	Project Work at University/ Academic/ Research Institution	PRJ	**8**	0	0	16	0	0	100	0	0
5..	PHY 405	Presentation of Project Work	PRJ	**4**	0	0	8	0	1	0	0	100
				24								

<u>Elective Core Courses:</u>

Elective 1

1. Open Elective
2. Electronics and Instrumentation
3. Advance Mathematical Methods
4. Advance Classical Electrodynamics

Elective 2

1. Quantum Field Theory

2. Advance Statistical Mechanics

3. Advance Properties of Matter

Elective 3, Elective4, Elective 5, Elective 6 from following Specialization Clusters or Electives Available at the Academic/Research Institution if the Project Work is taken at another academic/research institution.

A. AC: Astrophysics and Cosmology
B. CMP: Condensed Matter Physics
C. HEP: High Energy Physics
D. ON: Open Advance Physics Electives

PHY 101: CLASSICAL MECHANICS

1. Constraints, holonomic and non-holonomic constraints, D'Alembert's Principle and Lagrange's Equation, velocity dependent potentials, simple applications of Lagrangian formulation. Hamilton Principle, Calculus of Variations, Derivation of Lagrange's equation from Hamilton's principle. Extension of Hamilton's Principle for nonconservative and nonholonomic systems, Method of Lagrange's multipliers, Conservation theorems and Symmetry Properties, Noether's theorem. Conservation of energy, linear momentum and angular momentum as a consequence of homogeneity of time and space and isotropy of space.
2. Generalized momentum, Legendre transformation and the Hamilton's Equations of Motion, simple applications of Hamiltonian formulation, cyclic coordinates, Routh's procedure, Hamiltonian Formulation of Relativistic Mechanics, Derivation of Hamilton's canonical Equation from Hamilton's variational principle. The principle of least action.
3. Canonical transformation, integral invariant of Poincare: Lagrange's and Poisson brackets as canonical invariants, equation of motion in Poisson bracket formulation. Infinitesimal contact transformation and generators of symmetry, Liouvilee's theorem, Hamilton-Jacobi equation and its application.
4. Action angle variable adiabatic invariance of action variable: The Kepler problem in action angle variables, theory of small oscillation in Lagrangian formulation, normal coordinates and its applications. Orthogonal transformation, Euler's theorem, Eigenvalues of the inertia tensor, Euler equations, force free motion of a rigid body.

Reference Books:

1. Herbert Goldstein, Charles Poole, John Safko, Classical Mechanics, Perason Education
2. L.D. Landau and E.M. Lifshitz, Mechanics, Butterworth-Heinemann
3. A. Raychoudhary, Classical Mechanics, Oxford University Press
4. N. C. Rana and P. S. Joag Classical Mechanics, Tata McGraw Hill.
5. Ronald L. Greene, Classical Mechanics with Maple, Springer

PHY 102: QUANTUM MECHANICS- I

Linear spaces and Operators : Vector spaces, Linear independence, Bases, dimensionality, isomorphisms. Linear transformations, inverses, matrices, similarity transformations, Eigenvalues and Eigenvectors. Inner product, orthogonality and completeness, complete orthogonal set, Gramm-Schmidt orthogonalization procedure, Eigenvalues and Eigenvectors of Hermitian and Unitary transformations, diagonalization. Function space and Hilbert space. Complete orthonormal sets of functions.

Structure of Quantum mechanics: Postulates of QM, Hilbert space;Hermitian and unitary operators; Orthonormality, completeness andclosure. Dirac's bra and ket notation. Matrix Representation and change of basis. Operators and observables, significance of eigenvector and eigenvalues, Commutation relation; Uncertianity principle for two arbitrary Operators.

Measurement in quantum mechanics, Double Stren-Gerlach experiment for spin 1/2 system. Expectation values, time dependence of quantum mechanical amplitude, observable with no classical analogue, super position of amplitudes, identical particles. Hamiltonian matrix and the time evolution of Quantum mechanical States, time independent perturbation of an arbitrary system, simple matrix examples of time independent perturbation, energy given states of a two state system, diagonalizing of energy matrix, time independent perturbation of two state system the perturbative solution. Ammonia molecule as an example of two state system, weak field and strong field cases, general description of two state system, Pauli matrices.

Three dimensional problem in Spherical Polar coordinate. Hydrogen Atom. Orbital
angular momentum, angular momentum algebra, raising and lowering operators, Matrix representation for $j = 1/2$ and $j = 1$; spin; addition of two angular momentum, Clebsch-Gordan coefficients.

Reference Books:

1. Ashok Das and A.C. Melissions, Quantum Mechanics - A Modern Approach, Gordon and Breach Science Publishers.
2. P.A.M. Dirac, Lectures on Quantum Mechanics, Dover Publications.
3. R.Shankar, Principles of Quantum Mechanics, Springer.
4. Albert Messiah, Quantum Mechanics, Dover Publications
5. L.I. Schiff, Quantum Mechanics, Mc-Graw Hill.
6. Claude Cohen-Tannoudji, Bernard Diu, Frank Laloe, Quantum Mechanics, Wiley
7. J.J. Sakurai, Modern Quantum Mechanics, Pearson Education.
8. E. Merzbecher: Quantum Mechanics, John Wiley.

PHY 103: CLASSICAL ELECTRODYNAMICS

1. Electrostatics: Electric field, Gauss Law, Differential form of Gaussian law. Another equation of electrostatics and the scalar potential, surface distribution of charges and dipoles and discontinuities in the electric field and potential, Poisson and Laplace equations, Green's Theorem, Uniqueness of the solution with the Dirichlet or Neumann boundary Conditions, Formal Solutions of electrostatic Boundary value problem with Green's function, Electrostatic potential energy and energy density, capacitance.

   Boundary Value Problems in Electrostatics: Methods of Images, Point charge in the presence of a grounded conducting sphere, point charge in the presence of a charged insulated conducting sphere, point charge near a conducting sphere at a fixed potential, conducting sphere in a uniform electric field by method of images, Green function for the sphere, General solution for the potential, conducting sphere wit hemispheres at a different potentials, orthogonal functions and expansion.

2. Multipoles, electrostatics of Macroscopic Media Dielectric: Multipole expansion, multipole expansion of the energy of a charge distribution in an external field, Elementary treatment of electrostatics with permeable media. Boundary value problems with dielectrics. Molar polarizability and electric susceptibility. Models for molecular polarizability, electrostatic energy in dielectric media.
3. Time varying fields, Maxwell's equations conservation laws:Energy in a magnetic field, vector and scalar potentials, Gauge transformations, Lorentz gauge, coulomb gauge, Green function for the wave equation, Derivation of the equations of Macroscopic Electromagnetism, Poynting's Theorem and conservation of energy and momentum for a system of charged particles and EM fields. Conservation laws for macroscopic media.
4. Lorentz' transformations; Group symmetries of Lorentz' transformations, Electromagnetic field tensor, Relativistic electrodynamics using potential, Four vector formalism, Relativistic energy and momentum, transformation of four potentials and four currents, Relativistic transformations of electro-magnetic fields, Maxwell's equations in covariant form. Invariance of electric charge, covariance of electrodynamics.

Reference Books:

1. J.D. Jackson: Classical Electrodynamics, Wiley
2. David J. Griffiths: Introduction to Electrodynamics, Benjamin Cummings
3. L.D. Landau and E.M. Lifshitz, Classical Theory of Electrodynamics, Addison-Wesley.
4. L.D. Landau and E.M. Lifshitz, Electrodynamics of Continuous Media, Addison-Wesley.
5. Wolfgang K. H. Panofsky and Melba Phillips, Classical Electricity and Magnetism, Dover Publications.

PHY 104: MATHEMATICAL METHOD IN PHYSICS

Tensors: Coordinate transformations, scalars, contravariant and covariant vectors, definition of contravarient, mixed and covariant tensor of second rank, Addition, subtraction and contraction of tensors, quotient rule. Christoffel symbols, transformation of Christoffel symbols, covariant differentiation, Ricci's theorem, divergence, Curl and Laplacian tensor form, Stress and strain tensors, Hook's law in tensor form.

Second Order Differential Equations and Special functions: Separation of variables-ordinary differential equations, singular points, series solutions leading to Legendre, Bessel, Hermite, Laguerre as solutions. Orthogonal properties and recurrence relations of these functions. Spherical harmonics and associated Legendre polynomials. Hermite polynomials. Sturm-Liouville systems and orthogonal polynomials. Wronskian-linear independence and linear dependence.

Complex Variables: Functions of complex variable, Limits and continuity, differentiation, Analytical functions, Cauchy- Riemannn conditions, Cauchy Integral theorem, Cauchy integral formula, Derivatives of analytical functions, Liouville's theorem. Power series Taylor's theorem, Laurent's theorem. Calculus of residues –poles, essential singularities and branch points, residue theorem, Jordan's lemma, singularities on contours of integration, evaluation of definite integrals.

Integral Transforms: Fourier Transforms: Development of the Fourier integral from the Fourier Series, Fourier and inverse Fourier transform: Simple Applications: Finite wave train, Wave train with Gaussian amplitude, Fourier transform of derivatives, solution of wave equation as an application. Convolution theorem. Intensity in terms of spectral density for quasi monochromic EM Waves, Momentum representation, Application of Fourier transform to diffraction theory: diffraction pattern of one and two slits. Laplace transforms and their properties, Laplace transform of derivatives and integrals, derivatives and integral of Laplace transform. Convolution theorem. Impulsive function, Application of Laplace transform in solving linear, differential equations with constant coefficient with variable coefficient and linear partial differential equation.

Reference books:

1. George Arfken, Mathematical Methods for Physicists, Academic Press
2. L. A. Pipe, Applied Mathematics for Engineers and Physicists, McGraw Hill.
3. Merle C. Potter and Jack Goldberg, Mathematical Methods, Prentice Hall of India.
4. Fredrick W. Byron and Robert W. Fuller, Mathematics of Classical and Quantum Physics, Dover Publications.
5. Tulsi Dass and S.K. Sharma, Mathematical Methods in Classical and Quantum Physics, Orient Longman.

PHY 105 Physics Laboratory –I

Student is required to perform atleast 10 out of 12 experiments available in the Laboratory.

PHY 106 Computational Physics Laboratory –I

Short introduction to Programming using C and MatLab, applications based on curriculum of Semester – I , class projects may be implemented in any language.

PHY 201: STATISTICAL MECHANICS

Elementary probability theory : Preliminary concepts, Random walk problem, Binomial distribution, mean values, standard deviation, various moments, Gaussian distribution, Poisson distribution, meanvalues. Probability density, probability for continuous variables.

Extensive and intensive variables, laws of thermodynamics, Legendre transformations and thermodynamic potentials, Maxwell relations, applications of thermodynamics to (a) ideal gas, (b) magnetic material, and (c) dielectric material. The laws of thermodynamics and their consequences.

Statistical description of system of particles : State of a system, microstates, ensemble, basic postulates, behavior of density of states, density of state for ideal gas in classical limit, thermal and mechanical interactions, quasi-static process. Statistical thermodynamics : Irreversibility and attainment of equilibrium, Reversible and irreversible processes. Thermal interaction between macroscopic systems, approach to thermal equilibrium, dependence of density of states on external parameters, Statistical calculation of thermodynamic variables.

Classical statistical mechanics : Microcanonical ensembles and their Equivalence, Canonical and grand canonical ensembles, partition function, thermodynamic variables in terms of partition function and grand partition function, ideal gas, Gibbs paradox, validity of classical approximation, equipartition theorem. Maxwell-Boltzmann gas velocity and speed distribution. Chemical potential, Free energy and connection with thermodynamic variables, First and Second order phase transition; phase equilibrium.

Formulation of quantum statistics, Density Matrix, ensembles in quantum statistical mechanics, simple applications of density matrix. The theory of simple gases : Maxwell-Boltzmann, Bose-Einstein, Fermi-

Dirac gases. Statistics of occupation numbers, Evaluation of partition functions, Ideal gases in the classical limit.
Ideal Bose system : Thermodynamic behavior of an Ideal Bose gas, Bose-Einstein condensation. Thermodynamics of Black body radiation, Stefan-Boltzmann law, Wien's displacement law. Specific heat of solids (Einstein and Debye models). Ideal Fermi System : Thermodynamic behavior of an ideal Fermi gas, degenerate Fermi gas, Fermi energy and mean energy, Fermi temperature, Fermi velocity of a particle of a degenerate gas.

Reference Books:

1. F. Reif, Fundamentals of Statistical and Thermal Physics, McGraw Hill.
2. K. Huang, Statistical Mechanics, John Wiley & Sons.
3. R. K. Pathria, Statistical Mechanics, Pergamon Press.
4. B. B. Laud Fundamentals of Statistical Mechanics, New Age.
5. Mark W. Zemansky and Richard H. Dittman, Heat and Thermodynamics, McGraw Hill.
7. L. D. Landau and E. M. Lifshitz, Statistical Physics, Butterworth-Heinemann.
8. Richard P. Feynman, Statistical Mechanics. Westview Press.

PHY 202 : ATOMIC AND MOLECULAR PHYSICS

Atomic Structure and Atomic Spectra: Rutherford's Model and concept of stability of atom, Bohr's model, Sommerfeld's model, Stern-Gerlach experiment for electron spin, Revision of quantum numbers, exclusion principle, electron configuration, Hund's rule etc. Gross structure of energy spectrum of hydrogen atom. Non degenerate first order perturbation method, relativistic correction to energy levels of an atom, atom in a weak uniform external electric field – first and second order Stark effect, calculation of the polarizability of the ground state of hydrogen atom and of an isotropic harmonic oscillator; degenerate stationary state perturbation theory, linear Stark effect for hydrogen atom levels.
Orbital magnetic dipole moment, spin-orbit interaction energy, Hartree theory, LS coupling, origin of spectral lines, selection rules, some features of one-electron, two-electron spectra and X-ray spectra, fine spectra, hyperfine structure, Zeeman effect. Lamb shift (only qualitative description).

Molecular Structure: The nature of chemical bonds, valence bond approach and molecular orbital approach for molecular bonding (for H_2 molecule). Bonding and antibonding orbitals, pi- bonds, sigma - bonds, different kinds of bonding mechanism, Madelung constant, hybridization, bonding in hydrocarbons.
Molecular spectra: Rotational levels in diatomic and polyatomic molecules, vibrational levels in diatomic and polyatomic molecules, diatomic vibrating rotator, Born-Oppenheimer approximation, symmetry of the molecules and vibrational levels, experimental aspects of vibrational and rotational spectroscopy of molecules, polarization of light and Raman effect, Raman Spectroscopy.
Reference Books:
1. Robert Eisberg and Robert Resnick, Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles, Wiley.
2. H. E. White, Introduction to Atomic Spectra, McGraw Hill.
3. Arthur Beiser, Perspectives of Modern Physics, McGraw Hill.
4. Gerhard Herzberg Molecular Spectra and Molecular Structure, Krieger Pub Co.
5. C. N. Banwell, Fundamentals of Molecular Spectroscopy, Tata McGraw Hill.

PHY 203: QUANTUM MECHANICS- II

Symmetry in Quantum mechanics: Symmetry Operations and Unitary Transformations, conservation principles, space and time translation, rotation, space inversion and time reversal, symmetry and degeneracy.
Identical particles: Meaning of identity and consequences; Symmetric and anti-symmetric wavefunction; incorporation of spin, symmetric and antisymmetric spin
wave function of two identical particles, later determinant, Pauli exclusion principle.
Time Independent Approximation Methods: Non-degenerate perturbation theory, degenerate case, Stark effect, Zeeman effect and other examples, variational methods, WKB method, tunneling.
Time-dependent Perturbation Theory: Interaction Picture;Constant and harmonic perturbations; Fermi Golden rule; Sudden and adiabatic approximations. Beta decay as an example.
Scattering Theory: Differential cross-section, scattering of a wave packet, integral equation for the scattering amplitude, Born approximation, method of partial waves, low energy scattering and bound states, resonance scattering.
Density Matrices: Basic definition and some properties. Pure and Mixed states.

Reference Books:

1. S Flugge, Quantum Mechanics, Springer
2. Claude Cohen-Tannoudji, Bernard Diu, Frank Laloe, Quantum Mechanics, Wiley
3. Albert Messiah, Quantum Mechanics, Dover Publications
4. R.Shankar, Principles of Quantum Mechanics, Springer.
5. L.I. Schiff, Quantum Mechanics, Mc-Graw Hill.
6. J.J. Sakurai, Modern Quantum Mechanics, Pearson Education.
7. E. Merzbecher: Quantum Mechanics, John Wiley.

PHY 204: ELECTIVE-1

Open Elective

PHY 205 Physics Laboratory –II

Student is required to perform atleast 10 out of 12 experiments available in the Laboratory.

PHY 206: Computational Physics Laboratory –II

Numerical methods for solving problems in mechanics, electromagnetism, quantum mechanics, and statistical mechanics. Methods include numerical integration; solutions of ordinary and partial differential equations; solutions of the diffusion equation, Laplace's equation and Poisson's equation with relaxation methods; statistical methods including Monte Carlo techniques; matrix methods and eigenvalue problems. Implementations using C or MatLab or any programming language.