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# OFFICE OF THE
# DEAN OF THE FACULTY OF SCIENCE
## PATNA UNIVERSITY,
## PATNA - 800 005 (INDIA)

Ref. : D.FSc-290 Date : 04.08.2015

## NOTIFICATION

The Board of Courses and Studies for the subject of Physics is constituted with the following members as per decision of the meeting of the Faculty of Science held on 03.08.2015 in the Department of Chemistry, Patna University

**Chairman**

Prof. S.K.Sinha
Head of the Department of Physics, P.U.

**External Members**

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|---|
| 1. Dr. D.K.Sharma<br>Retd. Prof. of Physics, Patna University |
| 2. Dr. Arun Kumar Mishra<br>Head Deptt. of Physics, L.N.M.U., Darbhanga |

**Internal Members**

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|---|
| 1. Dr. A.K.Verma<br>Univ. Professor of Physics, Patna Science College,<br>Patna University. |
| 2. Dr. Dolly Sinha<br>Professor of Physics,<br>Patna University. |
| 3. Dr. R. Raman<br>Professor of Physics,<br>Patna Science College, P.U. |
| 4. Dr. Abha Sharan, Associate Professor of Physics,<br>M.M. College, Patna |
| 5. Dr. Sumita Singh, Senior Lecturer of Physics,<br>Patna University, Patna |
| 6. Dr. Amrendra Narayan, Senior Lecturer of Physics,<br>Patna University, Patna |
| 7. Dr. Shankar Kumar, Senior Lecturer of Physics,<br>Patna University, Patna |

Copy to
Chairman: Prof. S.K. Sinha.
HOD, Physics, P.U.

(Dr. Ram Jatan Sinha)
Dean Faculty of Science,
Patna University, Patna

## DEPARTMENT OF PHYSICS, PATNA UNIVERSITY

## M.Sc. PHYSICS

### (Four Semester Course)

### [Course Structure]

| Semester 1 (July to December) | | | | | |
|---|---|---|---|---|---|
| Code | Subject | Credit | E.S.E. | C.I.A. | Total |
| M-Phy-101 | Classical Mechanics and Electrodynamics | 5 | 70 | 30 | 100 |
| M-Phy -102 | Computational Methods in Physics | 5 | 70 | 30 | 100 |
| M-Phy -103 | Quantum Mechanics I | 5 | 70 | 30 | 100 |
| M-Phy -104 | Practical (Computational Methods) | 5 | 70 | 30 | 100 |

| Semester 2 (January to June) | | | | | |
|---|---|---|---|---|---|
| Code | Subject | Credit | E.S.E. | C.I.A. | Total |
| M-Phy -201 | Mathematical Physics | 5 | 70 | 30 | 100 |
| M-Phy -202 | Quantum Mechanics II | 5 | 70 | 30 | 100 |
| M-Phy -203 | Electronics I | 5 | 70 | 30 | 100 |
| M-Phy -204 | Practical – Core Physics I | 5 | 70 | 30 | 100 |

| Semester 3 (July to December) | | | | | |
|---|---|---|---|---|---|
| Code | Subject | Credit | E.S.E. | C.I.A. | Total |
| M-Phy -301 | Atomic and Molecular Physics | 5 | 70 | 30 | 100 |
| M-Phy -302 | Condensed Matter Physics | 5 | 70 | 30 | 100 |
| M-Phy -303 | Electronics II | 5 | 70 | 30 | 100 |
| M-Phy -304 | Practical – Core Physics II | 5 | 70 | 30 | 100 |

| Semester 4 (January to June) | | | | | |
|---|---|---|---|---|---|
| Code | Subject | Credit | E.S.E. | C.I.A. | Total |
| M-Phy -401 | Thermodynamics and Statistical Mechanics | 5 | 70 | 30 | 100 |
| M-Phy -402 | Nuclear and Particle Physics | 5 | 70 | 30 | 100 |
| M-Phy -403 | **Elective Paper I** | 5 | 70 | 30 | 100 |
| M-Phy -404 | **Elective Paper II**<br>Part 1: Practical - 50 marks<br>Part 2: Dissertation - 50 marks | <br>2.5<br>2.5 | <br>35<br>35 | <br>15<br>15 | <br>50<br>50 |

**DEPARTMENT OF PHYSICS, PATNA UNIVERSITY**

**M.Sc. PHYSICS**

**(Four Semester Course)**

**[Course Structure]**

**Elective – I Code : M-Phy-403**

**Elective theory Papers for Semester 4 (One to be selected from the following set of 10 options).**

| Code | Subject | Credit | E.S.E. | C.I.A. | Total |
|---|---|---|---|---|---|
| **M-Phy-403** | Advanced Quantum Mechanics | **5** | **70** | **30** | **100** |
| | Advanced Condensed Matter Physics | | | | |
| | Atmospheric Physics | | | | |
| | Biophysics | | | | |
| | General Relativity and Cosmology | | | | |
| | Lasers and Photonics | | | | |
| | Measurement and Instrumentation | | | | |
| | Modeling and Simulation in Physics | | | | |
| | Nano Science | | | | |
| | Plasma Physics | | | | |

**Elective – II Code: M-Phy-404**

**Part 1 : Practical on any of the topic from the set of following options.**

**Part 2 : Dissertation - On any topic on Physics**

| Code | | Subject | Credit | Marks | | |
|---|---|---|---|---|---|---|
| | | | | E.S.E. | C.I.A. | Total |
| **Phy-M-404** | **Part 1** | Advanced Quantum Mechanics | **2.5** | **35** | **15** | **50** |
| | | Advanced Condensed Matter Physics | | | | |
| | | Atmospheric Physics | | | | |
| | | Biophysics | | | | |
| | | Lasers and Photonics | | | | |
| | | Measurement and Instrumentation | | | | |
| | | Modeling and Simulation in Physics | | | | |
| | | Nano Science | | | | |
| | | Numerical Computing | | | | |
| | | Plasma Physics | | | | |
| **M-Phy-404** | **Part 2** | **Dissertation** [On any topic on Physics] | **2.5** | **35** | **15** | **50** |

## M.Sc. PHYSICS, PATNA UNIVERSITY

**(Four Semester Course)**
**[Course Structure]**

### Marks and Workload Distribution

There shall be **04** papers; each of **05** credits in each semester. Each paper will be of **100** marks.

**End Semester Examination (ESE)** will carry **70** marks.

**Continuous Internal Assessment (CIA)** will carry **30** marks.

Pass marks in every semester paper is 40%.

Aggregate mark in a semester must be at least 45% for clearing the subject papers of each semester.

Total credit: 80

Semester I- 20 credit

Semester II- 20 credit

Semester III- 20 credit

Semester IV- 20 credit

1 credit is equivalent to 10 theory hours or 20 laboratory hours.

| Theory Paper | | Credit – 05 | | Total Marks - 100 | |
|---|---|---|---|---|---|
| **Type of Examination** | **Duration** | **Question Pattern & Details of Evaluation** | **No of Questions to be set** | **Distribution of Marks** | **Total** |
| **End Semester Examination [Written]** (70 marks) | **3 Hours** | Group A: Multiple Choice Type | 10 | 2X10= 20 | **70** |
| | | Group B:Short Answer Type (5 questions one from each unit) | 05 | 5X4 = 20 | |
| | | Group C: Long Answer Type (5 questions one from each unit) | 05 | 10X3 = 30 | |
| **Continuous Internal Assessment [CIA]** (30 marks) | **1 Hour** | **Mid-semester Test - 02 (written) (each of 7.5 mark)** | | | **7.5X2** |
| | | Group A: Multiple Choice Type | 05 | ½X5 = 2.5 | |
| | | Group B: Short Answer Type (5 questions one from each unit) | 03 | 1X2 = 2 | |
| | | Group C: Long Answer Type (3 questions) | 03 | 3X1 = 3 | |
| | | **Assignment** | | | 05 |
| | | **Seminar/Quiz** | | | 05 |
| | | **Attendance, Punctuality & Conduct** | | | 05 |
| **Practical Paper** | | | | **Total Marks - 100** | |
| **End Semester Examination (ESE)** | **6 Hours** | **1 Experiment to be performed** | | | 70 |
| **Continuous Internal Assessment (CIA)** | | | | | 30 |
| **Elective Practical and Presentation of Dissertation** | **6 Hours** | **1 Experiment to be performed plus Dissertation presentation** | | 35+35 | 70 |
| **CIA of Practical and Dissertation** | | | | 15+15 | 30 |

## Detailed Syllabus: Semester 1 Core Papers (Theory)

### M-Phy – 101 Classical Mechanics and Electrodynamics (5 Credits)

**The End Semester Examination will be of 3 hour duration and will carry 70 marks. ( . The Question paper will be divided into three parts A, B and C. Part A will have ten compulsory multiple choice type questions covering the whole syllabus with two from each unit (10 X 2 = 20). Part B will have Five short answer questions, with one question from each unit. The student is required to answer any four out of them (4 X 5 = 20). Part C will have five long answer questions with one question from each unit. The student is required to answer any three out of them (3 X 10 = 30).**

**UNIT-1 : Hamiltonian Dynamics**

Hamilton's equation in different co-ordinate systems, Examples of Hamiltonian Dynamics (harmonic oscillator : 1 & 2 Dimentional , Motion of a particle in central force field, charged particle in an electromagnetic field , compound pendulum. **[6 periods]**

Calculus of variation (Euler Lagrange equation) and Modified Hamilton's Principle (its derivation from D' Alembert's Principle) , Derivation of Hamiltonian's Canonical equations from modified Hamiltonian principle, Δ-variation and principle of least path in differential forms. **[6 periods]**

**Unit – 2 : Canonical Transformation**

Canonical Transformation through four generating functions with various examples. Infinitesimal Contact transformation, Integral invariance of Poincare', Poisson's and Lagrange Brackets and its properties, Invariance with respect to C.T., Liouville's theorem.

**[ 10 periods]**

**Unit – 3 : Theory of Small Oscillations**

3a)Two coupled oscillators, Normal modes and coordinates with examples, General theory of small oscillations, Solution of eigenvalue equations with reference to triatomic molecule.

**[6 periods]**

3b) Hamilton Jacobi theory and Transition to Quantum Mechanics. **[5 periods]**

**Unit – 4: Electromagnetic field tensor**

Review of four vector and Lorentz transformation in four dimensional space, Electromagnetic field tensor, Transformation of fields, field due to a point charge in uniform motion, Lagrangian Formulation of the motion of a charged partical in an Electromagnetic field, Maxwell's equations. **[ 10 periods]**

**Unit – 5 : Fields and Radiation from Accelerated Charge**

Retarded potentials, Lienard- Wiechert Potentials, Potentials for a charge ion in uniform motion, Fields of an accelerated charge, Radiation from an accelerated charged particle at low velocity, angular distribution of power radiated, Reaction force of radiation. **[10 periods]**

**M-Phy-102 Computational Methods in Physics (5 Credits)**

**The End Semester Examination will be of 3 hour duration and will carry 70 marks. The Question paper will be divided into three parts A, B and C. Part A will have ten compulsory multiple choice type questions covering the whole syllabus with two from each unit (10 X 2 = 20). Part B will have Five short answer questions, with one question from each unit. The student is required to answer any four out of them (4 X 5 = 20). Part C will have five long answer questions with one question from each unit. The student is required to answer any three out of them (3 X 10 = 30).**

**Unit-1: Introduction to C programming language:**

Algorithms, structured programming, Constants and variables, arithmetic expressions, input and output statements, logical expressions and conditional statements, iteration, functions, Arrays, Strings, Pointers, I/O functions, Files.

**Unit-2: Data interpretation and analysis:**

Precision and accuracy, error analysis, propagation of errors, least square fitting: linear, polynomial and nonlinear regression, goodness of fit and chi square test, Elementary probability theory, random variables, binomial, poisson and normal distributions.

**Unit-3: Finite difference methods:**

Computer arithmetic, normalised floating point representation, its consequences and pitfalls; Methods of finding roots of equations: Bisection method, Newton-Raphson method, Successive Approximation method; Solution of simultaneous algebraic equations: Gauss Elimination method, Gauss-Siedel iterative method.

**Unit-4: Numerical Techniques:**

Interpolation: Newton's Forward and Backward Interpolation Formula, Lagrange interpolation, Difference tables, Spline interpolation; Series approximation of functions: Taylor series, Numerical Differentiation , Numerical integration: Trapezoidal rule, Simpson's rule, Numerical solution of Differential Equations: Euler's method, Runge- Kutta methods.

**Unit-5: Some application of Numerical methods in Physics:**

Largest and smallest Eigenvalues, Diagonalisation of matrices, Initial value problems, 2-dimensional Laplace's Equation, Use of spreadsheets for calculations and graphs, Simulation of simple Physical problems.

**M-Phy-103 Quantum Mechanics I (5 Credits)**

**The End Semester Examination will be of 3 hour duration and will carry 70 marks. The Question paper will be divided into three parts A, B and C. Part A will have ten compulsory multiple choice type questions covering the whole syllabus with two from each unit (10 X 2 = 20). Part B will have Five short answer questions, with one question from each unit. The student is required to answer any four out of them (4 X 5 = 20). Part C will have five long answer questions with one question from each unit. The student is required to answer any three out of them (3 X 10 = 30).**

**Unit 1: Physics of microparticles:**

Equations of motion of microparticles; Inadequacy of Classical Mechanics, Schrodinger wave function and probability amplitude, wave packet: its physical interpretation, expectation values of dynamic variables, Continuity equation, Heisenberg's uncertainty relation, Quantization and wave particle duality, Postulates of Quantum Mechanics.

**Unit 2: Mathematical Foundations:**

Linear vector spaces, dimensionality, basis, eigenvalue equations, orthogonality and completeness conditions; Observables,Dirac's **Bra & ket** notations, Properties of Hermitian operators, unitary and similarity transformation, operators; Fourier Transform, Wave function as a vector in Hilbert space, Superposition principle; Representations, Relation between ket and wave function, Eigenvalue spectrum of linear momentum and its wavefunctions; Transformation between coordinate and momentum representations, Ehrenfest's theorem, Fourier theorem.

**Unit 3: Bound states and Potential Barriers:**

Quantization as an eigenvalue problem, Particle in a Box (1 dimensional and 3 dimensional), Particle in a Square well, Square Potential barrier, Linear Harmonic Oscillator, Hydrogen atom.

**Unit 4: Quantum Dynamics:**

Schrodinger, Heisenberg and Interaction pictures; Linear Harmonic Oscillator solution using Schrodinger picture and Heisenberg picture (Matrix Mechanics),

Angular Momentum,spin and parity operators: symmetry & conservation principle, definition of angular momentum, ladder operators, allowed values, construction of angular momentum matrices; Spin and Pauli spin matrices; Coupling of angular momentum, C.G. Coefficients.

**Unit 5: Interpretation** :

State of a quantum system and measurement problems; Statistical interpretation; Copenhagen interpretation and other schools of thought, GHA experiment; Quantum fluctuations and quantum transitions, Cpllapse of wave packet, Quantum causality.

**M-Phy – 104 Practicals Computational Methods (5 Credits)**

Practical based on Paper M-Phy-102

M-Phy-201 **Mathematical Physics (5 Credits)**

**The End Semester Examination will be of 3 hour duration and will carry 70 marks. The Question paper will be divided into three parts A, B and C. Part A will have ten compulsory multiple choice type questions covering the whole syllabus with two from each unit (10 X 2 = 20). Part B will have Five short answer questions, with one question from each unit. The student is required to answer any four out of them (4 X 5 = 20). Part C will have five long answer questions with one question from each unit. The student is required to answer any three out of them (3 X 10 = 30).**

**Unit 1: Linear Differential equations and special functions:**

Linear Differential Equations, Power series solutions; Special Functions: Hermite, Legendre, Bessel, Lauguerre Polynomials; Fourier and Laplace Transforms.

**Unit 2: Elements of Complex analysis:**

Analytic functions, Taylor and Laurent series, calculus of residues, nature of singularities, Evaluation of definite integrals, Jordan's lemma

**Unit 3: Green's Function**

Green's Function, Dirac Delta Function, Properties and applications.

**Unit 4: Group Theory:**

Groups, subgroups, cosets, invariant subgroups, factor groups, homomorphism and isomorphism, orthogonality theorems, Continuous groups with special reference to O(3), SU(2),SU(3).

**Unit 5: Elementary Tensor Analysis**

Coordinate transformations, Contravariant and covariant vectors, Contravariant, covariant and mixed tensors, tensor fields, symmetric and skew symmetric tensors, fundamental operations with tensors, metric tensor, conjugate tensors, associated tensors.

**M-Phy-202** **Quantum Mechanics 2 (5 Credit)**

**The End Semester Examination will be of 3 hour duration and will carry 70 marks. ( ). The Question paper will be divided into three parts A, B and C. Part A will have ten compulsory multiple choice type questions covering the whole syllabus with two from each unit (10 X 2 = 20). Part B will have Five short answer questions, with one question from each unit. The student is required to answer any four out of them (4 X 5 = 20). Part C will have five long answer questions with one question from each unit. The student is required to answer any three out of them (3 X 10 = 30).**

**Unit 1: Identical Particles:**

Identical particles, Exchange operators; Bosons and Fermions; Symmetry and statistics.

**Unit 2: Time-independent perturbation theory:**

Time-independent perturbation theory: Non- degenerate and degenerate states (upto second order); Variational method; Application: Zeeman effect, Stark effect and Anharmonic oscillator; helium atom and hydrogen molecule, Heitler London theory.

**Unit 3: Time dependent perturbation theory:**

Transition amplitude 1st and 2nd order, selection rules, constant perturbation (1st order), Fermi's golden rule, Harmonic perturbation, Interaction of atom with electromagnetic radiation, dipole approximation, Spontaneous emission, Stimulated emission, Adiabatic and sudden approximations, Einstein coefficients, Masers and Lasers.

**Unit 4: Theory of Scattering (Kinematics):**

Laboratory and centre of mass reference frames, Differential and total cross sections, scattering amplitudes using green's function, scattering by symmetric potential.

**Unit 5: Theory of Scattering (Dynamics):**

Partial wave analysis, Phase shift, scattering amplitudes in terms of phase shift, optical theorem, scattering by square well potential and perfectly rigid sphere; Born approximation, its validity, application to square well potential and Yukawa potential.

M-Phy-203 **Electronics (5 Credit)**

**The End Semester Examination will be of 3 hour duration and will carry 70 marks. The Question paper will be divided into three parts A, B and C. Part A will have ten compulsory multiple choice type questions covering the whole syllabus with two from each unit (10 X 2 = 20). Part B will have Five short answer questions, with one question from each unit. The student is required to answer any four out of them (4 X 5 = 20). Part C will have five long answer questions with one question from each unit. The student is required to answer any three out of them (3 X 10 = 30).**

**Unit 1: Semiconductor devices:**
BJT, JFET, MOSFET (Enhancement and depletion types), UJT, SCR, TUNNEL Diode, Zener Diode,structure working and characteristics.

**Unit 2: Amplifiers and feedback:**
BJT biasing, design of a CE transistor amplifier, small signal model, emitter follower. Negative feedback and its properties (effect of feedback on different parameters), types of feedback; Oscillators: Principles, Barkhausen criterion, frequency stability, phase shift oscillator, Wien bridge oscillator.

**Unit 3: Operational Amplifiers**
Operational amplifier block diagram, ideal and practical op-amp characteristics; Op amp circuits: inverting and non-inverting amplifier, adder, subtractor, differentiator, integrator, current to voltage converter, first order active filters.

**Unit 4: Digital Electronics**
Number systems and codes, binary arithmetic, logic gates : AND, OR, NAND, NOR, NOT, XOR. Boolean algebra theorems, De-morgan`s theorems, Minterm and Maxterm representation, simplification using Boolean algebra theorems and K- maps, half and full adders, flip-flops-RS and JK. Elementary ideas of Registers, counters, comparators.

**Unit 5: Microprocessor and microcontroller**

Microcomputer block diagram,system buses,8085 Microprocessors, architecture and operation ,Assembly language instructions (classification only) . 8051 Microcontroller Architecture ,Ports and elementary idea of interfacing.

**M-Phy-204 Practicals ( (5 Credit)** — Core Physics I

**SEMESTER 3**

**M-Phy-301 Atomic and Molecular Physics, Lasers (5 Credit)**

**The End Semester Examination will be of 3 hour duration and will carry 70 marks. The Question paper will be divided into three parts A, B and C. Part A will have ten compulsory multiple choice type questions covering the whole syllabus with two from each unit (10 X 2 = 20). Part B will have Five short answer questions, with one question from each unit. The student is required to answer any four out of them (4 X 5 = 20). Part C will have five long answer questions with one question from each unit. The student is required to answer any three out of them (3 X 10 = 30).**

**Unit 1: Atomic Physics:**

**Prerequisite**: Vector Atom Model (LS, JJ Coupling ), Fine Sructure and Hyperfine Structure, Zeeman Effect, Paschen- Back and Stark – Effect. **(Zero Credit )**

Intensity, Shape and width of spectral lines, Independent particle model, He- atom as an approximation for many electron atomic systems, Slater determinants to write possible multiplets. **[10 Lectures]**

**Unit 2: Electronicand Molecular Spectra:**

**Prerequisite :** Molecule as Non -rigid rotator, Anharmonic Oscillator (vibration- rotation spectrum) Frank-Condon principle, NMR & ESR. **(Zero credit)**

Spectra/Vibration of Polyatomic molecule, Electronic spectra of polyatomic molecules, Chemical analysis by electronic spectroscopy, Spectra of hydrogen molecule. **[10 Lectures]**

**Unit 3: Molecular Potential:**

Born-Oppenheimer approximation and its breakdown, Analysis by infrared techniques, Molecular orbital theory, LCAO approximation theories. **[8-10 Lectures]**

**Unit 4: Raman Spectroscopy**

Vibrational and pure rotational Raman spectra; Structure determination,Raman and Infrared spectroscopic Technique and instrumentation. . **[8-10 Lectures]**

**Unit 5: Laser**

**Prerequisite**:

Significance of Einstein's A and B coefficients, pumping schemes' Characteristics of Laser beams Principle of Optical Fiber Communication, Numerical Aperture of Maridonal and Axial Rays. **(zero credit)**

Laser Operation : Oscillator versus Amplifier, , Laser resonators, Laser rate Equatoins for Three and four level Laser systems, Liquid (Dye) Lasers, Gas ($CO_2$, Nitrogen and Eximer) lasers, Laser Applications in industry, Nuclear science, Spectroscopy , Light detection and Ranging (LIDAR), Scanning laser beam devices, Laser communication (**Injection Laser Diode and Avalanche Photo Diode**), optical computing, medical applications.

**[14 Lectures]**

## M-Phy-302 Condensed Matter Physics (5 Credit)

**The End Semester Examination will be of 3 hour duration and will carry 70 marks. The Question paper will be divided into three parts A, B and C. Part A will have ten compulsory multiple choice type questions covering the whole syllabus with two from each unit (10 X 2 = 20). Part B will have Five short answer questions, with one question from each unit. The student is required to answer any four out of them (4 X 5 = 20). Part C will have five long answer questions with one question from each unit. The student is required to answer any three out of them (3 X 10 = 30).**

**Unit 1: Crystal structure:**
Reciprocal lattice and applications, Brillouin Zones, Laue equations and Bragg`s law. Laue and powder diffraction; Structure factor, atomic form factor, Intensity of diffraction maxima, extinctions due to Lattice centering.

**Unit 2: Electronic Properties:**
Motion of electron in periodic lattice, Bloch theorem, nearly free electron model, tight binding and cellular methods, effective mass, intrinsic and extrinsic semi conductors. Fermi Surface. Cyclotron resonance and deHass-van Alphen effect.

**Unit 3: Magnetic Properties:**
Heisenberg model, Molecular field theory, Spin waves and magnons. Curie-Weiss law for susceptibility, Theories of ferromagnetism, anti-ferromagnetism and ferrimagnetism.

**Unit 4: Superconductivity:**
Meissner effect, London equation. Flux quantisation, Josephson effect; Crystal Defects: Point defects, line defects, planar faults, role of dislocations in Plastic deformation and crystal growth, colour centres

**Unit 5: Dielectrics and Related Properties:**
Microscopic concept of dielectric polarisation, Langevin theory of Polarization, Claussius-Mossotti equation, Dielectrics in Alternating Field, Complex Dielectric Constant and dielectric loss, Ferro-electricity, Optical properties of solids.

**SEMESTER 4**

**M-Phy-401 Thermodynamics and Statistical Mechanics (5 Credit)**

**The End Semester Examination will be of 3 hour durationand will carry 70 marks. The Question paper will be divided into three parts A, B and C. Part A will have ten compulsory multiple choice type questions covering the whole syllabus with two from each unit (10 X 2 = 20). Part B will have Five short answer questions, with one question from each unit. The student is required to answer any four out of them (4 X 5 = 20). Part C will have five long answer questions with one question from each unit. The student is required to answer any three out of them (3 X 10 = 30).**

**UNIT 1 : Thermodynamics:**

Thermodynamic Potentials, Maxwell Equations, Chemical Potential, Phase equilibria. Free energy and connection with thermodynamic quantities; First and second order phase transitions.

**UNIT 2 : Classical statistical mechanics:**

Postulates of classical statistical mechanics, ensemble distribution function, Liouville's theorem, microcanonical ensemble, Classical ideal gas and its entropy, energy and pressure, Canonical ensemble and partition function, Grand canonical ensemble and partition function.

**UNIT 3 : Quantum statistics and Applications I:**

Density matrix, quantum ensembles, Ideal Bose gas, Bose condensation, liquid He II, superfluidity and Landau's theory.

**UNIT 4 : Quantum statistics and Applications II:**

Ideal Fermi gas, Specific heat and Pauli paramagnetism, Principle of detailed balance, Landau diamagnetism, white dwarfs and Chandrasekhar limit.
Ising model, Random walk and Brownian motion.

**UNIT 5 : Irreversible processes:**

Features of Equilibrium and Non-equilibrium thermodynamics, linear theory of non equilibrium thermodynamics, current and Affinity, Onsager relation, Fluctuations, Microsystems.

**M-Phy-402 Nuclear and Particle Physics (5 Credits)**

**The End Semester Examination will be of 3 hour durationand will carry 70 marks. The Question paper will be divided into three parts A, B and C. Part A will have ten compulsory multiple choice type questions covering the whole syllabus with two from each unit (10 X 2 = 20). Part B will have Five short answer questions, with one question from each unit. The student is required to answer any four out of them (4 X 5 = 20). Part C will have five long answer questions with one question from each unit. The student is required to answer any three out of them (3 X 10 = 30).**

**Unit 1: Nuclear forces:**

Exchange forces and tensor forces. Low energy nucleon- nucleon scattering, Effective range theory; Deuteron problem, High energy nucleon-nucleon scattering (Qualitative discussion), Charge independence, spin dependence and charge symmetry of nuclear forces, Isospin formalism; Meson theory of Nuclear Forces.

**Unit 2: Nuclear reactions:**

Kinematics and conservation laws, Nuclear reactions and cross sections, Theory of compound nucleus, Breit-Wigner single level formula, Mechanisms of nuclear fission and fusion, nuclear reactors.

**Unit 3: Nuclear models:**

(a) Single particle shell model: Magic numbers, spin, parity, magnetic dipole moment, electric dipole moment, (b) The Nilsson unified model, (c) Collective model: vibrational and rotational states, $\beta$ and $\gamma$ bands.

**Unit 4: Nuclear decay:**

(a) Fermi theory of $\beta$ decay, allowed and forbidden transitions, Parity violation in $\beta$ decay and Helicity of neutrino. (b) Radiative transitions in nuclei ($\gamma$ -decay) Spontaneous decay, Internal conversion, Mossbauer effect.

**Unit 5: Elementary Particle Physics:**

Conservation laws and symmetry, Strangeness, hypercharge, CPT invariance, Classification of elementary particles, SU(2) symmetry and its application to decay and scattering processes, SU(3) symmetry and the Quark model, Elementary idea of chromodynamics.

**Phy – M – 403** **Elective paper 1** **(5 Credit)**

One to be chosen from the following options:

| |
|---|
| **A. Advanced Quantum Mechanics** |
| **B. Advanced Condensed Matter Physics** |
| **C. Atmospheric Physics** |
| **D. Biophysics** |
| **E. General Relativity and Cosmology** |
| **F. Lasers and Photonics** |
| **G. Measurement and Instrumentations** |
| **H. Modeling and Simulation in Physics** |
| **I. Nano[illegible]Science** |
| **J. Plasma Physics** |

**M-Phy-403A** **Advanced Quantum Mechanics** **(5 Credit)**

**The End Semester Examination will be of 3 hour durationand will carry 70 marks. The Question paper will be divided into three parts A, B and C. Part A will have ten compulsory multiple choice type questions covering the whole syllabus (10 X 2 = 20). Part B will have Five short answer questions, with at least one question from each unit. The student is required to answer any four out of them (4 X 5 = 20). Part C will have five long answer questions with at least one question from each unit. The student is required to answer any three out of them (3 X 10 = 30).**

**Units 1: Relativistic Quantum Mechanics**
Postulates of Quantum Mechanics, Space time description of Schrodinger Wave Equation, Klein Gordon equation;

**Unit 2**:
Dirac equation, covariant form; Plane wave solution; Dirac interpretation of negative energy states and concept of antiparticles; Spin and magnetic moment of the electron, Non relativistic reduction, Helicity and chirality; Properties of $\gamma$ matrices; Charge conjugation; Normalization and completeness of spinors.

**Unit 3: Quantum Field Theory**
Second quantization – Lagrangian field theory, Hamiltonian formulation, Quantization of scalar field, Quantization of complex scalar and "Schrodinger" field, Bosons and Fermions.

**Unit 4: Quantum Chromodynamics**
Introduction to quantum chromodynamics, Quark model.

**Unit 5:**
Standard model, Grand Unified Theories

**M-Phy-403B Advanced Condensed Matter Physics (5 Credit)**

**The End Semester Examination will be of 3 hour durationand will carry 70 marks. The Question paper will be divided into three parts A, B and C. Part A will have ten compulsory multiple choice type questions covering the whole syllabus (10 X 2 = 20). Part B will have Five short answer questions, with at least one question from each unit. The student is required to answer any four out of them (4 X 5 = 20). Part C will have five long answer questions with at least one question from each unit. The student is required to answer any three out of them (3 X 10 = 30).**

**Unit 1: Electron States :**

Hartree and Hartree-Fock approximations, correlation energy, Screening, plasma oscillations. Dielectric function of an electron gas in random phase approximation, limiting laws & Friedel oscillation.

**Unit 2: Electron-electron interaction :**

Lindhard's expression for wave length and frequency dependent dielectric constant. Static screening, Kohn effect.

**Unit 3: Superconductivity:**

Energy gap, Cooper pair, BCS theory, Ginzsburg –Landau theory, Josephson junction and its application, Microscopic quantum interference. High temperature superconductivity.

**Unit 4: Magnetism :**

The band model for ferromagnetism and its temperature dependence. Ferrimagnetism, Antiferromagnetism, magnetism effects in nanomaterials.

**Unit 5: Dielectric Properties:**

Theory of dielectrics, Piezoelectricity, Ferroelectricity, Anti-ferroelectricity and their Applications, Nano-structured ferroelectric materials, Synthesis and characterization techniques of ferroelectric nano-materials, multiferroic and smart materials.

**M-Phy- 403C Atmospheric Physics (5 Credit)**

**The End Semester Examination will be of 3 hour durationand will carry 70 marks. The Question paper will be divided into three parts A, B and C. Part A will have ten compulsory multiple choice type questions covering the whole syllabus (10 X 2 = 20). Part B will have Five short answer questions, with at least one question from each unit. The student is required to answer any four out of them (4 X 5 = 20). Part C will have five long answer questions with at least one question from each unit. The student is required to answer any three out of them (3 X 10 = 30).**

**Unit 1: Introduction and Atmospheric Chemistry:**

General description and basic facts; Regions of the Atmosphere, Atmospherric chemistry: Composition, Minor constituents, cycles of main elements, chemistry of sulphur, carbon, nitrogen compounds, photochemical pollution, aerosols.

Radiation, absorption of radiant energy in the atmosphere, solar radiation, Chapman profile, photochemistry of ionosphere, stratospheric ozone, ozone hole; Greenhouse effect and its consequences, effective temperature.

**Unit-3: Atmospheric thermodynamics and Cloud Physics:**

Atmospheric system, Application of first law of thermodynamics to air and clouds, main processes in the atmosphere,cooling, potential temperature, adiabatic expansion with condensation, vertical stability, convective instability.

**Unit-4: Cloud Physics:**

Cloud physics and Atmospheric Electricity: Classification of clouds, growth of drops by condensation, growth by collision and coalescence, warm rain, ice formation, snow, hail and rain by ice process, ice precipitation. Electric field and space charge, Fundamental problem of atmospheric electricity, Thunderstorm electricity, Lightning.

**Unit-5: Atmospheric Dynamics:**

Principle forces acting on a parcel of air, acceleration of air parcel, equation of motion, continuity equation, scales of motion, important features of large scale atmospheric motion, Large scale mid latitude circulation system, thermal circulation, global crculation pattern, mid latitude cyclones.

**M-Phy-403D** **Biophysics** **(5 Credit)**

**The End Semester Examination will be of 3 hour durationand will carry 70 marks. The Question paper will be divided into three parts A, B and C. Part A will have ten compulsory multiple choice type questions covering the whole syllabus (10 X 2 = 20). Part B will have Five short answer questions, with at least one question from each unit. The student is required to answer any four out of them (4 X 5 = 20). Part C will have five long answer questions with at least one question from each unit. The student is required to answer any three out of them (3 X 10 = 30).**

**Unit-1:**

Bioenergetics: Principles of Thermodynamics, redox potential and free energy change of the reactions, Biological energy transducers.

**Unit-2:**

Physical techniques in protein, nucleic acids and polysaccharide structural analysis: UV-Vis spectroscopy, Infrared spectroscopy, Fluorescence spectroscopy, Atomic absorption spectroscopy, Raman spectroscopy, NMR, Mass spectroscopy, Circular dichorism spectroscopy, X Ray Diffraction technique, TEM and SEM.

**Unit-3:**

Centrifugation: Principles, types, Differential and density gradient centrifugation and their applications; Chromatography: Principles, types(Paper, TLC, Affinity, Ion exchange, Gel filtration, GLC, HPLC) and their applications.

**Unit-4:** Electrophoresis: Principles and types[Polyacrylamide gel electrophoresis (PAGE), SDS-PAGE, agarose gel electrophoresis, 2D electrophoresis and their applications.

**Unit-5:**

Theoretical techniques and their application to Biomolecules: Hard sphere Approximation, Ramchandran plot, Potential energy surfaces, Outline of Molecular Mechanics Method, Brief ideas about semi-empirical and ab-initio quantum theoretical methods, molecular charge distribution, molecular electrostatic potential and field and their uses.

**M-Phy-403E General Relativity and Cosmology (5 Credit)**

**The End Semester Examination will be of 3 hour durationand will carry 70 marks. The Question paper will be divided into three parts A, B and C. Part A will have ten compulsory multiple choice type questions covering the whole syllabus (10 X 2 = 20). Part B will have Five short answer questions, with at least one question from each unit. The student is required to answer any four out of them (4 X 5 = 20). Part C will have five long answer questions with at least one question from each unit. The student is required to answer any three out of them (3 X 10 = 30).**

**Unit-1: Tensors:**

Tensor analysis, covariant and contravariant tensors, contraction, metric tensor, energy-momentum tensors of (1) perfect fluid and (2) electromagnetic field, parallel transport and connection, covariant derivatives, metric connection.

**Unit-2: General Relativity:**

Equality of gravitational and inertial masses, equivalence principle, geodesics, time and distance in general relativity, curvature tensor and its properties, principle of general covariance.

**Unit-3: Field Equation:**

Einstein field equations, Schwarzschild solution, motion of test particles and light in the Schwarzschild field, gravitational red shift, experimental situation.

**Unit-4: Elements of cosmology:**

The universe as we know it, experimental data, Homogeneity and isotropy, 3 degree Kelvin radiation, Robertson-Walker metric, Friedmann models.

**M-Phy-403F** **Lasers and Photonics** **(5 Credit)**

**The End Semester Examination will be of 3 hour durationand will carry 70 marks. The Question paper will be divided into three parts A, B and C. Part A will have ten compulsory multiple choice type questions covering the whole syllabus (10 X 2 = 20). Part B will have Five short answer questions, with at least one question from each unit. The student is required to answer any four out of them (4 X 5 = 20). Part C will have five long answer questions with at least one question from each unit. The student is required to answer any three out of them (3 X 10 = 30).**

**Unit 1: Basic Principles:**

Laser rate equation for three level and four level systems, Dynamics of Laser Process: switching, Mode locking, mode pulling, lamb dip, hole burning,; Energy levels and radiating properties of molecules, liquids and solids, Laser amplifier, Laser resonators, Techniques of laser excitation.

**Unit 2: Non-linear optical effects:**

Harmonic generation, Second harmonic generation, Phase matching, Third harmonic generation, Optical mixing, parametric generation, Self focussing of light, Two photon absorption, Doppler free two photon spectroscopy, Laser spectroscopy.

**Unit 3: Applications of Laser:**

Fabrication of electronic components, Material processing; Laser Communication, Ho;ography, Military applications, Medical applications, Star Wars, Laser hazards and Laser safety, Optical Amplifiers, Infrared optical devices, Laser gooling, Trapping.

**Unit 4: Optical Fiber Communiucation:**

Optical Fiber structure, Waveguiding and Fabrication of Fiber, Types of Fiber and solution of Maxwell's wave equation inside fiber, Signal degradation and attenuation in Optical Fibers.

**Unit 5: Optical Fiber Systems:**

Optical sources (ILD and PIN Diode) and Optical Detectors (APD); Analog and Digital optical fiber Transmission System (PDH, SDH and WDM Technology).

**M-Phy-403G** **Measurement and Instrumentations (5 Credit)**

**The End Semester Examination will be of 3 hour durationand will carry 70 marks. The Question paper will be divided into three parts A, B and C. Part A will have ten compulsory multiple choice type questions covering the whole syllabus (10 X 2 = 20). Part B will have Five short answer questions, with at least one question from each unit. The student is required to answer any four out of them (4 X 5 = 20). Part C will have five long answer questions with at least one question from each unit. The student is required to answer any three out of them (3 X 10 = 30).**

**Unit 1: Basic Principles**

Measuring Instruments: Accuracy, precision, sensitivity and resolution; Scale, standards and calibration; Uncertainties of measurements and errors, propagation of errors, statistical treatment of random errors, Distribution functions and their properties.

**Unit-2: Transducers:**

Temperature, pressure/vacuum, magnetic field, vibration, strain, displacement and force transducers: Principle, construction and working.

**Unit-3: Signal conditioning and recovery:**

Signal level and Impedance matching, Operational amplifier modules for different signal conditioning: addition, subtraction, scaling, differentiation and integration; Log and antilog amplifiers, analog multiplier and applications, instrumentation amplifier; Signal to noise considerations, Filters, Phase Lock Loop, Lock-in amplifier.

**Unit-4: Digital signal processing:**

A/D and D/A convertor, 7107 A/D convertor based DMM, Embedded systems: 8051 and Atmega 32 microcontollers – Basic features, Microcontroller development system.

**Unit-5: Computer interfacing of science experiments:** Real time and off-line data processing, Data acquisition systems and Data Loggers: Principle and design, Passive and Active Instrumentation with examples.

**M-Phy-403H Modeling and Simulation in Physics (5 Credit)**

**The End Semester Examination will be of 3 hour durationand will carry 70 marks. The Question paper will be divided into three parts A, B and C. Part A will have ten compulsory multiple choice type questions covering the whole syllabus (10 X 2 = 20). Part B will have Five short answer questions, with at least one question from each unit. The student is required to answer any four out of them (4 X 5 = 20). Part C will have five long answer questions with at least one question from each unit. The student is required to answer any three out of them (3 X 10 = 30).**

**Unit 1: Object oriented Programming language**

Object oriented paradigm with reference to C++: Objects and classes, Encapsulation and data abstraction, Delegation; Inheritance, Polymorphism: function and operator overloading, dynamic binding; message communication; Elementary idea about fortran 90 and java (Basic features only).

**Unit 2: Programming using Python:** Program development, Variables, expressions and statements, Functions, Conditionals and recursion, Iteration, Strings, Lists, Dictionaries, Tuples, Files, Types of errors and Debugging, Function Libraries: Numpi, scipi, Classes, Objects, Methods, Inheritance Python Function Libraries: Numpy, Scipy, Matplotlib. Use of Scilab and R for scientific programming.

**Unit 3: ODE and PDE:**

ODE: RK method, Leap Frog method; Application to electron motion in electric and magnetic fields; Non-linear equations; PDE: Elliptic equations: Poisson equation; Hyperbolic equations: wave equation; Parabolic equation: Diffusion equation for Lagrangian fluids.

**Unit 4: Matrix Problems**

Jacobi method for matrix inversion; Techniques for solving eigenvalue problems.

**Unit 5: Monte Carlo method and simulation**

Random number generators, Monte Carlo integration, Metropolis algorithm, Ising model, Molecular dynamics.

**M-Phy-403I** **Nano Science** **(5 Credit)**

**The End Semester Examination will be of 3 hour durationand will carry 70 marks. The Question paper will be divided into three parts A, B and C. Part A will have ten compulsory multiple choice type questions covering the whole syllabus (10 X 2 = 20). Part B will have Five short answer questions, with at least one question from each unit. The student is required to answer any four out of them (4 X 5 = 20). Part C will have five long answer questions with at least one question from each unit. The student is required to answer any three out of them (3 X 10 = 30).**

**Unit-1: Introduction and Basic Principles:**

Definition of Nanomaterials, Properties, Applications and Scope of nanoscience

Quantum size effect. Electron confinement in infinitely deep square well, confinement in one and two dimensional well, idea of quantum well structure, Quantum wells, quantum wires and Quantum Dots: Preparation and properties; Conduction electrons and dimensionality, Properties dependent on density of states.

Carbon nanostructures: Fullerines, structure, Superconductivity in C60, Carbon nanotubes: synthesis and structure, Electrical and Mechanical properties, Graphene.

**Unit-2: Synthesis**

Techniques for synthesis: Top down approach: Ball milling; Bottom up approach: Chemical methods of synthesis, RF Plasma and Pulsed Laser techniques, Biological methods: synthesis using microorganisms, and plant extracts.

**Unit – 3 : Characterization Techniques:**

Characterization tools for nanomaterials: Thermal analysis: DTA, DSC, TGA, dilatometry; Electrical measurements: LCR meter, electrometer amplifier; Optical, UV-Visible spectroscopy, IR spectroscopy, Ellipsometry, Raman Photoluminescence and spectroscopy, Atomic absorption spectroscopy, Structural characterization: X-ray Diffractometer; Magnetic characterization: Vibrating sample magnetometer; TEM, SEM, STM, AFM.

**Unit-4: Magnetic Nano Materials**

Magnetic nanoparticles, multiferroic and smart materials, Elementary idea of NEMS and nanotransistors.

**Unit – 5: Dielectric and Multiferroic materials**

Theory of dielectrics, Piezoelectricity, Ferroelectricity, Anti-ferroelectricity and their Applications, Nano-structured ferroelectric materials, Synthesis and characterization techniques of ferroelectric nano-materials, multiferroic and smart materials.

**M-Phy-403J Plasma physics** **(5 Credit)**

**The End Semester Examination will be of 3 hour durationand will carry 70 marks. The Question paper will be divided into three parts A, B and C. Part A will have ten compulsory multiple choice type questions covering the whole syllabus (10 X 2 = 20). Part B will have Five short answer questions, with at least one question from each unit. The student is required to answer any four out of them (4 X 5 = 20). Part C will have five long answer questions with at least one question from each unit. The student is required to answer any three out of them (3 X 10 = 30).**

**Unit 1: Basics (Single Particle Approach):**

Charged particles in uniform and non-uniform electromagnetic field, Plasma – the forth state of matter, Concept of electron and ion temperature, Debye Length, Cyclotron Frequency, Larmor radius, Drift velocity of guiding center, Magnetic moment, Magnetic mirror systems and their relation to the plasma confinement, Adiabatic Invariants. .

**Unit 2: MagnetoHydro Dynamics (Fluid Approach):**

Introduction to ideal MHD systems, Fundamental equations of magnetohydro dynamic systems, Diffusion and mobility of charged particles in plasma, Plasma as fluid and MHD equations, Approximations and linearization of MHD from dimensional considerations, Single fluid MHD equation, MHD Generator.

**Unit 3: Waves and instabilities in plasma:**

Waves in unmagnetised plasma, Energy transport, Ion acoustic waves and MHD waves, Issue of plasma stability and the use of normal mode to analyse stability, Interaction between plasma particles, Perturbation at two fluid interface, RayleighTaylor instability, Kelvin Helmholtz instability and Jeans instability.

**Unit 4: Kinetic Theory:**

Need for kinetic theory and MHD as approximation of kinetic theory, Meaning of f(v), Phase space for many particle motion, Velocity and space distribution function, Derivation of fluid equation and Electron-ion plasma oscillation frequency, Derivation of Landau damping, Equations of Kinetic Theory and Vlasov equations for fluid dynamics.

**Unit 5: Applications:**

Saha theory of thermal ionization, Application in Space Science, Controlled Thermonuclear Fusion, Plasma Jet Engine, Gas Laser and non linear effects.

**M-Phy-404** **Elective II** **(5 Credit)**

**Part 1 : Practical Based on Elective I** **(2.5 credit)**

**Part 2 : Project work and Dissertation on any topic on Physics (2.5 credit)**

**Part - A: Principles of Scientific Research** **(zero credit)**

Identification of the problem - Literature survey - Reference collection - Familiarity with ideas and concept of investigation - Internet Browsing - Drawing Inferences from data - Qualitative and Quantitative analysis - Results - Seminar - Synopsis writing - Art of writing a Research paper and Thesis - Power point presentation - OHP Presentation.

**Part - B: Dissertation on chosen topic**

For students to enter into preliminary research field both in theory and experiment the concept of Project work has been introduced in the final Semester. In the Project the student will do literature survey for exploring new developments from the books and journals, collecting literature / data and write a Dissertation based on his / her work and studies. The Project Work can also be based on experimental work/ computer modeling. Student will finally appear for viva voce before the examiners.