Placed at the meeting of
Academic Council
held on 26.03.2018

APPENDIX - CJ

MADURAI KAMARAJ UNIVERSITY

(University with Potential for Excellence)

M.Sc. Physics (Semester)

REVISED SYLLABUS

(Revised Syllabus with effect from the academic year 2018-2019)

1. Introduction of the Programme

The Master of Science in Physics is a full-time programme spread over 2 years and is divided into 4 semesters. The programme of study shall consist of 12core papers which are compulsory, 4 elective papers and 4 practicals. Each of these carries 100 marks. It has been developed to provide students the opportunity to be trained in recent development in Physics. The course is designed to impart the students a vigorous training in Physics both in theory and experiments. Our approach is a comprehensive one. It is believed that teachingstudents both how to ask and address questions. This programme has been designed to expose students' knowledge in Physics to contemporary national and international problems. At the end of the course, students are expected to have state-of-the-art quantitative skills valued both in academia and in the corporate world. During the course time, one gets an in-depth knowledge about core subjects like Solid State Physics, Mathematical Physics and Quantum Mechanics.

2. Eligibility for Admission

B.Sc., Physics/Applied Physics with Mathematics as ancillary subject and candidates who studied Physics / Mathematics at +2 level are eligible for seeking admission to M.Sc., Physics. Candidates belonging to general category should have secured at least 55 % of marks, OBC candidates must have secured 50 % of marks and SC / ST / Candidates with disability must have passed in the qualifying examination for admission, as prescribed by Government of Tamil Nadu / Madurai Kamaraj University.

2.1 Duration of the programme : 2 Years (4 Semesters)

2.2 Medium of Instruction of the programme : English

3. Objectives of the Programme

- To offer knowledge, understanding and skills to PG students
- To offer a balance between Theoretical and Experimental-Physics
- To improve the employability of the students
- To develop core competencies on critical thinking skills, hypothesizing and solving problems

4. Outcome of the Programme

- It serves as a basis to build a purely academic profile for further studies and research in Physics such as M.Phil.and Ph.D.
- On successful completion of this course, one can apply for the UGC-NET or JRF exam. The success in these exams makes teaching or research as good options.
- The degree holders can opt for further higher studies and career in various specializations of Physics such as in Medical Physics, Nano Physics and Particle Physics.

5. Core Subject Papers

Core Subject papers shall consist of 12 papers as listed below.

1. Mathematical Physics I
2. Mathematical Physics II
3. Solid State Physics I
4. Solid State Physics II
5. Quantum Mechanics I
6. Quantum Mechanics II
7. Classical Mechanics
8. Statistical Mechanics and Thermodynamics
9. Nuclear and Particle Physics
10. Electromagnetic Theory
11. Applied Electronics
12. Molecular Spectroscopy

6. Subject Elective Papers

Elective Papers shall consist of 4 papers as listed below.

1. (a) Computer Oriented Numerical Methods /
   (b) Computer programming in C++
2. (a) Nano Physics /
   (b) Introduction to Particle Physics /
   (c) Medical Physics
3. (a) Project /
   (b) Applied optics and Laser Physics /
   (c) Fiber optic communication

7. Non Major Electives

1. (a) Non-Conventional Energy Sources /
   (b) Introduction to Nanotechnology

8. Unitization

Each subject Paper shall consist of five units. One unit (preferably the 5th Unit) will be handled by the students as a part of peer team teaching / learning process.

9. Pattern of Semester Examination

Two-year M.Sc., Physics degree shall be having examinations of 12Core papers, 3 subject- Elective papers and one Non-major elective paper to be conducted in four semesters. Each semester shall consist of five examinations for five subjects. First and Third semester examinations shall be conducted in the month of November. The Second and Fourth semester examinations shall be held in the month of April. Each paper shall carry 100 marks of which 25 marks for internal assessment and 75 marks for external examinations for all the theory papers. For practicals, 40 marks for internal and 60 marks for external.

10. Scheme of Internal Assessment

The components of Internal Assessment marks shall be as follows, for theory.

Test	:	10 Marks (Average of the best two tests)
Assignment	:	5 Marks
Seminar/ Group Discussion	:	5 Marks
Peer- team teaching	:	5 Marks
Total	**:**	**25 Marks**

For Practical's, 40 marks is for internal.

11. External Examinations

External examination for each Theory paper shall be conducted for 75 marks.

Section A: 10 Multiple choice questions (One question from each unit) (10 x 1 = 10 marks)

SectionB: 5 Either / Or type questions (One question from Each Unit) (5 x 7 =35 marks)

Section C: 3 Out of 5 questions. This may include 2 problems. (3 x 10=30 marks)

Total : 75 Marks.

For Practical's, 60 marks for external

12. Question paper pattern

Internal Examination of each paper shall be for 10 marks having the following question pattern.

Section A	: 6 Objective type questions	(6 X 1=6 marks)
Section B	: 2 questions in either or type	(2 X 7=14 marks)
Section C	: One out of 2 questions	(1 X 10=10 marks)

Total : 30 marks which shall be converted into 10 marks.

External examination of each paper shall be for 75 marks having the following question paper pattern, for theory papers.

Section A:10 Objective type questions (2 questions from Each unit)(10 X 1=10 marks)

Section B: 5 questions in either or type (one question from Each unit) (5 X 7=35 marks)

Section C: 3 out of 5 questions (one question from Each unit) (3X 10=30 marks)

(This may include 2 problems)

Total: 75 marks

13. Scheme of Evaluation

Students shall be evaluated on the basis of internal tests, seminar, and assignment, peer-teaching and external examinations. Question paper setters shall be requested to prepare scheme of valuation for all the papers.

14. Passing Minimum

Total Passing Minimum	:	50 Marks out of 100 Marks
Internal Assessment	:	No minimum pass mark out of 25 Marks
External Assessment	:	34 Marks out of 75 Marks

14.1 Classification of Assessment of the Students:

- **First Class with distinction**: if student got 75% of marks and above, if he/she cleared all the papers in the first attempt
- **First Class**: if the student got 60% of marks and above
- **Second Class**: if the student got above 50% and below 60% of marks

15. Model Question Paper

QUANTUM MECHANICS I

Section A **(10 x 1 = 10 Marks)**

Answer All Questions

Choose the correct Answer

1. The ground state energy of a particle of mass m in a one dimensional infinite potential well is E_0 . If we extend this to three dimensional cubical box, what is the first excited state?
   (a) $3E_0$ (b) $6E_0$ (c) $9E_0$ (d) E_0
2. Consider linear harmonic oscillator. Which of the following state will exhibit minimum uncertainity?
   (a) All the eigen states
   (b) Only ground state
   (c) Superposition between ground state and first excited state
   (d) First excited state

3. In a quantum mechanical system, an observable is represented by an operator A. If $|\Psi\rangle$ is NOT any of the eigen state of the operator A, then the quantity $r = \langle\Psi|A|\Psi\rangle^2 - \langle\Psi|A^2|\Psi\rangle$ satisfies the relation
   (a) $r < 0$ (b) $r = 0$ (c) $r > 0$ (d) $r \leq 0$

4. If the $[A, B] = i$, then the value of $[A^2, B^4]$ is
   (a) 0 (b) 4i A B (c) $8i(AB^3 + B^3A)$ (d) $8i(AB^2 + B^2A)$

5. The quantum state $|\Psi\rangle = \sin(\theta)\,|0\rangle + \exp(i\omega)\cos(\theta)\,|1\rangle$, where $\langle 0|1\rangle = 0$, is orthogonal to
   (a) $\sin(\theta)\,|0\rangle$
   (b) $\cos(\theta)\,|1\rangle$
   (c) $-\sin(\theta)\,|0\rangle + \exp(-i\omega)\cos(\theta)\,|1\rangle$
   (d) $-\exp(-i\omega)\cos(\theta)\,|0\rangle + \sin(\theta)\,|1\rangle$

6. The ground state of the quantum system will have
   (a) no nodes (b) one node (c) two nodes (d) more than two nodes

7. The value of $[L^2, L_z L_y L_x]$ is
   (a) 1 (b) 0 (c) L_z (d) L

8. $[x^2, p^2]$ = _____
   (a) Zero (b) $4i\hbar$ x p (c) $2i\hbar$ (xp-px) (d) $2i\hbar$ (xp + px)

9. The trial wavefunction chosen in the variational method must be
   (a) Continuous and Single valued function
   (b) Continuous and multi valued function
   (c) Discontinuous and Single valued function
   (d) Discontinuous and multi valued function

10. Which one of the function given below represent the eigen function of the operator $-d^2/dx^2$ in the region $0 \leq x \leq \infty$ with the eigenvalue -4?
   (a) A exp(2x) (b) A exp(-2x) (c) A exp(i2x) (d) A exp(-i2x)

Section B **(5 x 7 = 35 Marks)**

Answer all the Questions

11 (A) State and prove Ehrenfest's theorem.

(OR)

11 (B) Find the discrete energy levels and normalized eigenfunctionsof a particle in a one-dimensional square well potential.

12 (A) Discuss the Schrodinger and Heisenberg picture in quantum mechanics.

(OR)

12 (B) Solve the one dimensional linear harmonic oscillator using matrix formalism.

13 (A) Describe the properties of Hermitian operator

(OR)

13 (B) Enumerate the postulates of quantum mechanics.

14 (A) Obtain the common eigenstatesof J^2 and J_z using ladder operator approach.

(OR)

14 (B) Construct the angular momentum matrices for J_x, J_y, J_z andJ^2 for the angular momentum quantum number $j = 1$.

15 (A) Deduce expressions for first order and second order perturbation corrections when the energy levels of the unperturbed Hamiltonian are non-degenerate.

(OR)

15 (B) Describe the variational principle using any one of the examples.

Section C (3 x 10 = 30 Marks)

Answer any three Questions

16. Solve the Hydrogen atom and get the eigenvalues and eigenfunctions.

17. Calculate the (ΔN^2) for the state $C_1 |n> + C_2|m>+C_3 |p>$, where $|C_1|^2 + |C_2|^2 + |C_3|^2 = 1$ and $|n>$, $|m>$ and $|p>$ are the number states of the harmonic oscillator. N is the number operator. Also evaluate $[a^2 , (a^\dagger)^2]$.

18. Show that the eigenvalues of Hermitian operators are real.

19. Describe the construction process for ClebschGordan coefficients.

20. Calculate the ground state energy of the linear harmonic oscillator by assuming the trial functionexp$(-b x^2)$ using variationalmethod.

16. Teaching Methodology

Methodology shall consist of stimulation of students' interest, presentation of teaching material, team formation and activities' determination, conduction of activities and discussion and assessment. For the sake of simplicity and easy understand, the methods like problem solving, discussion, lab demonstration and lecture method shall be adopted. The use of ICT shall be co-opted for the visual presentation of the lessons. One unit (mostly 5^{th} unit will be handled by the students).

17. Text Books

The list of text books is given at the end of syllabus of each paper.

18. Reference Books

The list of reference books is given at the end of syllabus of each paper.

19. Retotaling and Revaluation Provision

Students shall be provided the facility of applying for retotaling the marks within 15 days after the publication of results on payment of a minimum fee fixed by the University and they shall be allowed to apply for revaluation of their papers within 15 days after the publication of results on payment of a fee to be fixed by the University.

20. Transitory Provision (2+2)

Syllabus revision shall be done once in 2 years and afterwards 2 years shall be under transitory provision.

21. Subjects and paper related websites.

The related websites for each paper shall be provided at the end of the syllabus wherever necessary

I M.Sc., Physics	Major Paper- I	Marks :100
Semester I	**MATHEMATICAL PHYSICS-I**	Hrs/Week : 6
Code:		INT: 25, EXT: 75

No	Title of the paper	Sub. Code	Credits	Exam hrs	Marks		Total
					int	Ext	
Semester I							
1	Mathematical Physics-I		5	3	25	75	100
2.	Classical Mechanics		4	3	25	75	100
3	Applied Electronics		4	3	25	75	100
4	Practical I – Electronics		5	4	40	60	100
5	Major Elective –Computer Oriented Numerical Methods/ Computer programming in C++		5	3	25	75	100
Semester II							
6	Mathematical Physics-II		5	3	25	75	100
7	Electromagnetic theory		4	3	25	75	100
8	Statistical Mechanics and Thermodynamics		4	3	25	75	100
9	Practical II-General Physics		5	4	40	60	100
10	Major Elective – Nano Physics/ Introduction to Particle Physics/ Medical Physics		5	3	25	75	100
Semester III							
11	Solid State Physics – I		4	3	25	75	100
12	Quantum Mechanics – I		4	3	25	75	100
13	Molecular spectroscopy		4	3	25	75	100
14	Practical –III – Electronics		5	4	40	60	100
15	Non Major Elective- Non conventional energy sources/ Introduction to Nanotechnology		5	3	25	75	100
Semester-IV							
16	Solid State Physics – II		4	3	25	75	100
17	Quantum Mechanics – II		4	3	25	75	100
18	Nuclear and Particle Physics		4	3	25	75	100
19	Practical IV – General Physics		5	4	40	60	100
20	Major Elective-Project/ Applied Optics and Laser Physics / Fiber Optic Communication		5	3	25	75	100
	Total		90				2000

- **To understand various mathematical techniques and concepts**
- **To apply these techniques to solve physics problems.**

Unit I: Vectors

Integral forms of gradient, divergence and curl-line, surface and volume Integrals-Gauss, Stokes's and Green's theorem (plane)- statement and proof-scalar, gravitational and centrifugal potentials-applications- curvilinear coordinates-gradient, divergence and curl in Cartesian, spherical, cylindrical coordinates-equation of continuity- equation of heat flow in solids.

Unit II: Linear vector space and Matrices

Linear vector space-subspace, and dimensions-linearly dependent, independent and orthogonality vectors-inner product Space-Gram-Schmitt's orthoganalization method-Hilbert space-Schwartz inequality.

The Algebra of matrix- special matrices (orthogonal, unitary and Hermition), properties and applications-solution of linear equation- linear transformation - Eigen values and Eigen Functions-Caley-Hamilton's theorem and applications-Diagonalisation- Kroneckersum and product of matrix- Dirac and Pauli's matrix.

Unit III: Fourier series, Fourier integrals and Fourier transform

Dirichlets condition- determination of coefficients-function having arbitrary period-half range expansion in some typical wave form-applications of Fourier series in forced vibrations-Fourier integral-Representation of more complicated periodic phenomena-Fourier transform-Properties of Fourier transform (Linearity, similarity, modulation, convolution and Parseval'sindentity)-Fourier transform of derivatives-Fourier sine and cosine transform of derivatives-Function of two or three variables-Infinite Fourier transform- Some applications of Fourier transform.

Unit IV: Special function

Gamma and beta functions-properties and some basic relations- differential equation and series solution of Legendre and Bessel's and their polynomials - Laguerre polynomial-Rodrigue's formula for Legendre polynomials-generating function for $P_n(x)$ and $J_n(x)$ –recurrent relation-orthogonality relation. Hermite differential equation and Hermite polynomials-generating function of Hermite Polynomials-Recurrence formula for HermitePolynomials-Rodriguez formula for Hermite polynomial-orthogonality of Hermite polynomial.

Unit V Partial differential equation

Characteristics and boundary condition for PDEs-nonlinear particle differential equations- separation of variables in Cartesian, cylindrical and spherical polar coordinates-heat equation, Laplace equation and Poisson equations-non homogenous equation-Green's function-symmetry of Green function-Green function for Poisson equation-Laplace equation and Helmholtz equation-applications of Greens function in scattering problem.

TEXT BOOK:

1. Mathematical Physics and Classical Mechanics, Sathyaprakash, Sultan Chand &Sons, 2005

REFERENCE BOOKS:

1. Mathematical Physics, Eugene Butkov, Addition Wesley
2. Applied Mathematics for Engineers and Physicist, Pipes and Harvil
3. Matrices and Tensors, A.W.Joshi II Edition, Wiley Eastern Ltd, 1984
4. Chemical Applications of Group Theory, F.Albert Cotton II Edition
5. Mathematical Physics, B.D Gupta III Edition, 2005, Vikas publishing House Pvt.Ltd, New Delhi.
6. Mathematical Method for Physicist, G.Arfken and J.Weber IV Ed Academic press and prism book (1995)
7. Mathematical methods for Physics J.Mathews and R.C Walker, Addison-Wesley, 2nd Edition.
8. Advanced Engineering Mathematics, Erwin Kreyszig,IV Ed, New Age International
9. Mathematical Physics, H.K.Dass IV Ed,2004 S.Chand & company Ltd

I M.Sc., Physics	Major Paper- 2	Marks :100
Semester I	**Classical Mechanics**	Hrs/Week :6
Code:		INT:25, EXT:75

- **To know classical mechanical methods and theories**
- **To understand classical mechanical transformations, oscillations and concepts**
- **To apply them to solve physics problems**

Unit –I Lagrangian and Hamiltonian methods

Generalized coordinates - Lagrangian equation of motion- Variational principle and Lagrangian equation of motion – Hamiltonian equation of motion – Cyclic coordinates and Routh's procedure – Physical significance of the Hamiltonian – Hamiltonian equations form variational principle-The principle of least action - Simple applications.

UNIT –II Central field motion

Motion under a central force – General features of central force motion- Reduction of two body central force problem to the equivalent one body problem- Equation of amotion in a central field. Equation of orbit in a central field- condition for closed orbit (Bertrand's theorem)- The virial theorem- Kepler's law of planetary motion-scattering in a central force field- Rutherford's Alpha Particle Scattering.

Unit III Canonical Transformations

The equation of Canonical Transformations - examples of Canonical Transformations – Harmonic Oscillator- Lagrange and Poisson bracket – Equation of motion in Poisson bracket notation- Liouville's theorem.

Unit-IV Small oscillations

Formulation of the Problem-Eigen value equation and the principle axes Transformation-Frequencies of free vibrations and normal Coordinates-Free vibrations of a linear triatomic molecule and some macroscopic applications.

Unit –V Hamilton- Jacobi theory

Hamilton-Jacobi equation – Applications: Harmonic Oscillator and Kepler's Problem – The Hamilton –Jacobi equation for Hamilton's characteristic's function-Action and Angle variables- Harmonic Oscillator problem using action and angle variables- Kepler's problem in action- Angle variable

TEXT BOOK:

1. Classical Mechanics, H. Goldstein, II edn. (1980, Narosa). World student Edn

   Chapter: 3, 6 ,8,9,10 revelent sections.

REFERENCE BOOKS:

1. Mechanics, L.D. Laudau and E.M. Lifshitz
2. Classical Mechanics, T.W.B. Kibble
3. Classical Mechanics, N.C. Rana and P.S. Juog

I M.Sc., Physics	Major Paper- 3	Marks :100
Semester I	**APPLIED ELECTRONICS**	Hrs/Week :6
Code:		INT:25, EXT:75

COURSE OBJECTIVES:

- **To be familiar with various semiconductor devices and amplifier systems**
- **To understand various wave generators, wave shaping systems**
- **To develop skills in handling combinational sequential circuits**

UNIT I SEMICONDUCTOR DEVICES

Field effect transistor: The ideal voltage controlled current source – the Junction Field Effect transistor – the JFET volt – ampere characteristics – JFET transfer characteristics – The MOSFET – The enhancement MOSFET – volt – ampere characteristics – The depletion MOSFET – MOSFET circuit symbols – The DC analysis of FETS – The MOSFET as a resistance – switch – amplifier – small – signal FET models – CMOS devices.

UNIT II AMPLIFIER SYSTEMS

Operational amplifier – architectures – The gain stage with active load – The differential stage – DC level shifting – output stages – offset voltages and currents – Measurements of op– amp parameters – Frequency response and compensation – slew rate.

UNIT III WAVE FORM GENERATORS AND WAVESHAPING

Wave form Generators and wave shaping: Sinusoidal oscillators – Phase shift: oscillator – Wien bridge oscillator – General form of oscillator configuration – crystal oscillators – multivibrators – comparator – square - wave generation from a sinusoid – Regenerative comparator – Square and triangle - wave generators – pulse generators – The 555 IC timer – voltage time - base generators – step generators – modulation of a square wave.

UNIT IV DIGITAL CIRCUITS AND SYSTEMS

Combinatorial – Digital circuits: Standard Gate assembling Binary adders – Arithmetic functions – Digital comparators – Parity checker – Generators – Decoder - Demultiplexer – Data selector – multiplexer encoder – Read only Memory (ROM) – Two dimensional addressing of a ROM – ROM applications – programmable ROMs. – Erasable PROMS – programmable array logic – programmable logic arrays. Sequential circuits and systems: A1 Bit memory – The circuit properties of a Bistable Latch – The clocked SR Flip flops. J - K, – T -, and D - type Flip flops – shift registers – Ripple counters – Synchronous and Asynchronous counters – Application of counters.

UNIT V VERY LARGE SCALE INTEGRATED SYSTEMS

Dynamic MOS shift registers – Ratioless shift register stages – CMOS Domino logic - Random Access Memory (RAM) – Read - write memory cells – Bipolar RAM cells – Charge coupled device (CCD) – CCD structures – Integrated - Injection logic – Microprocessors and Microcomputers.

TEXT BOOK:

1. Micro Electronics (II ed.), Millman, J &Grabel, A.: Tata McGraw Hill, 2002, ISBN 0-07- 463736-3.

   Unit – I Chapter- 4
   Unit – II Chapter-14
   Unit – III Chapter-7 & 8
   Unit – IV Chapters-9
   Unit – V Chapters-15

REFERENCE BOOK:

1. Digital Principles and application (VI ed.) Malvino, A.P. & Leech, D andGoutamSaha : Tata McGraw Hill, 2006, ISBN 0-07- 060175-5.

I M.Sc., Physics	Major Paper- 4	Marks :100
Semester I	**PRATICAL –I**	Hrs/Week :8
Code:	**ELECTRONICS**	INT:40, EXT:60

Any eight Experiments

1.FET Amplifier

2.Amplitude modulation

3. Operational amplifier characteristics

4. Phase shift oscillator

5.Wien Bridge oscillator

6.Saw tooth wave generator

7. Emitter follower

8.UJT –Relaxation oscillator

9. Two stage RC coupled amplifier – With and without feedback

10.. Wave shaping circuits

11. Passive filter circuits - low high and band pass filters.

12. Determination of Planck's constant

I M.Sc., Physics	Major Paper- 5 (a)	Marks :100
Semester I	**MAJOR ELECTIVE –**	Hrs/Week :6
Code:	**COMPUTER ORIENTED NUMERICAL METHODS**	INT:25, EXT:75

Unit I

Iterative methods: Introduction – beginning an Iterative methods- the method of successive bisection- Newton Rapson Iterative method-the second method- The method of successive approximation- comparison of Iterative methods.

Unit- II

Solution of simulation algebraic equation - introduction-the gauss elimination method-pivoting-III condition equations. Refinement of the solution obtained by Gaussian elimination- the Gauss-Seidal iterative method – an algorithm to implement the Gauss-Seidal Method-Comparison of direct and iterative methods.

Unit – III

Interpolation: Lagrange Interpolation-difference Tables-Truncation error in interpolation-least squares approximation of function- linear regression- Algorithm for linear regression.

Unit – IV

Differentiation and integration: Formulae for numerical integration – Simpson's Rule-Gaussian Quadrature Formulae-Numerical solution of Differential Equations-Higher order equation.

Unit – V

Application to specific problem: program for solution of an equation by iterative method (Newton Raphson method) - Solution of simultaneous equation - Calculation of mean and variance - Calculation of correlation Coefficients-Linear regression - Solution of first order differential equation (Runge-Kutta method) - Solution of II order differential equation (Runge- Kutta method) - Evaluation of Definite integrals (Trapezoidal and Simpson rule) - Evaluation on inverse of a matrix - Evaluation of matrix polynomial. (Programs in C++ only)

TEXT BOOKS:

1. Computer oriented Numerical methods V.Rajaram II Edition 1989 Prentice Hall of India. Pvt.Ltd
2. Numerical Method for Scientific and Engineering Computation by M.K Jain S.R.K Iyengar, and R.K Jain, New Age International publishers.

REFERENCE BOOKS:

1. Elementary Numerical Analysis An Algorithmic Approach-S.D Conte & Carl de Boor, third Edition-McGraw Hill International company (1983)
2. Numerical Methods for Engineers – Steven C.Chopra. Raymond P.Canale-Second edition - McGraw Hill International Editions(1990)

I M.Sc., Physics	Major Paper- 5(b)	Marks :100
Semester I	**MAJOR ELECTIVE –**	Hrs/Week :6
Code:	**Programming in C++**	INT:25, EXT:75

UNIT I: INTRODUCTION

Identifiers & keywords - Literals – Operators – Type Conversion – Declaration of variables – Statements – Simple C++ program – Features of iostream.h – Manipulator Functions – Conditional Expressions – Switch Statement – Loop Statements - Breaking Control Statements.

UNIT II: FUNCTIONS, PROGRAM STRUCTURES & ARRAYS

Defining a function – Return statement – Types of functions – Actual and Formal Arguments – Local and Global variables – Default Arguments – Structure of the C++ program – Header files – Array Notation – Array Declaration- Array Initialization – Processing with Array – Arrays & Functions – Multidimensional Arrays – Character Array.

UNIT III: POINTERS, STRUCTURES & UNIONS

Pointer Declaration – Pointer Arithmetic – pointers and Functions – Pointers and Arrays – Pointers and Strings -Array of Pointers – Pointers to pointers – Declaration of Structure –

Initialization of Structures – Arrays of Structures – Arrays within a Structure – Structures within a Structure (Nested Structure) Pointers & Structures – Unions

UNIT IV: CLASSES AND OBJECTS

Introduction – Structures and classes – Declaration of class – Member Functions – Defining the object of a class – Accessing a member of class – Array of class objects – Pointers and classes – Unions and classes – Classes within classes (nested class) – Constructors-Destructors

UNIT V: INHERITANCE AND POLYMORPHISM

Introduction – Single Inheritance – Types of Base Classes- Type of Derivation – Ambiguity in Single Inheritances- Multiple Inheritance – Polymorphism – Early Binding – Polymorphism with pointers – Virtual Functions – Constructors under Inheritance.

TEXT BOOK:

1. D. Ravichandran, Programming with C++, Third edition, Tata McGraw Hill Publishing Company Ltd.,2011.

   Unit I-Ch.3, 4 &5 (Sec.3.1, 3.4, 3.7-3.14, 4.2, 4.4, 4.6, 4.8, 5.1., 5.1.1. - 5.1.3., 5.2, 5.4)

   Unit II-Ch. 6 & 7 (Sec.6.2 – 6.9, 6.18, 7.2 – 7.8)

   Unit III-Ch.8 & 9 (Sec.8.1 - 8.3, 8.6 – 8.9, 9.2, 9.4, 9.6 - 9.10)

   Unit IV-Ch.10 & 11 (Sec.10.1 – 10.10, 11.2, 11.3)

   Unit V-Ch.12 & 14 (Sec.12.1 – 12.5, 12.7, 14.1 -14.4, 14.8)

REFERENCE BOOKS:

1. YashavantKanettkar, Let us C++, 2nd edition, BPB Publications, 2013.
2. E. Balagurusamy, Object Oriented Programming with C++, 6th edition,

I M.Sc., Physics	Major Paper- 6	Marks :100
Semester II	**MATHEMATICAL PHYSICS-II**	Hrs/Week :6
Code:		INT:25, EXT:75

Objectives:

- **To know various Mathematical techniques**
- **To understand various Mathematical concepts**
- **To apply these techniques and concepts to solve Physics problems**

UNIT I: COMPLEX VARIABLES

Analytic Function-Cauchy-Riemann Equation-C-R in polar form-complex line Integral-Cauchy integral Theorem-Cauchy integral formula-derivative of analytic function (nth derivative)-expansion of analytic function-singular points and their classification- Singular point – Isolated singularity – Removal of singularity -Laurent's series

UNIT II COMPLEX INTEGRATION

Cauchy-Residue theorem – Residue – Calculation of residue at simple poles and poles of higher order – Evaluation of definitive integrals – Integration around unit circle – rectangular Contour-Jordan lemma – Semicircular contours – Poles on the real axis-integral of the form $\delta N\ F(x)\ dx$.

UNIT III TENSORS

Scalar, vector and tensors – difference between a tensor and a transformation matrix – second rank tensor – Definition – Examples – Contra variant, covariant and mixed tensors – Tensors in higher ranks- addition, multiplication and contraction of tensor Quotient law-metric tensor– Tensors in EM theory – Invariance of Maxwell's equations. Dirac delta function: Definition – properties – Delta sequence - Examples – Delta calculus.

UNIT IV: GROUP THEORY

Definition and nomenclature-rearrangement theorem-cyclic groups- Abelian groups - sub group and co sets - conjugate elements and class structure-identification of symmetry element and operations-molecular point groups-matrix representation of symmetry operations – the Great orthogonality theorem – character of representation-character table-generating symmetry operation-construction of character tables-irreducible representation of C_{2v} and C_{3v} groups-symmetry species-specifications-SU(2) and SU(3) groups in elementary particles.

UNIT V: PROBABILITY

The binomial distribution- the normal or Gaussian distribution-distribution of sum of normal variables - application to experimental measurements-the standard deviation about the mean.

TEXT BOOKS:

1. Mathematical Physics and Classical Mechanics, Sathyaprakash, Sultan Chand &sons, 2005
2. Matrices and Tensors, A.W. Joshi
3. Chemical applications of Group theory, F. Albert Cotton, II Ed.,
4. Probability, Seymour Lipschutz, Kanchan Jain, Schaum's outline series, McGraw Hill

I M.Sc., Physics	Major Paper- 7	Marks :100
Semester II	**ELECTROMAGNETIC THEORY**	Hrs/Week :6
Code:		INT:25, EXT:75

- **To be familiar with electromSagnetic theory**
- **To understand electromagnetic concepts**
- **To apply these theory and concepts to solve the Physics problems**

UNIT I - ELCTROSTATICS

Electric charge-Coulombs law -Electric field - Electrostatic potential- Gauss's Law-Applications of Gauss's Law-electric dipole-multipole expansion of electric fields- Poisson's equation - Laplace equation-Laplace equation in one independent variable-solutions to Laplace equation in spherical coordinates- Polarization -Field outside of a Dielectric medium -The electric field inside a dielectric-Gauss law in dielectric- The electric displacement – electric susceptibility and dielectric constant

UNIT II - MAGNETOSTATICS

Magnetic Field-Magnetic induction- force on a current carrying conductor- Biot-Savart Law-Application of Biot-Savart Law-Ampere's circuital law - Magnetic vector potential-magnetic field of a distant circuit- Magnetic Scalar potential-magnetic Flux-Magnetization –Magnetic field produced by magnetized material -Magnetic scalar potential and magnetic pole density

UNIT III - ELECTRODYNAMICS

Electromagnetic Induction-Faradays Law – The induced electric field – Energy in magnetic fields -Maxwell's equations- electrodynamics Before Maxwell – How Maxwell fixed Ampere's law - Maxwell's equations –Magnetic charge Maxwell's equations in matter - Boundary Conditions.

UNIT-IV-ELECTROMAGNETIC WAVES

Waves in one dimension –Thewave equation – sinusoidal waves -Electromagnetic waves in vacuum-The wave equation for E and B-Monochromatic plane waves –energy and momentum in electromagnetic waves- electromagnetic waves in Matter- propagation in linear media – reflection and transmission at normal incidence- absorption and dispersion - electromagnetic waves in conductors.

UNIT-V –POTENTIALS AND FIELDS

The Potential formulation - Scalar and Vector Potentials- Gauge Transformation - Coulomb Gauge and Lorentz Gauge – Lorentz force law in potential form – continuous distributions – retarded potentials –Jefimenko's equations – point charge –Lienard-Wiechert potentials

TEXT BOOKS:

1. John R.Reitz, Fredrick J.Milford, Robert W.Christy, Foundations of Electromagnetic theory, Third edition,Norosa Publishing House,New Delhi,1989.

   UNIT – I Ch.2 (2.1, 2.2, 2.3, 2.4, 2.6, 2.7, 2.8, 2.9, 3.1,3.2, 3.3, 3.4.4.1-4.5)

   UNIT – II Ch.8 (8.1, 8.2, 8.3, 8.4, 8.5, 8.6, 8.7, 8.8, 8.9,9.1,9.2,9.3)

2. David J.Griffiths, Introduction to Electrodynamics, Third edition, PHI Learning Private Limited,2012.

   UNIT – III Ch.7 (7.2.1,7.2.2, 7.2.4,7.3.1-7.3.6)

   UNIT – IV Ch.9 (9.1.1,9.1.2 ,9.2.1-9.2.3,9.3.1,9.3.2 &9.4.1)

   UNIT – V Ch.10 (10.1.1 -10.1.4 10.2.1,10.2.2 ,10.3.1)

REFERENCE BOOKS:

1. Paul Lorrain and Dale Corson, Electromagnetic Fields and waves, 2nd Edition, CBS Publishers & distributors,1986
2. Edward C.Jorden, Keith, G.Balmin,Electromagnetic waves and Radiating systems, Edward, Prentice-Hall of India.,New Delhi,1988.

I M.Sc., Physics	Major Paper- 8	Marks :100
Semester II	**STATISTICAL MECHANICS AND THERMODYNAMICS**	Hrs/Week :6
Code:		INT:25, EXT:75

Objectives:

- To describe the state of the system at equilibrium under various physical parameters.
- To discuss the physical properties of matter in bulk on the basis of the dynamical behavior of its microscopic constituents.
- To describe the statistical thermodynamic parameters for ideal gas and solids.

UNIT: I

Thermodynamic Potential – The laws of thermodynamics and their consequences – Combined first and second law of thermodynamics –The Helmholtz function and the Gibbs function – Thermodynamic potentials – Maxwell's relations – Stable and unstable equilibrium – Phase transition – The Clausius-Clapron equation – The third law of thermodynamics (Nernst Heat theorem).

UNIT: II

Application of Thermodynamics - Chemical potential – Phase equilibrium and phase rule – The Gibbs-Duhem Equation – Dependence of vapour pressure on total pressure – Surface tension – Vapour pressure of a liquid drop – The reversible voltaic cell – Thermodynamics of Blackbody radiation – Thermodynamics of magnetism.

UNIT: III

Statistical Mechanics - The Statistical basis of thermodynamics –Energy states and energy levels – Microstates and macrostates – Thermodynamic probability - Contact between statistics and the thermodynamics: physical significance of the number –Ensemble: Phase

space of a system - Lowville's theorem and its consequences - Canonical, Micro canonical, Grand canonical – density of states and connection to entropy.

UNIT: IV

Statistical Thermodynamics– Statistics: Bose-Einstein, Fermi-Dirac and Maxwell-Boltzmann statistics – The statistical interpretation of entropy. Distribution function: Bose-Einstein, Fermi-Dirac, Maxwell-Boltzmann– Comparison of distribution functions for indistinguishable particles – The partition function of a system – Thermodynamic properties of a system.

UNIT: V

Statistical Thermodynamics - Applications – The monoatomic ideal gas – The Sackur-Tetrode equation for the monoatomic ideal gas – The distribution of molecular velocities – The Principle of equipartition energy –The quantized linear oscillator – The Einstein theory of the Specific heat capacity of a solid – The Debye theory of the specific heat capacity of solid – Black body radiation.

TEXT BOOK:

1. **Thermodynamics, Kinetic theory and Statistical Thermodynamics** - F. W. Sears and G. L. Salinger, third edition, Narosa Publishing House,2013.

   UNIT: I : Chapter 7
   UNIT: II : Chapter 8
   UNIT: III : Chapter 11 and Ensembles* - reference book (1)
   UNIT: IV : Chapter 11
   UNIT: V : Chapter 12 and 13

REFERENCE BOOKS:

1. **Statistical Mechanics** -R K Pathria&Paul D. Beale, Elsevier-Academic Press, 3rd Edition, 2011
2. **Fundamentals of Statistical and Thermal Physics -** Frederick Reif, McGraw-Hill (e-Book: https://www.scribd.com/doc/205016520/Reif-Fundamentals of statistical and thermal physics).
3. **Fundamentals of Statistical Mechanics –** BB Laud, New Age International Publisher

I M.Sc., Physics	Major Paper- 9	Marks :100
Semester II	**PRACTICAL –II**	Hrs/Week :8
Code:	**General Physics**	INT:40, EXT:60

Any Eight experiments

1. Error Analysis and least squares
2. Refractive index of liquid using hollow prism
3. Cauchy's constants

4. Hyperbolic fringes
5. Elliptical fringes
6. Anderson's bridge
7. Mutual inductance using Carey Foster's bridge
8. Numerical integration
9. Wien's bridge
10. Owen's bridge
11. Optic bench- Biprism Experiment
12. Michelson's Interferometer.
13. Physical characteristics of thermistor

I M.Sc., Physics	Major Paper- 10 (a)	Marks :100
Semester II	**MAJOR ELECTIVE –**	Hrs/Week :6
Code:	**NANO PHYSICS**	INT:25, EXT:75

- **To be familiar with basic concepts of Nano Physics**
- **To understand various techniques used in Nano Physics**
- **To apply these concepts and techniques for practical applications**

Unit I

Introduction – Nano structures – Nano crystalline materials - Electron microscopy – Electron microscope – General consideration for imaging – Analytical and imaging techniques – Sample preparation – Advantages and Disadvantages of electron microscopes – Transmission electron microscope – Background – High resolution Transmission electron microscopy – Preparation and visualization of samples – Imaging simulation – Particle size analysis – Scanning electron microscope – detection of secondary electrons - detection of Backscattered electrons - Secondary electron imaging – Microscope imaging – Scanning probe microscopy – Imaging structures.

Unit II

Atomic force microscopy – Theory – Piezoelectric ceramic transducer – AFM instrumentation – Imaging modes – Measuring images with AFM – Resolutions in Atomic force microscope - Probe surface interactions - Surface contamination – Electrostatic forces – Surface material properties – Vibrating sensing mode – Torsion modes – Mechanical surface modification – Electrical surface modification - Atomic force microscopy for nanoparticles – Qualitative analysis – Techniques – Direct growth by Chemical vapour deposition of AFM tips – CVD MWNT tip preparation - CVD SWNT tip preparation – Sample preparation – Nanolithography – Adhesive mask technique – Photolithography – resolution in projection systems – Limitations – Perspectives – Electron beam lithography – Electron energy deposition in matter – Spatial-phase-locked Electron beam lithography

Unit III

Fabrication of nanostructures – Milling – Lithographic processes – Lift-off process – Vapour phase deposition methods of fabrication – Plasma-assisted deposition methods of fabrication – DC glow discharge – Magnetron sputtering – Vacuum arc deposition – Nanofabrication by scanning probe techniques – By Scanning force probes – Electrical structure generation by SFM – By Scanning tunneling microscope – Growth and characterization techniques – Molecular beam epitaxy – MBE apparatus – MOVPE – Liquid phase methods – Colloidal methods – Sol-gel methods – basic process –Electro deposition

Unit IV

Properties of individual nanoparticles – Metal nanoclusters – Magic numbers - Theoretical modelling of nanoparticles – Geometric structure – Electronic structure – Reactivity – Fluctuations – Magnetic clusters – Bulk to Nano transition – Carbon nanostructures – Carbon molecules – Carbon clusters – Carbon nanotubes – Applications of carbon nanotubes

Unit V

Quantum Wells, Wires and Dots – Preparation of quantum nanostructures – Size and dimensionality effects – Excitons – Single electron tunneling – Applications – Superconductivity – Microelctromechanical systems – Nanoelectromechanical systems

TEXT BOOKS:

1. Instrumentations and Nanostructures by A.S. Bhatia, NuTech books, 2009

Unit I – Page 192-194, 201 -204, Page 1 – 26, Page 52 – 64

Unit II – Page 65 – 86, Page 124 – 151

Unit III – Page 219 – 249

2. Introduction to Nanotechnology by Charles P. Poole Jr and Frank J. Owens, Wiley Student edition, Reprint 2008

Unit IV – Page 72 – 89, Page 103 – 132

Unit V – Page 226 – 256, Page 332 – 345

I M.Sc., Physics	Major Paper- 10 (b)	Marks :100
Semester II	**MAJOR ELECTIVE – INTRODUCTION TO PARTICLE PHYSICS**	Hrs/Week :6
Code:		INT:25, EXT:75

UNIT I

Historical introduction- Origin of isospin and strangeness.

UNIT II

Relativistic kinematics - Decay and two body scattering, Relativistic wave equation– Klein-Gordon and Dirac equations.

UNIT III

Symmetry: Discrete and Continuous groups - classification of particles - mesons, baryons and quarks - SU(n) symmetry - origin of colors.

UNIT IV

Electromagnetic interactions- Feynman rules for electrodynamics - electron-electron and electron-nucleon scattering - Rosen-Bluth formula - Deep inelastic scattering – introduction to Proton model, Weak interactions - Fermi theory - CP violation – introduction to neutrino oscillations.

UNIT V

Brief discussion of electro-weak theory - symmetry breaking - Higgs mechanism and the origin of mass - QCD and the standard model. Interface between particle physics and astrophysics – cosmology – big bang theory - dark matter - origin of dark energy.

REFERENCE BOOKS:

1. Particle Physics by Griffiths.
2. Quarks and Leptons by Halzen and Martin.
3. Quantum Mechanics by L. I. Schiff.
4. Nuclear and Particle Physics by W. E. Burcham and M. Jobes.

I M.Sc. Physics	Major Paper- 10 (c)	Marks :100
Semester II	**MAJOR ELECTIVE –**	Hrs/Week :6
Code:	**MEDICAL PHYSICS**	INT:25, EXT:75

Unit I

Sound in Medicine: General properties of sound, the body as a drum (percussion in medicine) The stethoscope, ultrasound pictures of the body, ultrasound to measure motion, physiological effects of ultrasound in therapy, the production of speech.

Physics of the ear and hearing: The outer ear, the middle ear, the inner ear, sensitivity of the ears, testing your hearing, deafness and hearing aids

Unit II

Light in Medicine: Measurement of light and its units, applications of visible light in medicine, applications of ultraviolet and infrared light in medicine, Lasers in Medicine applications of microscopes in medicine.

Physics of eye and vision: Focusing elements of the eye, some other elements of the eye, the retina – the light detector of the eye, how sharp are your eye? Optical illusions and related phenomena, defective vision and its correction, colour vision and chromatic aberration, instruments used in ophthalmology.

Unit-III

Ionising radiation and dosimetry: Generation of radiation, Interaction of charged particles with matter, interaction of high energy photons with matter, radiation depth of interaction, range, attenuation curves, dose and exposure measurement, maximum permissible levels, overview of measurement methods: film dosimeters, thermo luminescent dosimetry (TLD), dose measurement during radiography.

Unit-IV

Radioisotopes and nuclear medicine: Diagnosis with radioisotopes, isotopes, half-life, nuclear radiations, energy of nuclear radiations, units of activity, isotope generators, principles of measurement: counting statistics, sample counting, liquid scintillation counting, non-imaging investigations examples: haematological measurements, Glomerular filtration rate, radionuclide imaging, bone imaging, dynamic renal function.

Unit-V

Image Production: Radionuclide imaging: the gamma camera, energy discrimination, collimation, image display, single-photon emission tomography (SPET), positron emission tomography (PET), ultrasonic imaging: pulse–echo techniques, tissue interaction with ultrasound, transducer arrays, applications: Doppler imaging, CT imaging: absorption of X-rays, data collection, image reconstruction, beam hardening, spiral CT.

TEXT BOOKS:

1. Medical Physics–John R.Cameron& James G.Skofronick (John Wiley&Sons,New York1978)
2. B.H. Brown, R.H. Smallwood, D.C. Barber, P.V. Lawford, and D.R. Hose, Medical Physics and Biomedical Engineering, Institute of Physics Publishing, 1999
3. S.A. Kane, Introduction to Physics in Modern Medicine, CRC Press, 2009

REFERENCE BOOKS:

1. F.M. Khan, and J.P. Gibbons, Khan's the physics of radiation therapy. Lippincott Williams and Wilkins, 2014.
2. P. Suetens, Fundamentals of Medical Imaging. Cambridge university press, 2017.
3. W.J. Meredith, and J.B. Massey, Fundamental Physics of Radiology. Butterworth-Heinemann, 2013.

II M.Sc., Physics	Major Paper- 11	Marks :100
Semester III	**SOLID STATE PHYSICS- I**	Hrs/Week :6
Code:		INT:25, EXT:75

- **To be familiar the basics of crystal structures**
- **To understand the concepts of crystal structures**
- **To apply the acquired knowledge and understanding to solve problems**

UNIT I: CRYSTAL PHYSICS

Periodic arrays of atoms: Lattice Translation vectors – Basis and the Crystal Structure – Primitive lattice cell – Fundamental types of lattices: Two and three dimensional lattice types – Miller indices of Crystal Planes – Simple crystal structures:NaCl, hcp – Diffraction of waves by crystals- Bragg law — Reciprocal Lattice Vectors – Laue equations – quasi crystals.

UNIT II: CRYSTAL BINDING AND ELASTIC CONSTANTS

Crystals of inert gases (Vander walls – London interaction) – Ionic Crystals (Madelung Constant) – Covalent crystals - Metals – Hydrogen bonds – Atomic Radii — Elastic Compliance and Stiffness Constants – Elastic waves in cubic crystals.

UNIT III: PHONONS

Quantization of Elastic waves (phonons) – phonon momentum – Inelastic scattering by phonons – phonon heat capacity – plank distribution- Density of states in one and three dimension – Debye and Einstein model of density of state– Anharmonic crystal interactions – Thermal resistivity of phonon gas – umklapp processes.

UNIT IV: FREE ELECTRON FERMI GAS

Free electron gas in three dimensions – Heat capacity of the electron gas- Electrical conductivity and ohms law– Hall effect – Wiedmann Franz law, Nearly Free Electron Model: Origin and Magnitude of energy gap – Bloch functions – Kronig Penny Model – wave equation of an electron in a periodic potential: Bloch theorem-crystal momentum of an electron.

UNIT V: SEMI CONDUCTORS, FERMI SURFACES AND METALS

Band gap – Equations of Motions – Effective Mass –physical interpretation of the effective mass- Fermi Surface and Metals: Reduced Zone Scheme – Periodic Zone Scheme – Construction of Fermi Surfaces- Fermi surface of Cu - Calculation of energy band: Tight binding method - Wigner Seitz method –Idea of de Has Van Alphen Effect

TEXT BOOK:

1. Charles Kittel, Introduction to Solid State Physics VII Edition Wiley India Pvt. Ltd., 2011.
   Unit I-Ch. 1& 2 (pg3-19, 29-34, 36,37,48,49)
   Unit II-Ch. 3 (pg55-62, 66-79, 83-90)
   Unit III-Ch. 4 & 5(pg107-111, 117-130, 133-137)
   Unit IV-Ch. 6 & 7(146-155, 156-159, 164-167, 176-186)
   Unit V-Ch.8 & 9. (pg199-206, 209-212, 235-242, 244-252,262)

REFERENCE BOOKS:

1. S.O.Pillai ,Solid state physics - V Edition New Age Int. Ltd.
2. J.P. Srivastava, Elements of Solid state physics- Prentice-Hall of India Pvt. Ltd.

II M.Sc., Physics	Major Paper- 12	Marks :100
Semester III	**QUANTUM MECHANICS – I**	Hrs/Week :6
Code:		INT:25, EXT:75

COURSE OBJECTIVES:

- To understand basic concepts in Quantum Mechanics.
- To throw light on the formulation of Schrodinger, Dirac and Heisenberg mechanics
- To have a glimpse of perturbation theory and its applications.
- To study in detail, the effect of magnetic and electric field on quantum particles.

UNIT I: EQUATION OF MOTION OF MATTER WAVES

Time independent Schrodinger equation – Schrodinger equation for a free particle – Time dependent Schrodinger equation – Physical interpretation of wave function – Normalized and orthogonal wave functions – Solution of Schrodinger equation – Stationary state solution – Expectation values – Probability current density – Superposition of plane waves – Formulation of Schrodinger equation in momentum representation – Uncertainty principle – one dimensional square well potential – Linear Harmonic oscillator – Hydrogen atom.

UNIT II: MATRIX FORMULATION OF QUANTUM MECHANICS

Matrix algebra – types of matrices – Hermitian and unitary matrices – Hilbert space – Dirac's bra and Ket notation. Physical meaning of matrix elements – Equations of motion – Schrodinger picture – Heisenberg picture – Interaction picture – Poisson brackets and Commutator brackets – Matrix theory of Harmonic oscillator.

UNIT III: GENERAL FORMALISM OF QUANTUM MECHANICS

Linear Operator-Eigen functions and Eigen values- Hermitian Operator-postulates of quantum mechanics- Dirac's notation- Equations of motion.

UNIT IV: ANGULAR MOMENTUM STATES

Commutation relations for the generators – Choice of representation, Construction of angular momentum matrices – Combination of Angular momentum states – Eigen values of the total Angular momentum – ClebschGordan coefficients – Recursion relations – Construction procedure – $j_1 = 1/2$, $j_2 = 1/2$

UNIT V APPROXIMATION METHODS FOR BOUND STATES

Stationary perturbation theory – non degenerate case – First order perturbation – Evaluation of first order Energy – Evaluation of first order correction to wave function –Zeeman effect without electron spin – First order stark effect in hydrogen atom – Variation method: Expectation value of the energy – Application to excited states – Ground State of Helium atom – Variation of the parameter Z.

TEXT BOOKS:

1. Quantum Mechanics (III ed.), Schiff, L.I.: McGraw Hill, 1968, ISBN-0-07-085643-5.
2. Quantum Mechanics,Satyaprakash& Swati Satya:KedarNath Ram Nath& Co, 2006.
3. Quantum MechanicsAruldhas, J, Prentice – Hall of India, 2002, ISBN81- 203-1962.

REFERENCE BOOKS:

1. A Text Book of Quantum Mechanics, Mathews, P.M. &Venkatesan, K., Tata McGraw Hill, 1978, ISBN 0-07-096510-2.
2. Quantum Mechanics (II ed.), Bransden, B.H. &Joachain, C.J: Pearson Education, 2005.ISBN 81-297-0470-6.
3. Quantum Mechanics (III ed.), Merzbacher, E: John Wiley, 2004, ISBN9971- 51-281-5.
4. Introduction to Quantum Mechanics Ghatak, A: Macmillan, 1996, ISBN0333- 92419

II M.Sc., Physics	Major Paper- 13	Marks :100
Semester III	**MOLECULAR SPECTROSCOPY**	Hrs/Week :6
Code:		INT:25, EXT:75

UNIT I: MOLECULAR SYMMETRY

Molecular spectroscopy – introduction – experimental methods – information derived from work on gases – applications – symmetry operations – symmetry elements

UNIT II: ROTATION OF MOLECULES

Classification of Molecules-Interaction of radiation with rotating molecule-Rotational spectra of rigid diatomic molecules-Isotope effect in rotational spectra –Intensity f rotational lines-Non-rigid rotator-Vibrational excitational effect-Linear polyatomic molecules-Symmetric top molecules-Asymmetric top molecules-Stark effect- Quadrupole hyperfine interactions-Microwave spectrometer-Information derived from rotational spectra

UNIT 3: INFRARED SPECTROSCOPY

Vibrational energy of a diatomic molecule- Infrared spectra; Preliminaries –Infrared section rules- Vibrating diatomic molecules-Diatomic vibrating rotator- Asymmetry of rotation-

Vibration band-vibration of polyatomic molecules-More about unharmonicity-Fermi resonance-Hydrogen bonding-Rotation-Vibration spectra of polyatomic molecules-Normal modes of vibration in crystal- Solid state effects-Interpretation of vibrational spectra-Group frequencies-Inversion vibration of ammonia-IR spectrophotometer-Instrumentation-Sample handling techniques.

UNIT 4: RAMAN SCATTERING

Theory of Raman Scattering-Rotational Raman Spectra-Vibrational Raman spectra-Mutual exclusion principle-Raman spectrometer-Sample handling techniques-Fiber coupled Raman spectrometer-Polarization of Raman scattered light- Single crystal Raman spectra-Structure termination using IR and Raman spectroscopy.

UNIT 5: ELECTRONIC SPECTRA OF DIATOMIC MOLECULES

Vibrational coarse structure- Vibrational analysis of band systems-Deslandres table – Progressions and Sequence-Information derived from vibrational Analysis-Frank-Condon principle - Intensity of vibrational electronic spectra - Rotational fine structure of electronic, vibration spectra- The Fortrat parabola –Dissociation-Pre Dissociation-Electronic angular momentum in diatomic Molecules-Photo electron spectroscopy.

TEXT BOOK:

1. Molecular structure and spectroscopy, G. Aruldhas, prentice Hall of India 2001
2. Fundamentals of Molecular Spectroscopy, C.N. Banwell, Tata McGraw-Hill Education, 1994

II M.Sc., Physics	Major Paper- 14	Marks :100
Semester III	**PRACTICAL –III**	Hrs/Week :6
Code:	**Electronics**	INT:40, EXT:60

Any eight Experiments

1. Universal NAND and NOR gates
2. Verification of De Morgan's theorem and Boolean functions
3. Active filters –Low, High and band pass filter
4. IC 555 Timer – Square wave generation
5. Solve simultaneous equation (Two variables only) using IC 741
6. JK flip-flop-Up and Down counters
7. Half adder and Full adder circuits using IC's
8. Optimization of Boolean functions-Karnaugh Map Method
9. Notch filter using IC and study of it's characteristic.
10. Microprocessor based Experiments-Addition, subtraction and Multiplication
11. Study of Wide band amplifier
12. Ring counter

II M.Sc., Physics	NON MAJOR ELECTIVE – 15(a)	Marks :100
Semester III	**NON-CONVENTIONAL ENERGY SOURCES**	Hrs/Week :6
Code:		INT:25, EXT:75

Objectives:

- **To be familiar with various forms of non-conventional energy**
- **To understand the salient features of non-conventional energy**
- **To appreciate the various applications of non-conventional energy**

UNIT: I

Classification of energy resources – Consumption trend of primary energy sources – importance of non-conventional energy sources – Advantages and disadvantages of conventional energy sources – salient features of non-conventional energy sources – Environmental aspects of energy –World energy status.

UNIT: II

Solar Energy Basics – Introduction – The Sun as a source of energy – Extraterrestrial and Terrestrial radiations – Spectral distribution of solar radiation –Depletion of solar radiation – Measurements of solar radiation – Solar collectors –Classification – Liquid flat plate collector – tubular collector – Solar water heater – Box type solar cooker

UNIT: III

Wind energy – Introduction – Global winds – Local winds – nature of winds –Wind turbine siting – Major applications of wind power – Horizontal axis wind turbine – Environmental aspects – Wind energy programme in India

UNIT: IV

Biomass Energy – Introduction – useful forms of biomass, their composition and fuel properties – Biomass resources – Biomass gasification – Downdraft type – Updraft type – Biogas production from waste biomass – Availability of raw materials and gas yield - Biomass energy programme in India

UNIT: V

Geothermal energy – Introduction – Applications – Origin and distribution of geothermal energy – Tidal energy - Origin and nature of tidal energy – Limitations of tidal energy – Ocean thermal energy – Origin and characteristics of resource - Ocean thermal energy conversion technology.

TEXT BOOK:

Non-Conventional Energy resources, B H.Khan, McGraw Hill, 2nd edition, 2009.

UNIT: I : 1.3 – 1.5, 1.8 – 1.10 & 1.13

UNIT: II : 4.1, 4.2, 4.4 – 4.7, 5.1, 5.1.1, 5.1.4, 5.1.7, 5.2 & 5.6.1

UNIT:III : 7.1.1, 7.1.2, 7.2, 7.2.1, 7.3, 7.4, 7.7.1, 7.12 & 7.13

UNIT: IV : 8.2, 8.3, 8.6, 8.6.1, 8.6.2, 8.9, 8.9.6 & 8.11

UNIT: V : 9.1, 9.2, 10.1, 10.1.1, 10.1.2, 10.3, 10.3.1, 10.3.2

REFERENCE BOOKS:

1. **Non-Conventional energy sources** - G.D. Roy, Khanna Publications
2. **Solar energy utilization** - G.D. Roy, Khanna Publications.

II M.Sc., Physics	NON MAJOR ELECTIVE – 15(b)	Marks :100
Semester III	**Introduction to Nanotechnology**	Hrs/Week :6
Code:		INT:25, EXT:75

- **To impart the basics knowledge on nanotechnology**
- **To develop the understanding on the exotic properties of nanostructured materials**
- **To emphasize the importance and development of nanotechnology in various field.**

Unit-I: Introduction to nanoscience

History and importance of nanotechnology, opportunity at the nanoscale, length and time scale in structures, difference between bulk and nanoscale materials and their significance, properties at nanoscale, optical, electronic, magnetic and chemical.

Unit-II: Nanostructures and dimensions

Classification of nanostructures: zero, one, two and three dimensional nanostructures, size dependency in nanostructures, quantum size effects in nanostructures, chemistry of tailored nano shapes, quantum dots, nanowells, nanoribbons and nanowires.

Unit-III: Synthesis of nanomaterials

Synthesis of nanomaterials, top down and bottom up approach, method of nanomaterials preparation, wet chemical routes of synthesis: reduction, sol-gel, hydrothermal, sonochemical synthesis, physical routes, physical vapor deposition (PVD), chemical vapor deposition (CVD), laser ablation, sputtering. (Basic concept only)

Unit-IV: Characterization of nanomaterials

Scanning electron microscope (SEM), transmission electron microscope (TEM), comparing SEM, TEM and SPM for different classes of nanomaterials (Basic concept only).

Unit-V: Applications of nanomaterials

Nanotechnology in energy systems, textiles, food and health care, agriculture, automotive industry, solar technology, pharmaceutical and drugs, nanoelectronics, nanosensors and devices.

TEXT BOOKS:

1. T. Pradeep, *Nano: The Essentials*, 1st Ed., McGraw Hill, 2007.
2. Chattopadhyay, Banerjee, *Introduction to Nanoscience and Nanotechnology*, PHI, 2009.

REFERENCE BOOKS:

1. C. Binns, *Introduction to Nanoscience and Nanotechnology*, Vol. 14, John Wiley & Sons, 2010.
2. A.K. Bandyopadhyay, Nano Materials, New Age International Publisher.
3. P.C. Poole Jr, and F.J. Owens, *Introduction to Nanotechnology*, John Wiley & Sons, 2003.
4. R. Kelsall, I.W. Hamley, and M. Geoghegan, *Nanoscale Science and Technology*, John Wiley & Sons, 2005.

II M.Sc., Physics	Major Paper- 16	Marks :100
Semester IV	**SOLID STATE PHYSICS – II**	Hrs/Week :6
Code:		INT:25, EXT:75

UNIT I: PLASMONS, POLARITONS AND POLARONS

Plasma optics, Dispersion relation for EM waves—Transverse and Longitudinal mode of plasma oscillations-Plasmons – Polaritons – Electron-Electron interaction – Electron- Phonon Interaction - Polarons – Optical reflectance – Excitons - Frenkelexcitons- weakly bound excitons

UNIT II: SUPERCONDUCTIVITY

Experimental survey – Occurrence of superconductivity- Destruction of superconductivity by magnetic Fields-Meissner effect- Isotope effect - Theoretical survey: Thermodynamics of the super conducting transition – BCS theory of superconductivity –Type II Superconductors-Josephson Superconductor Tunneling- High temperature Super conductors-Critical Fields and critical currents

UNIT III: DIELECTRICS AND FERROELECTRICS

Macroscopic electric field –Depolarization Field-Local electric field of an atom- Dielectric constant and polarizability –Electronic polarizability- Structural phase transitions – Ferroelectric Crystals-Classification of Ferroelectric Crystal.

UNIT IV: DIA, PARA, FERRO AND ANTIFERROMAGNETISM

Quantum theory of Dia, Para Magnetism-HundRule-Ferromagnetic order-Curie point and the exchange integral - Magnons – Neutron Magnetic Scattering – Ferrimagnetic order – Antiferromagnetic order - Ferromagnetic Domains –Anisotropy Energy- - single Domain Particles – Magnetic bubble domains.

UNIT V: POINT DEFECTS

Lattice Vacancies – Diffusion – Colour centers –F Centers- –Shear strength of single crystals – slip- dislocations- Burgers vector – Stress fields of dislocations – dislocation densities -Alloys-Hume Rothery Rule-Order –Disorder Transformation- -Kondo effect.

TEXT BOOK:

1. Charles Kittel, Introduction to Solid State Physics VII Edition Wiley India Pvt. Ltd., 2011.

   Unit I-Ch.10& 11(pg272-279, 287-291, 294-299, 307,308, 312-319)

   Unit II-Ch. 12 (pg335-342, 346-349, 354,355, 360-362, 366-369, 371-373)

   Unit III-Ch. 13(pg380-413)

   Unit IV-Ch. 14,15 (pg443-446, 450-454, 456-466, 468-472, 477,480)

   Unit V-Ch. 18,20&21(541-548, 587-595, 598, 611-618, 624-630)

REFERENCE BOOKS:

1. S.O.Pillai,Solid state physics – 5th EditionNew Age Int. Ltd.
2. M.A.Wahab, Solid state physics- 2nd EditionNarosa Publishing House Pvt. Ltd.
3. S.O. Pillai, Problems and Solutions in Solid State Physics, New Age International, New Delhi.,1994.
4. M. Ali Omar, Elementary Solid State Physics-Principles and Applications, Addison-Wesley, London, 1974.
5. H.P. Myers, Introductory Solid State Physics, 2nd Edition, Viva Book, New Delhi,1998.

II M.Sc., Physics	Major Paper- 17	Marks :100
Semester IV	**QUANTUM MECHANICS – II**	Hrs /Week:6
Code:		INT:25, EXT:75

COURSE OBJECTIVES:

- To understand advanced level - Quantum Mechanics.

- To acquire knowledge on approximation methods employed in solving quantum mechanical problems.
- To throw light on relativistic mechanics and quantum theory of radiation.
- To have a glimpse of perturbation theory and its applications.

UNIT I QUANTUM THEORY OF SCATTERING

Representations of quantum system - General Formulation of Scattering Theory Born Approximation – Condition for validity of Born Approximation – Scattering by a screened coulomb potential: Rutherford's scattering formula from Born approximation – Partial wave analysis (Theory only).

UNIT II TIME DEPENDENT QUANTUM APPROXIMATIONS

Time-Dependent perturbation theory – First order perturbation – Perturbation constant in time – Physical significance – Transition probability – Fermi's golden rule – Harmonic perturbation – Adiabatic approximation – Sudden approximation.

UNIT III IDENTICAL PARTICLES AND SPIN

Identical particles – Physical meaning of identify – Symmetric and antisymmetric wave functions – Construction from unsymmetrized function – Distinguishability of identical particles – Exclusion principle – Connection with statistical mechanics – Pauli's spin matrices for an electron and their properties – Electron spin matrices for an electron and their properties – Electron spin functions – Symmetric and antisymmetric wave function of a hydrogen molecule.

UNIT IV RELATIVISTIC WAVE EQUATIONS

Schrodinger's relativistic equation for a free particle – Klien-Gordon equation – E.M. potentials – Separation of the equation – Energy levels in a Coulomb field – Dirac's relativistic equation – Dirac matrices – Free particles solution – Charge and current densities – Magnetic moment of the electron – Spin angular momentum of the electron – Approximate reduction (spin-orbit energy) – Negative energy states.

UNIT V QUANTUM THEORY OF RADIATION

Transition probability for emission and absorption – Einstein's coefficients in a radiation field – Einstein's transition probabilities for absorption and emission in a radiation field.

TEXT BOOK:

1. Quantum Mechanics (III ed.), Schiff, L.I.: McGraw Hill, 1968, ISBN-0-07-085643-5.

REFERENCE BOOKS:

1. Quantum Mechanics, Satyaprakash& Swati Satya:KedarNath Ram Nath& Co, 2006.
2. A Text Book of Quantum Mechanics,Mathews, P.M. &Venkatesan, K., Tata McGraw Hill, 1978, ISBN 0-07-096510-2.
3. Quantum Mechanics Aruldhas, J.- Prentice–Hall of India, 2002, ISBN 81-203-1962-1.

4. Quantum Mechanics (II ed.), Bransden, B.H. &Joachain, C.J.: Pearson Education, 2005. ISBN 81-297-0470-6.
5. Quantum Mechanics (III ed.), Merzbacher, E.: John Wiley, 2004, ISBN 9971-51-281-5.
6. Introduction to Quantum Mechanics,Ghatak, A.: Macmillan, 1996, SBN 0333-92419-3.

II M.Sc., Physics	Major Paper- 18	Marks :100
Semester IV	**NUCLEAR AND PARTICLE PHYSICS**	Hrs/Week :6
Code:		INT:25, EXT:75

Unit-I: The Q Equation:

Introduction - Types of Nuclear Reactions- The Balance of Mass and Energy in Nuclear Reaction- The Q Equation- Solution of the Q Equation- Centre of Mass Frame in Nuclear Physics. **The Nucleus -**Introduction, Rutherford scattering and Estimation of the Nuclear size- Nuclear Radius- Nuclear spin- Moments and Statistics.

Unit-II: Radioactivity

Alpha Rays: Range of α-particles, Disintegration Energy of Spontaneous α-Decay, Barrier penetration. **Beta Rays:** Introduction - Continuous β-ray Spectrum-- Pauli's Neutrino Hypothesis- Fermi's Theory of Beta Decay- The Detection of Neutrino- Parity Non-conservation in Beta Decay- **Gamma Emission:**Introduction, - γ-ray Emission-Selection Rules, Internal Conversion, Nuclear Isomerism.

Unit-III: Model of Nucleus

Liquid Drop Model of Nucleus: Introduction, Binding Energies of Nuclei; Weizsacker'sSemi-empirical Mass Formula, Mass Parabolas: Prediction of Stability Against β-decay - Stability limits - Barrier Penetration-Decay probabilities for Spontaneous Fission- Nucleon Emission.

Shell Model of Nucleus:

Introduction-The Evidence that led to the Shell Model-Main assumptions of the Single-Particle Shell Model-Spin-orbit Coupling in Nuclei -The Single Particle Shell Model-Parabolic Potential - Square Well Potential- Predictions of the Shell Model.

Unit-IV: Nuclear energy and force

Nuclear Energy -Introduction- Neutron Induced Fission- Asymmetrical Fission- Mass Yield- Emission of Delayed Neutrons- Energy Released in the Fission - Fission of Lighter Nuclei -Chain Reaction- Neutron Cycle in a Nuclear Reactor- Nuclear Reactors.

Nuclear Force: Introduction, The Ground State of the Deuteron- Magnetic Dipole and Electric Quadrupole Moments of the Deuteron - Central and Non-Central Forces: Exchange Forces: Meson Theory of Nuclear Forces-Nucleon-Nucleon Scattering.

Unit V: Elementary particles.

Classification ofelementary particles – particle interaction- conservation laws-isospin-hypercharge-strangeness- Charge conjugation Time Reversal – The CPT Theorem -SU_3 Symmetry-Quark theory

TEXT BOOKS:

1. **Nuclear physics-An Introduction – S.B.Patel** – New Age International (P) Limited (Reprint 2003)
2. **Nuclear Physics –** D.C. Tayal, Himalaya Publishing House, (reprint 2007)

REFERENCE BOOKS:

1. Nuclear Physics – Theory and experiment – R.R. Roy and B.P. Nigam – New Age International (P) Ltd., (2001 Edi)
2. Nuclear Physics-V. Devanathan–(Narosa Publishing House, New Delhi, 2006)
3. M.L. Pandya and R.P.S. Yadav, "Elements of nuclear physics", Kedarnath Ram nath publishers, 1996
4. Introduction to Nuclear Physics – Harold Enge.
5. Nuclear physics – Irving Kaplan – (Narosa Publishing House,1987)

II M.Sc., Physics	Major Paper- 19	Marks :100
Semester IV	**PHYSICS PRACTICAL – IV**	Hrs/Week :6
Code:	**General Physics**	INT:40, EXT:60

Any Eight Experiments

1. Study of Susceptibility measurements-Guoy balance method

2.Study of Susceptibility measurements-Quincke's method

3. Hall effect

4. Dielectric parameter of a given liquid

5. Ultrasonic study of liquids.

6. Refractive index of a liquid using laser light

7. Laser based diffraction experiments

8. Experiments using fiber optic kit

9. Arcspectrum – constant deviation spectrograph

10. Refractive index of a liquid using newton's rings

11. Interference spectral analysis

12.Ultraviolet spectral analysis

II M.Sc., Physics	Major Paper- 20 (a)	Marks :100
Semester IV	**MAJOR ELECTIVE –**	Hrs/Week :6
Code:	**PROJECT**	INT:25, EXT:75

I M.Sc., Physics	Major Paper- 20(b)	Marks :100
Semester IV	**MAJOR ELECTIVE -**	Hrs/Week :6
Code:	**APPLIED OPTICS AND LASER PHYSICS**	INT:25, EXT:75

UNIT-I: PHYSICAL OPTICS, PHOTONIC CRYSTALS AND METAMATERIALS

Wave motion, superposition of waves, interference, diffraction, polarization, basics of coherence theory, temporal and spatial coherence, statistical properties of laser speckle patterns, information processing using speckle patterns, laser speckle contrast imaging.

Photonics crystals – 2D & 3D, colloidal photonic crystals, light propagation through disordered media, localization of light, photonic glass, random lasing, optical metamaterials, optical properties of metal dielectric composites, electric and magnetic metamaterials, negative index metamaterials, nonlinear optics with metamaterials.

UNIT–II: APPLICATIONS OF OPTICAL TECHNIQUE

Image formation (first – order optics), aberrations, prisms and mirrors, stops and apertures, basic optical devices, the design of optical systems: general, aplanatic points, solid immersion lens, numerical aperture increasing lens. Mie scattering technique, AFM colloidal probe technique, magnetic chaining technique, knife edge scanning to measure laser beam profile, knife edge scanning based liquid refractometer.

UNIT-III: OPTICAL MICROSCOPY & IMAGING TECHNIQUES

Basics of optical microscopy, bright field and dark field microscopy, polarizing microscopy, phase contrast microscopy, fluorescence microscopy, fluorescence confocal microscopy, light sheet fluorescence microscopy, nonlinear optical microscopy, two photon fluorescence microscopy.

UNIT-IV: BASIC PRINCIPLES AND TYPES OF LASERS

Principles of lasers, population inversion, conditions of lasing action, characteristics of a laser coherence, monochromaticity, divergence, intensity, Einstein's coefficients, laser pumping, two and three level laser systems.

Solid state lasers: Ruby laser, Nd:YAG Laser, semiconductor lasers, features of semiconductor lasers, diode lasers, gas laser : He-Ne laser, CO_2 laser, liquid lasers; dye lasers.

UNIT–V: LASER PROPERTIES, PRODUCTION AND APPLICATIONS OF LASERS

Laser pumping, resonators, vibrational modes of resonators, numbers of modes/unit-volume, open resonators, control resonators, Q factor, losses in the cavity, threshold condition, quantum yield, model locking (active and passive),Ether drift and absolute rotation of the earth-laser isotope separation, laser range finder-laser in pollution detection, holography-optical communication, optical fiber.

TEXT BOOKS:

1. M.Bornand, E. Wolf, Principles of Optics, 7th Ed., Cambridge University Press 1999.
2. J.D. Joannopoulos, R.D. Meade, J.N. Winn, Photonic Crystals: Molding the Flow of light, 2nd Ed, Princeton University Press, 2008.
3. V.Shalaevand W. Cai, Optical Metamaterials: Fundamentals & Applications, 2nd Ed., Springer, 2010.
4. W.J. Smith, Modern Optical Engineering, 3rd Ed., McGraw Hill, 2000.
5. B.B. Laud, Lasers and Nonlinear Optics, 3rd Ed., New Age Int. Pub. 2011.

REFERENCE BOOKS:

1. A.K. Ghatak and K.Thyagarajan, Optical electronics, Cambridge University Press, 1989
2. Seigman, Lasers, 3rd Ed., Oxford Univ, Press 1986
3. Maitland and Dunn, Laser Physics. N.H. Amsterdam, 1969
4. J. Hecht, The laser Guidebook 1986
5. O. Seelto, Principles of Laser, 5th Ed., Springer Publication 2010.

I M.Sc. Physics	Major Paper- 20(c)	Marks :100
Semester IV	**MAJOR ELECTIVE-**	Hrs/Week :6
Code:	**FIBER OPTIC COMMUNICATION**	INT:25, EXT:75

Unit –I OVER VIEW OF OPTICAL FIBER COMMUNICATION

Forms of communication system-The evolution of fiber optic Systems-Elements of an optical fiber transmission link-Optical fiber modes and configurations-Fiber types-Rays and modes-step index fiber structure –single mode fibers-Graded index numerical aperture(NA)

Unit –II FIBR MATERIALS AND FABRICATIONS

Glass Fibers-Halide glass fibers-Active glass fibers – Plastic – Clad glass fibers-Plastic fibers – Fiber Fabrication –Outside vapour phase oxidation-Vapour phase axial deposition-Modified chemical vapor deposition – Double – Crucible method.

Unit –III OPTICAL SOURCE AND DETECTOR

Energy Bands- Intrinsic and Extrinsic material – The PN junction –Direct and indirect band gap- Semiconductor device fabrication- LED- LED structure- Light source materials-Modulation capacity- Laser diode modes and threshold condition- Laser diode structure and radiation pattern – single mode laser – Physical principle of Photodiodes- the pin photo detectors – Avalanche photodiode.

Unit –IV POWER LAUNCHING, COUPLE AND SIGNAL DEGRADATION

Source to fiber power launching – source output pattern power – power launching verses wavelength- Equilibrium numerical aperture – Nonimaging microsphere laser diode to fiber coupling fiber to fiber joints – Mechanical misalignment.

UNIT – V FIBER AND FACE PREPARATION

Fiber and face preparation – Attenuation Units-Absorption-Scattering Losses-Bending losses-Core and cladding losses- Signal distortion in optical wave guide –Fiber splicing –Splicing techniques- Optical fiber connectors.

TEXT BOOK:

1. Optical fiber Communication by Gerd Keiser – Second edition – McGrew – Hill International Edition 1991. Chapter 1 ,2,4,5.