

As Per NEP 2020

University of Mumbai



Title of the program

A-P.G. Diploma in Physics

B- M.Sc. (Physics) (Two Year)

-2023-24

C- M. Sc. (Physics) (One Year)

-2027-28

University Department of Physics(Autonomous)

Syllabus for

Semester – Sem I & II

Ref: GR dated 16th May, 2023 for Credit Structure of PG

Preamble

1. **Introduction:** Physics is the most of basic of sciences. It seeks to understand natural phenomena in a quantitative manner, and to answer some of the oldest and deepest questions ever asked by human beings: What are things made of? Is there a limit to the smallest things that we can think of? Did the world have a beginning? Will it have an end? At the same time, it provides the base of much of the technology that we take for granted in the 21st century: computers, artificial satellites, mobile phones, TV, microwave ovens... Indeed, it will not be an exaggeration to say that modern human life is shaped by technologies that are largely based on a foundation of physics. Physics as a discipline has existed for three hundred years and has a large 'core' body of knowledge. Our M.Sc. programme lays emphasis on the courses that constitute this core component, while providing students with a bouquet of optional papers covering almost all branches of physics. Those who wish to pursue higher studies in the subject are thereby well equipped to choose their branch of study. The programme also aims at equipping future teachers (at college as well school level) with a thorough grounding in the subject. Since physics is the base of much of modern technology, the programme also gives adequate hands-on experience to students who may go on to work in applied fields. Finally, viewing physics as a training ground for the mind the programme also aims to equip those who go into other fields of work with logical thinking and a critical attitude. During the current academic year 2023-24, University Department of Physics is following NEP-2020 program.

2:Aims and Objectives: Create the facilities and environment in all the educational institutions to consolidate the knowledge acquired at +2+3 level and to motivate and inspire the students to create deep interest in Physics, to develop broad and balanced knowledge and understanding of physical concepts, principles and theories of Physics. •Learn, design and perform experiments in the labs to demonstrate the concepts, principles and theories learned in the classroom.

3: Learning outcomes:

- I. The students would be able to have strong foundation knowledge and comprehend the basic concepts and principles in Physics.
- II. The students would be able to progress in their academic performance through structured curricula.
- III. The students would be able take up competitive exams in different sectors, can be entrepreneurs and succeed in higher education in Physics.
- IV. The students would be able to experience a well resourced environment for learning Physics
- V. To motivate and inspire the students to create deep interest in Physics, to develop broad and balanced knowledge and understanding of physical concepts, principles and theories of Physics.

4: Any other points:

- I. During the course work students will be provided hands on training on highly sophisticated state of art equipments.
- II. Students will be provided internship at the various government lab and nearby industries.
- III. Collaborative activities with national and international institutes/industries to cater the need of regional development.

R: _____

5. Credit Structure of the Program (Sem I, II, III & IV) (Table as per with sign of HOD and Dean)

PG Program as per NEP 2020 Structure

The University department of Physics has currently 1 PG degree program namely M.Sc Physics with 68 seats. The Structure of three PG Degree programs under NEP 2020 is enclosed herewith. Program Name: M.Sc Physics with 68 seats

**Credit Distribution Structure for Two Years/ One Year PG
M.Sc (Physics)**

M.Sc (Physics)									
Ye ar	Lev el	Sem	Major		RM	OJT / FP	RP	Cum . Cr.	Degre e
			Mandatory	Electiv e					
1	6.0	Sem 1	3 x 4 + 2 x 1 = 14	4	4	--	--	22	
			Phys-(501) Classical Mechanics	Phys- (505) Electiv e 1 (List attache d)	Phys- (506) Research Methodo logy	--	--		
			Phys-(502) Quantum Mechanics 1						
			Phys-(503) Mathematical Physics						
			Phys-(504) Practical-1						
		Sem 2	3 x 4 + 2 x 1 = 14	4	4	--	--	22	
			Phys-(511) Introduction to Programming	Phys- (515) Electiv e 2 (List attache d)	--	Phys- (516) Resea rch Projec t--			
			Phys-(512) Quantum Mechanics 2						
			Phys-(513) Nuclear Physics						
			Phys-(514) Practical-2						
Cum. Cr. for PG Diploma			28	8	4	4	--	44	
Exit Option: 1 yr PG Diploma (44 credits) after Three Year UG Degree									

Year	Level	Sem	Major		RM	OJT / FP	RP	Cum. Cr.	Degree
			Mandatory	Elective					
2	6.5	Sem 3	3 x 4 + 2 x 1 = 14	4	--	--	4	22	
			Phys-(601) Electrodynamics	Phys-(605) Elective 3 (List attached)	--	--	Phys-(606) Research Project		
			Phys-(602) Electronics						
			Phys-(603)						

			Solid State Physics						
			Phys-(604) Practical-3	attache			t		
			3 x 4 = 12	d)	--	--	6	22	
		Sem 4	Phys-(611) Introduction to Programming	Phys- (615) Electiv e 4 (List attache d)	--	--	Phys- (616) Resea rch Projec t		
			Phys-(612) Quantum Mechanics 2						
			Phys-(613) Nuclear Physics						
Cum. Cr. for 1 yr PG Degree			26	8	--	--	10	44	
Exit Option: 1 yr PG Degree (44 credits) after Four Year UG Degree									
Cum. Cr. for 2 yr PG Degree			5 4	16	4	--	14	88	
Exit Option: 2 yr PG Degree (88 credits) after Three Year UG Degree									

LIST OF ELECTIVES

	Elective 1 Phys-(505A-505H)	Elective 2 Phys-(515A-515H)	Elective 3 Phys-(605A-605H)	Elective 4 Phys-(615A-615H)
A	Experimental Techniques In Nuclear Physics	Particle Physics	Nuclear Structure	Nuclear Reactions
B	Laser Physics	Accelerator and Beam Physics	Quantum Field Theory	Group Theory
C	Astronomy and Astrophysics	Applied Thermodynamics	General Theory of Relativity and Cosmology	Space Plasma Physics
D	Surfaces and Thin Films	Properties of Solids	Fundamentals of Materials Science	Materials and their Applications
E	Liquid Crystals	Polymer Physics	Semiconductors Physics	Semiconductor Technology
F	Nanoscience and Nanotechnology	Electronic Structure of Solids	Computational Methods in Physics	Energy Studies
G	Signal Modulation and Transmission Techniques	Microwave Electronics, Radar and Optical Fiber Communication	Digital Communication Systems and Python Programming language	Computer Networking
H	VLSI Design and Embedded Systems	VIIDL, C++ and Python Programming	Embedded C, ARM and Interfacing	Bio-medical Physics and Instrumentation

Vaishali A. Bambole

Sign of HOD

Prof. Vaishali A. Bambole
Department of Physics

Professor & Head
Department of Physics
University of Mumbai

Shivram Garje

Sign of Dean

Prof Shivram Garje
Science and Technology

Department of Physics (Autonomous)
University of Mumbai
PROGRAMME OUTCOMES OF M.Sc. (PHYSICS)

1. To navigate learners towards the frontiers of Physics
2. To establish a world-class academic programme, with dual emphasis on foundational teaching and active participation in frontier research
3. To establish the best in class infrastructure for facilitating the process of learning and research with core strengths of the Department
4. To nurture learning in various sub-disciplines of Physics viz Theoretical, Experimental and Computational, expanding into areas of High Energy Physics, Astronomy and Space Physics, Materials Science, Soft Matter Physics, Atomic and Nuclear Physics
5. To network with national and global academic institutions through vibrant exchange programmes and collaborations in teaching and research
6. To instill in the learners the spirit of inquiry and innovation
7. To create opportunity platforms for nucleation and incubation of entrepreneurs
8. To build synergistic channels for productive knowledge transfer and utilization through industry partners
9. To create value added linkages and career opportunities for faculty and students through effective networking both at national and international levels
10. To ensure the creation of responsible personnel through engagement in socially relevant outreach programmes

The Department has the M.Sc.(Physics) offered as

1. M.Sc.(Physics) by papers
2. M.Sc.(Physics) by research

The latter is a unique programme initiated by the founder head (Late) Prof M.C.Joshi, supported by the Department of Atomic Energy (DAE) through the scientists of the Bhabha Atomic Research Centre (BARC) and Tata Institute of Fundamental Research (TIFR). The programmes are designed with syllabi adhering to the proposed academic objectives.

M.Sc.(PHYSICS) By Papers

PROGRAMME SPECIFIC OUTCOMES (PSO)

The programme ensures that the learners

1. Acquire core competency in the areas of Basic and Applied Physics (PSO1)
2. Are exposed to the state-of-art facilities in the Department and collaborating institutions in the neighborhood (PSO2)
3. Are familiarized with current trends in a wide variety of sub-disciplines and emerging areas of Physics (PSO3)
4. Are able to apply their acquired skills in other interdisciplinary areas of science and technology(PSO4)
5. are equipped with knowledge to engage in teaching in academic institutions, research in National research laboratories and R&D based industries as also initiating technology based entrepreneurship (PSO5)

CLASSICAL MECHANICS

The course discusses in length, the two frameworks of analytical mechanics viz **Lagrangian** and **Hamiltonian**. The first unit reviews Newtonian Mechanics and compares it with Lagrangian mechanics that is discussed following the introduction of **d'Alembert's principle** and concepts of virtual work. This is followed by the **Conservation laws** in both formalisms and introduction of the Calculus of variations. The unit on **Central Force** introduces the concept of constants of motion, transformations and cyclic co-ordinates and emphasizes their use in solving real problems. The unit on Hamiltonian dynamics introduces the **Poisson bracket** and discusses the problems of canonical transformations and associated functions. The link between Classical and Quantum Mechanics is brought about by the concept of Poisson brackets.

Course outcomes:

At the end of the course, the learner is able to

1. Understand the principle of virtual work and the concepts of least action, the formalisms of Lagrange and Hamiltonian (CO1)
2. Describe the motion of a system in Lagrangian and Hamiltonian formalisms (CO2)
3. Understand the features of motion under central force, periodic motion, small oscillations as they appear in other areas of Physics (CO3)
4. Use the Poisson brackets in Hamiltonian dynamics and solve related problems (CO4)
5. Understand the linkages of the techniques of Classical Mechanics in solving problems in areas of Statistical Mechanics (Phase space), Molecular Physics (CO5)

Mapping of Course Outcomes with Programme Specific Outcomes

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2		1	2
CO2	3	2		1	2
CO3	3	2		2	2
CO4	3	2		2	2
CO5	3	3		3	3

1: Low 2: Moderate 3: High

QUANTUM MECHANICS I

The course introduces the concepts and postulates of **wave mechanics** to the formulation of quantum mechanics, **the matrix formulation**, the development of Dirac notation, the operators for quantum angular momenta. The one-dimensional Schrodinger equation is discussed at length and the problems addressed are Particle in a box, harmonic oscillator, unbound states, potential well, two particle problem, radial equation and complete solution of the hydrogen atom problem using spherical harmonics and other special functions.

Course Outcomes:

At the end of the course, the learner is able to

1. Understand the basic principles of Quantum mechanics and the need for its formalism (CO1)
2. Understand the Uncertainty Principle and formulation of Schrodinger equation (CO2)
3. Understand the importance of Dirac formalism, vector spaces and apply the same in solving problems of potential barrier, square well potential (CO3)
4. Apply the techniques of solving differential equations using various special functions as they appear in the solution of Schrodinger equation for Hydrogen atom problem (CO4)
5. Solve the various boundary value and potential problems using the techniques of quantum mechanics (CO5)

Mapping of Course Outcomes with Programme Specific Outcomes

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2			3
CO2	3	2			2
CO3	3	2		2	2
CO4	3	2		2	2
CO5	3	2		2	2

1: Low 2: Moderate 3: High

MATHEMATICAL METHODS IN PHYSICS

The course commences with a unit on **Matrices and Tensors**; the vector spaces are discussed in the light of matrices and tensors. The emphasis is on solving eigen value problems as they appear in Classical and Quantum Mechanics and other applied areas of Physics. The basics of tensor analysis are introduced to understand the formulation of Relativistic Electrodynamics and other advanced areas of theoretical Physics. The unit on **Functions of Complex Variables** has a review of complex numbers and the algebra and discusses the calculus of complex variables with Cauchy Riemann for analytic functions, Cauchy Goursat theorem, Cauchy's integral formula and the Residue theorem and its application in solving complex and real integrals. The units on **Differential Equations** introduces the Frobenius method of series solution of linear differential equations and the associated polynomial solutions of Legendre, Laguerre, Hermite and Bessel functions. The **Integral Transforms** of Fourier and Laplace and their application in solving linear differential equations and **partial differential equations** are discussed. The Green's function method of solving differential equations is addressed.

Course Outcomes:

At the end of the course the learner will be able to

1. Solve eigenvalue problems using matrices as they appear in Classical and Quantum Mechanics (CO1)
2. Apply tensor analysis to understand the formulation of relativistic electrodynamics and other areas of Physics (CO2)
3. Apply residue theorem of complex variables to solve real and definite integrals (CO3)
4. Understand the emergence of special functions as solutions of differential equations and to solve problems in physics (CO4)
5. Solve partial differential equations using integral transforms in boundary value problems (CO5)

Mapping of Course Outcomes with Programme Specific Outcomes

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2			2
CO2	3	2		2	2
CO3	3	2		2	2
CO4	3	2		2	2
CO5	3	2	2	3	3

1: Low 2: Moderate 3: High

Introduction to Programming

The advances in computer technology have brought the need to devise numerical algorithms to optimize their usage in problem solving. The implementation of a mathematical method with an appropriate convergence check in a programming language is termed as a numerical algorithm. The presently used programming languages for scientific computing are C, C++ as against the formerly used FORTRAN and PASCAL. The operating system used by computational scientists is generally UNIX or LINUX as against the DOS or WINDOWS. The present course discusses the Numerical methods of interpolation, curve-fitting, differentiation and integration using the various standard techniques of Difference table, Runge-Kutta, Newton-Raphson methods with programs in C/C++. Some of the emerging problems of Monte-Carlo methods for simulation and Random number generation are also discussed. The course is supported by hands-on problem solving.

Course Outcome:

At the end of the course, the learner can

1. Understand the use of programming language and write simple programs for mathematical problems (CO1)
2. Develop flowcharts for analyzing a given mathematical problem and solve them numerically (CO2)
3. Apply the techniques of numerical methods in interpolation to generate difference tables of a given data set (CO3)
4. Analyze a given data set and fit them to a suitable polynomial equation and present them graphically (CO4)
5. Simulate models for a given mathematical problem by techniques of Monte Carlo and other related techniques (CO5)

Mapping of Course Outcomes with Programme Specific Outcomes

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3				2
CO2	3			2	2
CO3	3			3	
CO4	3	2			
CO5	3	2		3	2

1: Low 2: Moderate 3: High

QUANTUM MECHANICS II

The course focuses on the application of Quantum Mechanics to problems of **Angular momentum** of electrons viz addition of angular momenta, **Clebsch Gordon coefficients**; estimation of scattering amplitude in **scattering theory**. The time independent and time dependent perturbation theory is discussed with illustrative examples. The methods of Ritz **variational method**, **WKB method** are presented and applied to real problems.

Course Outcomes:

At the end of the course, the learner can

1. Gain understanding of the mathematical foundations of the angular momenta of a system of particles (CO1)
2. Apply the concept of non-relativistic Hamiltonian for an electron with spin and perform calculation using angular momentum techniques (CO2)
3. Apply various approximation methods in the solution of time independent and time dependent Schrodinger equations (CO3)
4. Apply the perturbation theory to various forms of Schrodinger equation in scattering theory and partial wave analysis (CO4)
5. Apply the quantum mechanical principles to solve problems of wave propagation, scattering phenomena (CO5)

Mapping of Course Outcomes with Programme Specific Outcomes

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3	2			2
CO2	3	2			2
CO3	3	2			2
CO4	3	2			2
CO5	3	2		3	3

1: Low 2: Moderate 3: High

NUCLEAR PHYSICS

The course in Nuclear Physics introduces not only the **nuclear structure** but also throws light on the **nuclear reactions**. Special emphasis is on gaining knowledge about the safety norms and the prevalent regulatory framework of nuclear safety in India.

An understanding of the **nuclear sizes and their estimation**, the constituent protons and neutrons and the formation of deuteron is gained by in-depth discussion with examples. The various nuclear models like the Shell model, Nilsson model etc. are introduced with its assumptions, predictions and limitations.

The **mechanisms of the decay schemes** of the charged particles (alpha and beta) with their energetics, the transition rules for gamma decay with the associated selection rules and the information obtained from Fermi-Curie plots are described. The interaction of charged particles and radiation with matter is discussed. The conservation laws associated with the various nuclear reactions are introduced. The study entails an in-depth discussion of the fission and fusion reactions with special thrust on the Nuclear Programme of India.

Particle Physics is introduced in close association with nuclear physics to understand the sub-atomic elementary particles, specially the quarks. The various concepts viz Quark Model, Standard model, Eight fold way are described. The ideas of Quantum Electrodynamics, Quantum Chromodynamics are introduced. The problem of Neutrino is addressed with regards to some of its properties. The concepts of helicity, parity, parity violation, some standard experiments are introduced. The current advances in the field are brought in appropriately to understand the importance of the accelerators, detectors and the significance of the High Energy Collider experiment of CERN.

Course Outcome:

At the end of the course, the learner

1. Gains knowledge about the nuclear properties such as mass, size, spin and the methods adopted for their estimation
2. Gains awareness of safety and regulatory norms adopted in the nuclear programme in the country
3. Understands the various nuclear models,
4. Understands the nuclear reactions with the ideas of decay mechanisms, interaction of radiation with matter and the experimental methods of analysis
5. Gains insight into the basics of Particle Physics with introductory ideas of the fields of Quantum Electrodynamics and Quantum Chromodynamics

Mapping of Course Outcomes with Programme Specific Outcomes

	PSO1	PSO2	PSO3	PSO4	PSO5
CO1	3			2	2
CO2	3	3	3		3
CO3	3				2
CO4	3	3	2	2	2
CO5	3	3	3	2	2

1: Low 2: Moderate 3: High

Syllabus

Core Subjects:

Classical Mechanics (60 lectures, 4 credits) (100 Marks)

Unit-1

Review of Newton's laws, Mechanics of a particle, Mechanics of a system of particles, Frames of references, rotating frames, Centrifugal and Coriolis force, Constraints, D'Alembert's principle and Lagrange's equations, Velocity-dependent potentials and the dissipation function, Simple applications of the Lagrangian formulation. Hamilton's principle, Calculus of variations, Derivation of Lagrange's equations from Hamilton's principle, Lagrange Multipliers and constraint extremization Problems, Extension of Hamilton's principle to nonholonomic systems, Advantages of a variational principle formulation

Unit-2

Conservation theorems and symmetry properties, Energy Function and the conservation of energy. The Two-Body Central Force Problem: Reduction to the equivalent one body problem, The equations of motion and first integrals, The equivalent one-dimensional problem and classification of orbits, The virial theorem, The differential equation for the orbit and integrable power-law potentials, The Kepler problem: Inverse square law of force, The motion in time in the Kepler problem, Scattering in a central force field, Transformation of the scattering problem to laboratory coordinates.

Unit-3

Small Oscillations: Formulation of the problem, The eigenvalue equation and the principal axis transformation, Frequencies of free vibration and normal coordinates, Forced and damped oscillations, Resonance and beats.

Legendre transformations and the Hamilton equations of motion, Cyclic coordinates and conservation theorems, Derivation of Hamilton's equations from a variational principle.

Unit-4

Canonical Transformations, Examples of canonical transformations, The symplectic approach to canonical transformations, Poisson brackets and other canonical invariants, Equations of motion, infinitesimal canonical transformations and conservation theorems in the Poisson bracket formulation, The angular momentum Poisson bracket relations.

Main Text: Classical Mechanics, H. Goldstein, Poole and Safco, 3rd Edition, Narosa

Publication (2001)

Additional References:

- 1.** Classical Mechanics, N. C. Rana and P. S. Joag. Tata McGraw Hill Publication.
- 2.** Classical Mechanics, S. N. Biswas, Allied Publishers (Calcutta).
- 3.** Classical Mechanics, V. B. Bhatia, Narosa Publishing (1997).
- 4.** Mechanics, Landau and Lifshitz, Butterworth, Heinemann.
- 5.** The Action Principle in Physics, R. V. Kamat, New Age Intl. (1995).
- 6.** Classical Mechanics, Vol I and II, E. A. Deslougue, John Wiley (1982).
- 7.** Theory and Problems of Lagrangian Dynamics, Schaum Series, McGraw (1967).
- 8.** Classical Mechanics of Particles and Rigid Bodies, K. C. Gupta, Wiley Eastern (2001)

Quantum Mechanics-I (60 lectures, 4 credits) (100 Marks)

Unit-1: Theory:

de Broglie hypothesis; Heisenberg's uncertainty principle; probability waves. Postulates of QM: Observables and operators; measurements; the state function and expectation values; the time-dependent Schrodinger equation; time development of state functions; solution to the initial value problem. Superposition and Commutation: The superposition principle; commutator relations; their connection to the uncertainty principle; degeneracy; complete sets of commuting observables.

Unit-2: Formalism:

Dirac notation; Hilbert space; Hermitian operators and their properties. Matrix mechanics: Basis and representations; matrix properties; unitary and similarity transformations; the energy representation. Schrodinger, Heisenberg and Interaction pictures.

Unit-3: Schrodinger equation solutions-1 Time development of state functions and expectation values; conservation of energy, linear momentum and angular momentum; parity.

General properties of one-dimensional Schrodinger equation. Particle in a box. Harmonic oscillator. Unbound states; one-dimensional barrier problems. Finite potential well.

Unit-4: Schrodinger equation solutions-2

Schrodinger equation in 2D and 3D and Examples, Its solution in spherical coordinate systems.

Texts:

1. Richard Liboff, Introductory Quantum Mechanics, 4th ed., 2003. (RL)
2. DJ Griffiths, Introduction to Quantum Mechanics, 1995. (DG)
3. A Ghatak & S Lokanathan, Quantum Mechanics: Theory & Applications. 5th ed., 2004. (GL)

Additional References:

1. W Greiner, Quantum Mechanics: An Introduction, 4th ed., 2004.
2. R Shankar, Principles of Quantum Mechanics, 2nd ed., 1994.
3. SN Biswas, Quantum Mechanics, 1998.

Mathematical Methods of Physics- No of credits: 4 (100 Marks)

Unit-I

Complex Variables, Limits, Continuity, Derivatives, Cauchy-Riemann Equations, Analytic functions, Harmonic functions, Elementary functions: Exponential and Trigonometric, Taylor and Laurent series, Residues, Residue theorem, Principal part of the functions, Residues at poles, zeroes and poles of order m , Contour Integrals, Evaluation of improper real integrals, improper integral involving Sines and Cosines, Definite integrals involving sine and cosine functions.

Unit-II

Matrices, Eigenvalues and Eigen vectors, orthogonal, unitary and hermitian matrices, Diagonalization of Matrices, Application to Physics problems. Introduction to Tensor Analysis, Addition and Subtraction of Tensors, summation convention, Contraction, Direct Product, Levi-Civita Symbol

Unit-III

General treatment of second order linear differential equations with non-constant coefficients, Power series solutions, Frobenius method, Legendre, Hermite and Laguerre polynomials, Bessel equations. Nonhomogeneous equation– Green's function, Sturm-Liouville theory.

Unit-IV

Integral transforms: three dimensional Fourier transforms and its applications to PDEs (Green function of Poisson's PDE), convolution theorem, Parseval's relation, Laplace transforms, Laplace transform of derivatives, Inverse Laplace transform and Convolution theorem, use of Laplace's transform in solving differential equations.

Main references:

1. S. D. Joglekar, Mathematical Physics: The Basics, Universities Press 2005
2. S. D. Joglekar, Mathematical Physics: Advanced Topics, CRC Press 2007
3. M. L. Boas, Mathematical methods in the Physical Sciences, Wiley India 2006
4. G. Arfken and H. J. Weber: Mathematical Methods for Physicists, Academic Press 2005

Additional references:

1. A. K. Ghatak, I. C. Goyal and S. J. Chua, Mathematical Physics, McMillan
2. A.C. Bajpai, L.R. Mustoe and D. Walker, Advanced Engineering Mathematics, John Wiley
3. E. Butkov, Mathematical Methods, Addison-Wesley
4. J. Mathews and R.L. Walker, Mathematical Methods of physics

5. P. Dennery and A. Krzywicki, Mathematics for physicists
6. T. Das and S.K. Sharma, Mathematical methods in Classical and Quantum Mechanics
7. R. V. Churchill and J.W. Brown, Complex variables and applications, V Ed. Mc Graw. Hill
8. A. W. Joshi, Matrices and Tensors in Physics, Wiley India

Sem-1, Laboratory-1

Experiment	References
Carrier lifetime by pulsed reverse method	Semiconductor electronics by Gibson
Resistivity by four probe method	Semiconductor measurements by Runyan
Temperature dependence of avalanche and Zener breakdown diodes	a) Solid state devices - W.D. Cooper b) Electronic text lab manual - PB Zbar c) Electronic devices & circuits - Millman and Halkias
DC Hall effect	a) Manual of experimental physics - E.V.Smith b) Semiconductor Measurements - Runyan c) Semiconductors and solid state physics -Mackelvy d) Handbook of semiconductors – Hunter
Determination of particle size of lycopodium particles by laser diffraction method	a). A course of experiments with Laser - Sirohi b). Elementary experiments with Laser- G. white
Magneto resistance of Bi specimen	Semiconductor measurements by Runyan
Microwave oscillator characteristics	a) Physics of Semiconductor Devices by S.M.Sze
Temperature on-off controller using. IC	a) Op-amps and linear integrated circuit technology by Gayakwad
Waveform Generator using ICs	a) Operational amplifiers and linear integrated circuits— Coughlin & Driscoll b) Op-amps and linear integrated circuit technology — R. Gayakwad c) Operational amplifiers : experimental manual C.B. Clayton
Instrumentation amplifier and its applications	a) Operational amplifiers and linear integrated circuits - Coughlin & Driscoll b) Integrated Circuits - K. R. Botkar
Study of 8 bit DAC	a) Op-amps and linear integrated circuit technology — R. Gayakwad b) Digital principles and applications by Malvino and Leach
16 channel digital multiplexer	a) Digital principles and applications by Malvino and Leach b) Digital circuit practice by RP Jain
Study of elementary digital voltmeter	Digital Electronics by Roger Tokheim (5 th Edition, page 371)

Note: Minimum number of experiments to be performed and reported in the

journal = 06 with minimum 3 experiments from each Group. i.e. Group A: 03 and Group B: 03

Additional references:

- [1] Digital theory and experimentation using integrated circuits - Morris E. Levine (Prentice Hall)
- [2] Practical analysis of electronic circuits through experimentation - Lome Macronaid (Technical Education Press)
- [3] Logic design projects using standard integrated circuits - John F. Waker (John Wiley & sons)
- [4] Practical applications circuits handbook - Anne Fischer Lent & Stan Miastkowski (Academic Press)
- [5] Digital logic design, a text lab manual - Anala Pandit (Nandu printers and publishers Pvt. Ltd.)

Numerical Techniques and Programming

(45 lectures+15 tutorials, 4 credits)

Unit – I: Python Programming

Introduction, data-types, variables and constant, typecasting, operators (assignment, logical, arithmetic etc), user input (console), conditional statements (if else, nested if else and elif), arrays (list, tuple, sets and dictionary), loops in python – for loop, while loop & nested loops, string manipulation, user defined functions, modules: math, numpy; basics of object oriented programming, creating class and object, constructors.

Unit – II: Numerical Methods: Roots of Equations, Interpolation, Curve fitting, and Derivatives

Roots of polynomial and transcendental equation, bisection method, false position method, Newton-Raphson method.

Linear interpolation, Lagrange's interpolation formula, Newton's forward and backward interpolation formula.

Least squares method principle, fitting a straight line, fitting an exponential curve, fitting curve of the form $y=ax^b$, fitting a parabola, fitting through a polynomial.

Numerical differentiation.

Unit – III: Numerical Integration and Solution to Simultaneous Equations

Newton cotes formula: Trapezoidal rule, Simpson's one third rule, Simpson's three eighth rule, Gauss quadratics method.

Gaussian elimination method, Gaussian elimination with pivotal condensation method, Gauss-Jordan elimination method, Gauss—Seidal iteration method, Gauss-Jordan matrix inversion method.

Unit – IV: Solution of Differential Equation

Numerical solution of Ordinary differential equation: Taylor series method, Runge-Kutta method.

Classification of 2nd order partial differential equation, Solution of partial differential equation: Difference equation method over a rectangular domain for solving elliptic, parabolic and hyperbolic partial differential equation

References:

1. *Scientific Computing in Python*, 2nd Edition, Abhijit Kar Gupta
2. <https://www.iuac.res.in/phoenix/python4schools/Python-for-Education.pdf>
3. Jain M.K., Iyengar SRK, Jain R. K.: *Numerical methods for scientific and Engineering Computation*, New Age International, 1992.
4. *Numerical Recipes in C++* (2nd ed.), W. H. Press, S. A. Teukolsky, W. T. Vetterling and B. P. Flannery
5. H. M. Antia: *Numerical methods for scientists and engineers*.
6. Babu Ram: *Numerical Methods*, Pearson Education India, 2009

Quantum Mechanics-II (60 lectures, 4 credits)

Unit-1: Angular Momentum:1

Orbital angular momentum operators in cartesian and spherical polar coordinates, commutation and uncertainty relations, spherical harmonics. Two-particle problem - coordinates relative to the centre of mass; radial equation for a spherically symmetric central potential. Hydrogen atom, eigenvalues and radial eigenfunctions, degeneracy, probability distribution. Ladder operators, eigenvalues and eigenfunctions of L^2 and L_z using spherical harmonics, angular momentum and rotations.

Unit-2 Angular Momentum:2

Total angular momentum J ; L.S coupling; eigenvalues of J^2 and J_z .

Addition of angular momentum, Clebsch Gordon coefficients for $j_1=j_2=1/2$ and $j_1=1, j_2=1/2$, coupled and uncoupled representation of eigenfunctions. Angular momentum matrices; Pauli spin matrices; spin eigenfunctions; free particle wave functions including spin, addition of two spins. Identical particles: symmetric / antisymmetric wavefunctions.

Unit-3: Perturbation Theory and Variational Methods:

1. Time-independent perturbation theory: First-order and second-order corrections to non-degenerate perturbation theory. Degenerate perturbation theory - First order energies and secular equation. Time-dependent perturbation theory and applications. Ritz variational method: basic principles, illustration by simple examples.

Unit-4: Scattering theory:

Scattering cross section and scattering amplitude; partial wave phase shift -- optical theorem, S-wave scattering from a finite spherical attractive and repulsive potential wells; centre of mass frame; Born approximation.

Texts:

1. Richard Liboff, *Introductory Quantum Mechanics*, 4th ed., 2004. (RL)

2. DJ Griffiths, *Introduction to Quantum Mechanics*, 1995. (DG)
3. A Ghatak & S Lokanathan, *Quantum Mechanics: Theory & Applications*.
5th ed., 2004. (GL)

Additional References:

1. W Greiner, *Quantum Mechanics: An Introduction*, 4th. ed., 2004.
2. R Shankar, *Principles of Quantum Mechanics*, 2nd ed., 1994.
3. SN Biswas, *Quantum Mechanics*, 1998.

Electrodynamics

Unit-1:

- Units in Electrodynamics, Maxwell's equations, The Pointing vector, The Maxwellian stress tensor
- Electromagnetic waves in vacuum, Polarization of plane waves. Electromagnetic waves in matter, frequency dependence of conductivity, frequency dependence of polarizability, frequency dependence of refractive index.

Unit-2:

- Wave guides, boundary conditions, classification of fields in wave guides, phase velocity and group velocity, resonant cavities.
- Introduction to plasmas, quasi-neutrality, particle motions in EM fields in a plasma, adiabatic invariants, magnetic confinement.

Unit-3:

- Lorentz Transformations, Four Vectors and Four Tensors, The field equations and the field tensor, Maxwell equations in covariant notation.
- Relativistic covariant Lagrangian formalism: Covariant Lagrangian formalism for relativistic point charges, the energy-momentum tensor, Conservation laws.

Unit-4:

- Moving charges in vacuum, gauge transformation, the time dependent Green function, The Lienard-Wiechert potentials, Leinard-Wiechert fields, application to fields-radiation from a charged particle
- Antennas, Radiation by multipole moments, Electric dipole radiation, Complete fields of a time dependent electric dipole, Magnetic dipole radiation

Main References:

- W. Greiner, Classical Electrodynamics (Springer- Verlag, 2000) (WG).
- M. A. Heald and J. B. Marion, Classical Electromagnetic Radiation, 3rd edition (Saunders, 1983) (HM)
- J. D. Jackson, Classical Electrodynamics, 4Th edition, (John Wiley & sons) 2005 (JDJ)

Additional references:

- D.J. Griffiths, Introduction to Electrodynamics, 2nd Ed., Prentice Hall, India,1989.
- J.R. Reitz ,E.J. Milford and R.W. Christy, Foundation of Electromagnetic Theory, 4th ed., Addison -Wesley, 1993
- Andrew Zangwill, Modern Electrodynamics, Cambridge Univ. Press, 2013

Sem-2 Laboratory-2

Experiment	References
Zeeman Effect using Fabry-Perot etalon / Lummer — Gehrecke plate	a). Advance practical physics - Worsnop and Flint b). Experiments in modern physics - Mellissinos
Characteristics of a Geiger Muller counter and measurement of dead time	a). Experiments in modern physics- Mellissinos b). Manual of experimental physics --EV-Smith c). Experimental physics for students - Whittle &. Yarwood
Ultrasonic Interferometry- Velocity measurements in different Fluids	Medical Electronics- Khandpur
Measurement of Refractive Index of Liquids using Laser	Sirohi- A course of experiments with He-Ne Laser; Wiley Eastern Ltd.
I-V/ C-V measurement on semiconductor Specimen	Semiconductor measurements - Runyan
Double slit- Fraunhofer diffraction (missing order etc.)	Advance practical physics - Worsnop and Flint
Determination of Young's modulus of metal rod by interference method	Advance practical physics - Worsnop and Flint (page 338)
Adder-subtractor circuits using ICs	a) Digital principles and applications -- Malvino and Leach b) Digital circuits practice - R.P. Jain
Study of Presettable counters - 74190 and 74193	a) Digital circuit practice - Jain & Anand b) Digital principles and applications -- Malvino and Leach c) Experiments in digital practice -Jain & Anand
TTL characteristics of totem pole, open collector and tristate devices	a) Digital circuits practice - Jain & Anand b) Digital principles and applications -- Malvino and Leach
Pulse width modulation for speed control of dc toy motor	Electronic Instrumentation - H. S. Kalsi
Study of sample and hold circuit	Integrated Circuits - K. R. Botkar
Switching Voltage Regulator	Integrated Circuits - K. R. Botkar

ELECTIVES-1

Phys-505A: Experimental Techniques in Nuclear Physics

Unit 1:

1. Radiation sources: electrons, heavy charged particles, electromagnetic radiation, neutrons, neutrinos, and muons.
2. Charge particle interaction: Stopping power, energy loss and range, straggling, bremsstrahlung, Cherenkov radiation; Interaction of photons: photoelectric effect, Compton scattering, pair production; Slow and fast neutron cross-sections, neutron interactions and detection; Interaction of neutrino; Interaction of muons.
3. Radiation exposure and dose, biological effects, radiation safety in Nuclear Physics Laboratory.

Unit 2:

1. Characteristics of detectors: detector response and sensitivity, energy resolution, timing characteristics, dead time, detection efficiency. Modes of detector operation.
2. Gas-filled detectors: ionization chamber, gridded ionization chamber, multi-wire proportional counter, Geiger-Muller counter, resistive plate chamber.
3. Radiation Survey Meter, dosimeter, Area Monitor

Unit 3:

1. Scintillation detectors: organic (crystals, liquids and plastics) and inorganic (alkali halide and activated). Light collection, Photomultiplier tubes.
2. Semiconductor detectors: silicon detectors (surface barrier, ion-implanted, lithium-drifted), germanium detectors (HPGe, clover, segmented)
3. Introduction to large detector arrays: charge-particle, gamma, plastic, neutron, muon detector arrays

4. Cherenkov detectors, tracking detectors, introduction to hybrid detector.

Unit 4:

1. Electronics for pulse signal processing: Coaxial cables, pre-amplifiers, amplifiers, pulse shaping networks in amplifiers, biased amplifiers, discriminators, constant fraction discriminator, single channel analyser, analog to digital converter, multi- channel analyser, time to amplitude converter, introduction to digital signal processing, instrumentation standards.

2. Coincidence Techniques and its applications, ΔE -E detectors for charged particles identification, time of flight measurements, electric and mass analysers.

References:

[1] Radiation Detection and Measurement, Glenn F. Knoll, John Wiley and sons, Inc.

[2] Techniques for Nuclear and Particle Physics Experiments, W.R. Leo, Springer-Verlag [3] Techniques for Nuclear and Particle Physics Experiments, Stefaan Tavernier, Springer

[4] Radiation detectors. C.F. Delaney and E.C. Finch. Clarendon Press, Oxford

[5] Nuclear radiation detectors, S.S. Kapoor and V.S. Ramamoorthy, New Age

Phys-505B: Laser Physics (60 lectures, 4 credits)

Unit 1: Laser characteristics and Resonators: Principles, Properties of laser radiation, Einstein Coefficients, Light amplification, Threshold condition for laser oscillations, Homogeneous and inhomogeneous broadening,

Laser rate equations for 2, 3 and 4 level, variation of laser power around threshold, optimum output coupling, Open planar resonator, Quality Factor, ultimate line width of the laser, Transverse and Longitudinal mode selection.

Unit 2: Non-linear optics: Techniques for Q-switching, Mode Locking, Hole burning and Lamb dip in Doppler broadened Gas laser, Non-linear oscillator model, Non-linear polarization and wave equation, perturbative solution of the Nonlinear oscillator equation, Harmonic generation, Second harmonic generation, Phase matching third harmonic generation. Optical wave mixing, parametric generation of light, parametric oscillation, tuning of parametric oscillators. Non-Linear susceptibilities, non-linear susceptibility tensor, non-linear materials

Unit 3: Laser Systems: Solid State Laser, Gas lasers, liquid lasers, Eximer lasers. Semiconductor Laser, liquid-dye and chemical lasers, high power laser systems and industrial applications.

Unit 4: Spectroscopic Instrumentation and applications: Raman scattering, photo-acoustic Raman Spectroscopy. Raman Amplification and Raman laser, special techniques in non-linear spectroscopy, polarization spectroscopy, multi-photon spectroscopy, photofluorescence excitation spectroscopy.

Holographic Optical Element: HOE, Design aspects, resolution, vibration and motion analysis by Holographic techniques, holography, Spatial Frequency filtering, optical Communication, optical computers. Laser ablation, Laser in Biomedicine.

Main References:

1. B. Laud, Laser and Non-linear optics, Wiley Eastern Ltd., (1991).
2. A.K. Ghatak and K. Thyagarajan, optical electronics, Cambridge University Press (1991).
3. S.C Gupta Optoelectronic devices and systems, Prentice Hall of India.
4. (WH) Wilson and Hawkes: Optoelectronics, Prentice Hall of India.
5. Yariv, Optical Electronics in Modern Communications, Oxford University Press (1997),
6. Laser Spectroscopy- Basic concepts and instrumentation by Demtroder (ed. 3, Springer)

Additional Reference books:

1. Laser: Svelto
2. Optical electronics: Wariv
3. Laser spectroscopy: Demtroder
4. Non-linear spectroscopy: Etekhov
5. Introduction to modern optics: G.R.Flowles

Phys-505C: Astronomy and Astrophysics

Unit 1

1. Introductory Astronomy: Wavelength bands of observation: radio, infrared, optical, UV, X-ray and Gamma-ray, Celestial sphere and different coordinate systems (introductory), right ascension and declination. Timekeeping: Sidereal and Solar. Basic definitions: apparent luminosity, absolute luminosity. Distance ladder: Trigonometric and spectroscopic.

Unit 2

1. Stellar Structure and Evolution: Stellar parameters: Mass, Radius, Luminosity, and Chemical Composition, Spectral types. Stellar physics: Equation of state, Opacity, Nuclear energy generation, Saha Ionization equilibrium, Planck Blackbody Radiation, Radiative and convective transport of energy, Internal structure of stars and Virial Theorem. Stellar atmosphere: Absorption and Emission of lines, Stellar Evolution: H-R diagram, Hayashi phase,

Main sequence, Horizontal Branch, Red Giant and Asymptotic Giant Branches. Planetary Nebulae and Supernova remnants.

2. Compact objects: White dwarfs and Chandrasekhar Limit. Neutron stars and Black holes: Pulsars, X-ray and Gamma-ray sources. Binary systems: Accretion process and associated phenomena.

Unit 3

1. Galactic Astronomy: Galactic structure: Nucleus, Bulge, Disk and Corona. Morphology of Galaxies: Dwarfs, Ellipticals, Spirals and Irregulars. Rotation Curves: Dark Matter. Interstellar Medium and Molecular Complexes: Star formation, Metal Content, Initial Mass Function. Galactic and Globular clusters and their ages. Spiral arms and magnetic fields.

2. Extragalactic Astronomy: Classification of Galaxies: Hubble sequence. Groups and Clusters of Galaxies: Missing mass (M/L). Gravitational Lenses. Intergalactic Medium: Diffuse Radiation and Magnetic Fields, Damped Lyman alpha absorbers. Active Galactic Nuclei: Seyferts, BL Lacs and Quasars, Unified Models. Dynamical and chemical evolution of galaxies: Interactions and mergers.

Unit 4

Newtonian Cosmology:

1. Introduction to Newtonian cosmology. Hubble law for Expanding Universe. Age and distance scale in cosmology. Early Universe: Thermal history & Nucleosynthesis of light elements. Cosmic Microwave Background Radiation.

Main References:

[1] F. Shu, The Physical Universe. An Introduction to Astronomy; University Science Books, Sausalito 1982.

[2] Unsold and B. Bescheke, The New Cosmos, 4th ed.; Springer Verlag 1991.

[3] J.V. Narlikar, Introduction to Cosmology; CUP, 1993.

[4] G.B. Rybicki & A.P. Lightman, Radiative Processes in Astrophysics; Wiley Intl. 1979.

[5] Arnab Rai Choudhuri, Astrophysics for physicists; CUP, 1998

Phys-505D: Surfaces and Thin Films (60 lectures, 4 edits)

Unit 1: Physics of Surfaces, Interfaces and Thin films

Mechanism of thin film formation: Condensation and nucleation, growth and coalescence of islands, Crystallographic structure of films, factors affecting structure and properties of thin films; Properties of thin films:- Transport and optical properties of metallic, semiconducting and dielectric films; Application of thin films

Unit 2: Thin films : Formation & Measurement

Vacuum Techniques: Review:- Production of low pressures; Measurement of pressure, Leak detections, Materials used

Preparation of Thin Films: Thermal evaporation, Cathode Sputtering, Chemical Deposition, Laser Ablation, Langmuir Blochet Films

Thickness Measurements: Stylus Method, Electrical Method, Quartz Crystal Method, Optical Methods, mass measurements (microbalance)

Unit 3: Nano Science and Nano Technology

Band structure and Density of States at Nanoscale, Quantum mechanics for nanoscience- size effects, application of Schrodinger equation, quantum confinement. Growth techniques for nano materials- Top down, Bottom up technique. Nano technology applications- nano structures of Carbon, BN nanotubes, Nanoelectronics, nanobiometrics

Unit 4: Surface Analytical Techniques

X-ray Photoelectron spectroscopy (XPS), Auger Electron spectroscopy (AES), Depth profiling by Ar ions, Low Energy Electron Diffraction (LEED), Secondary Ion Mass spectroscopy (SIMS), Rutherford Backscattering spectroscopy (RBS), Transmission Electron Microscopy (TEM), Scanning Electron Microscopy (SEM) with EDAX, Scanning Probe Microscopy – a) Scanning Tunneling Microscopy (STM), and b) Atomic Force Microscopy (AFM)

References:-

Unit 1:

- K.L. Chopra “Thin Film Phenomena” McGraw Hill Inc (1969)
- Ludmila Eckertova “Physics of Thin Films” Plenum Press NY (1986)

Unit 2:

- Roth “Vacuum Technology” North Holland Amsterdam
- Ludmila Eckertova “Physics of Thin Films” Plenum Press NY (1986)
- Thin Film Phenomena LK Chopra McGraw Hill 1969

Unit 3:

- “Introduction to NanoScience and Nanotechnology” K.K. Chattopadhyay and A.N. Banerjee PHI learning (2009)
- “Nanotechnology- Principles and Practices “ S.K. Kulkarni, Capitalpublishing 2007

Unit 4:

- “Surface and Thin Film Analysis” ed H. Bubert and H. Jennet, Wiley –VCH (2003)
- “Fundamentals of Surface and Thin Film Analysis” L.C. Feldman and J.W. Mayer North Holland amsterdam (1986)
- “Surface Analytical Methods” D.J. O’Conner, B.A. Sexton and R. St. C. Smart (ed) Springer Verlag (1991)

Soft Condensed Matter: Liquid Crystals

Course Objective

Liquid Crystals are soft condensed matters involved in major areas of Science, Engineering and Technology. Starting from the building blocks of our body, to the most of the food we eat or drink, and toiletries we use every day, all fall under the domain of soft matter. These materials have great impacts society at very different points, including the current challenges of climate change and of sustainable energy. These materials are unique in their properties and are promising material for various applications such as Liquid Crystal Displays, Liquid Crystal Thermometers, Optical Imaging, Erasable Optical Disks, Light Modulators and full color electronic slides for Computer Aided Design etc.

The basic aim of course on Liquid Crystals is to provide fundamental concepts of these smart functional materials, their different types and its phases. The effect of various external stimuli like light, heat, electric and magnetic fields on liquid crystals will be also covered. The different characteristics properties and important phenomena that describe equilibrium and non-equilibrium behavior of soft matter systems will be taught. The syllabus also aims to cover Polymer dispersed Liquid Crystals, Liquid Crystals Elastomers and their potential applications in understanding different systems.

Module	Detail	Hrs.
1.	Introduction to Liquid Crystals (LCs): Discovery of liquid crystals, classification and different types of mesophases, discotic liquid crystals, unusual shaped liquid crystals, ferroelectric or chiral smectic liquid crystal, Antiferroelectric Liquid Crystals (AFLC), Ferrielectric Liquid Crystal (FLC), Twisted Grain Boundary (TGB) and blue phases.	13
2.	Theoretical Insights: Phase transition: concept of phase, first order phase transition, condition for phase coexistence, Clapeyron equation, Ehrenfest classification of phase transition, Vander walls equation of state, Maxwell's construction, Landau-de Gennes theory, Maier-Saupe theory, Onsager-Marcf theory, McMillan's model.	11
3.	Physical properties of liquid crystals: Physical coefficients of anisotropic materials, anisotropy in liquid crystals, light and liquid crystal, Effect of electric field on liquid crystals, dielectric properties, measurement of permittivity, effect of magnetic Field, magnetic susceptibility and anisotropy, elastic, viscous properties and their measurements.	12

4.	Liquid Crystal Polymer (LCP) and Liquid Crystal Elastomers (LCE): Introduction, classical rubber elastic theory, Gaussian elasticity of a cross-linked macromolecular network, Liquid Crystal Polymers, Types of Monomeric Units, Main Chain Liquid Crystal Polymers (MCLCPs), Side Chain Liquid Crystal Polymers (SCLCPs), phase transitions and phase diagrams in LCPs, Liquid Crystals Elastomers and its types.	11
5.	Synthesis, Characterization Techniques and Applications Synthesis of liquid crystal-strategies and methods, techniques used for identification and characterization of phases, Polarizing Optical Microscopy (POM), Differential Scanning Calorimetry (DSC) and Differential Thermal Analysis (DTA), Refractometer study, Ultrasonic study, survey over flat panel technologies, Applications of Liquid Crystal, Liquid Crystal Polymer and Elastomers, Future scope.	13

References:

1. Introduction to Liquid Crystals Chemistry and Physics (2nd Edition October 2019) by Peter J. Collings and John W. Goodby CRC Press Routledge Publication
2. The Physics of Liquid Crystals (2nd Edition 1995) by P. G. de Gennes and J. Prost Oxford University Press,
3. Applications of liquid crystals by Gerhard Meier Springer Publication
4. Liquid Crystals: Fundamentals by Shri Singh, David A. Dunmur World Scientific, 2002
5. Liquid Crystals: Experimental Study of Physical Properties and Phase Transitions by Satyendra Kumar (Editor), Cambridge University Press (2011)
6. Liquid Crystalline Polymers: Volume 1 and 2 Processing and Applications by Thakur, Vijay Kumar, Kessler, Michael R.(Editors) Springer (2016)
7. Liquid Crystal Elastomers: Materials and Applications by Wim H. de Jeu (Editor) Springer-Verlag Berlin and Heidelberg GmbH & Co. KG.

Phys-505F: Nanoscience and Nanotechnology (60 lectures, 4 credits)

Unit 1:

Metal nanoclusters: Magic numbers, Theoretical Modeling of nanoparticles, Geometric Structure, Electronic Structure, Reactivity, Fluctuations, Magnetic clusters, Bulk-to-Nano transition; Semiconducting nanoparticles: Optical properties, Photofragmentation, Coulomb Explosion; Rare-gas and molecular clusters: Inert gas clusters, Superfluid clusters, Molecular clusters, Nanosized Organic crystals; Methods of synthesis: RF plasma, Chemical methods, Thermolysis, Pulsed-Laser method, Synthesis of nanosized organic crystals

Cohesive Energy: Ionic solids, Defects in Ionic solids, Covalently bonded solids, Organic crystals, Inert-gas solids, Metals, Conclusion

Quantum wells, wires and dots: Fabricating Quantum Nanostructures: Solution fabrication, Lithography; Size and dimensionality effects: Size effects, Size effects on conduction electrons, Conduction electrons and dimensionality, Fermi gas and density of states, Potential wells, Partial confinement, Properties dependent on density of states; Excitons, Single electron Tunneling; Applications: Infrared detectors, Quantum dot lasers.

(Owens and Poole: Chapter 3, 6 and 9)

Unit 2:

Vibrational Properties: The finite One-dimensional monoatomic lattice, Ionic solids, Experimental Observations: Optical and acoustical modes; Vibrational spectroscopy of surface layers of nanoparticles – Raman spectroscopy of surface layers, Infrared Spectroscopy of surface layers; Photon confinement, Effect of dimension on lattice vibrations, Effect of dimension on vibrational density of states, effect of size on Debye frequency, Melting temperature, Specific heat, Plasmons, Surface-enhanced Raman Spectroscopy, Phase transitions

Electronic Properties: Ionic solids, Covalently bonded solids; Metals: Effect of lattice parameter on electronic structure, Free electron model, The Tight-Binding model; Measurements of electronic structure of nanoparticles: Semiconducting nanoparticles, Organic solids, Metals

Carbon nanostructures: Introduction; Carbon molecules: Nature of the carbon bond, New Carbon structures; Carbon clusters: Small Carbon clusters, Buckyball, The structure of molecular C₆₀, Crystalline C₆₀, Larger and smaller Buckyballs, Buckyballs of other atoms; Carbon nanotubes: Fabrication, Structure, Electronic properties, Vibrational properties, Functionalization, Doped Carbon Nanotubes, Mechanical properties; Nanotube Composites: Polymer-carbon nanotube composites, Metal-Carbon nanotube composites; Graphene nanostructures.

(Owens and Poole: Chapter 7, 8 and 10)

Unit 3:

Mechanical Properties of Nanostructured Materials : Stress-Strain Behavior of materials; Failure Mechanism of Conventional Grain-Sized Materials; Mechanical Properties of Consolidated Nano- Grained Materials; Nanostructured Multilayers; Mechanical and Dynamical Properties of Nanosized Devices : General considerations, Nanopendulum, Vibrations of a Nanometer String, The Nanospring, The Clamped Beam, The challenges and Possibilities of Nanomechanical sensors, Methods of Fabrication of Nanosized Devices

Magnetism in Nanostructures : Basics of Ferromagnetism; Behavior of Powders of Ferromagnetic Nanoparticles : Properties of a single Ferromagnetic Nanoparticles, Dynamic of Individual Magnetic Nanoparticles, Measurements of Superparamagnetism and the Blocking Temperature, Nanopore Containment of Magnetic Particles; Ferrofluids; Bulk nanostructured Magnetic Materials: Effect of nanosized grain structure on magnetic properties, Magnetoresistive materials, Carbon nanostructured ferromagnets; Antiferromagnetic nanoparticles

Nanoelectronics: N and P doping and PN junctions, MOSFET, Scaling of MOSFETs;

Spintronics: Definition and examples of spintronic devices, Magnetic storage and spin valves, Dilute magnetic semiconductors; Molecular switches and electronics: Molecular switches, Molecular electronics, Mechanism of conduction through a molecule; Photonic crystals

(Owens and Poole: Chapter 12, 13 and 14)

Unit 4:

An introduction to nanochemistry concepts: Nanochemistry introduction, Surface, Size, Shape, Self-assembly, Defects, The bio-nano interface, Safety.

Gold: Introduction, Surface, Size, Shape, Self-assembly, Defects, Bio-nano, Gold-Nanofood for thought.

Cadmium Selenide: Introduction, Surface, Size, Shape, Self-assembly, Defects, Bio-nano, CdSe- Nanofood for thought.

Iron Oxide: Introduction, Surface, Size, Shape, Self-assembly, Bio-nano, Iron Oxide-Nanofood for thought.

Carbon: Introduction, Surface, Size, Shape, Self-assembly, Bio-nano, Conclusion, Carbon-Nanofood for thought.

(Cademartiri and Ozin: Chapter 1, 3, 5, 6, and 7)

References:

1. The Physics and Chemistry of Nanosolids, *Frank J. Owens and Charles P. Poole*, Wiley- Interscience, 2008.
2. Concepts of Nanochemistry, *Ludovico Cademartiri and Geoffrey A. Ozin*, Wiley-VCH, 2009.

Phys-505G: Signal Modulation and Transmission Techniques, (60 lectures, 4 credits)

Unit 1:

Single Sideband Techniques: Evolution and description of SSB, Suppression of carrier, Suppression of unwanted sideband, Extensions of SSB, Frequency Modulation: Theory of frequency and phase modulation, Noise and frequency modulation, Generation of frequency modulation. *Radio Receivers:* Receiver types, AM receivers, Communication receivers, FM receivers, Single- sideband receivers, Independent-sideband receivers

Unit 2

Transmission Line Theory: Fundamental of transmission lines, Different types of transmission lines; Telephone lines and cables, Radio frequency lines, Micro strip transmission lines. Definition of characteristics impedance, Losses in transmission lines, Standing waves, Quarter and Half wavelength lines, Reactance properties of transmission lines, Fundamental of the Smith charts and its applications

Unit 3

Electromagnetic Radiation and Propagation of Waves: Fundamental of electromagnetic waves, Effects of the environment, Propagation of waves; Ground waves, Sky wave propagation, Space waves, Tropospheric scatter propagation, Extraterrestrial communication

Unit 4:

Antennas: Basic considerations, Wire radiators in space, Terms and definitions, Effects of ground on antennas, Antenna Coupling at medium frequencies, Directional high frequency antennas, UHF and Microwave antennas, Wideband and special purpose antennas

Main References:

[1] Electronic Communication Systems by George Kennedy and Bernard Davis, 4th ed., Tata McGraw-Hill Publishing Company Ltd., New Delhi.

[2] Electronic Communication Systems-*Fundamentals through Advanced* by Wayne Tomasi; 4th Edition, Pearson education Singapore.

Additional References:

- [1] Electronic Communications by Dennis Roddy & John Coolen, (4th ed., Pearson Ed.)
- [2] Modern Electronic Communication by Gary M. Miller, (6th ed., Prentice Hall International Inc.)

Phys-505H: Computational methods in physics (45 lectures+15 tutorials, 4 credits)

Unit I - Deterministic Methods

Molecular dynamics (MD) method: Integrating equation of motion of q few variables, three—body problem, role of molecular dynamics (MD), the basic machinery, Lennard—Jones potentials modeling physical system, boundary conditions, time integration algorithm, starting a simulation, simulation of microcanonical (NVE) and canonical ensemble (NVT), controlling the system (temperature, pressure), thermostats and barostats, equilibration, running, measuring and analyzing MD simulation data, measurement of statistical quantities, interatomic potentials, force fields.

References:

1. A Molecular Dynamics Primer, Furio Ercolessi, <http://www.fisica.uniud.it/~ercolessi/md/>
2. Understanding Molecular Simulation, Daan Frenkel and B. Smit, Academic Press, 1996.
3. Computational Physics, J. M. Thijssen, Cambridge Univ. Press, 1999.
4. Molecular Dynamics Simulation— Haile (Wiley Professional)
5. A first course in computational Physics, Paul, L. Pavries, Pub. John Wiley and Sons, 1994.

Unit II – Stochastic Methods

Random number: Definition, True and Pseudo random number generators (RNG), uniform and non-uniform RNG, Linux RNG, testing a RNG.

Monte Carlo simulation: Buffon's needles, MC Integration, hit and miss, stochastic processes, sample mean integration, important sampling, Markov Chain, Metropolis method, master equation, introduction to 2d-Ising model.

Case Study: Phase transition in 2d Ising model.

References:

1. Computer Simulation of Liquids, M. P. Allen and D. J. Tidesley (Oxford University Press)
2. Understanding Molecular Simulation, Daan Frenkel and B. Smit, Academic Press, 1996.
3. Monte Carlo Methods, M. H. Kalos and P. A. Whitelock, John Wiley & Sons, NY 1986.

4. A Guide to Monte Carlo Simulations in Statistical Physics, Landau & Binder (Cambridge University Press).

5. Statistical Mechanics - Algorithms and Computations, Krauth (Oxford University Press).

Unit III - Electronic Structure

Revision: Matrix Formulation (Vector Spaces, Basis, Eigenvalue problem) and Introductory Quantum Mechanics (State function, expectation value, central force problem, hydrogen—atom, perturbation theory applied to helium atom)

Many—body theory, Born—Oppenheimer approximation, many—body wavefunction, variational principle, functionals and functional derivatives, Hartree approximation, Hartree—Fock theory, electron—density and Thomas—Fermi model, Hohenberg—Kohn theorems, Kohn—Sham theory.

References:

6. Principles of Quantum Mechanics, by R. Shankar

7. Introductory Quantum Mechanics, by Richard Liboff

8. Quantum Chemistry, by Ira Levine

9. A Chemists Guide to DFT, by W. Koch and M. C. Holthausen

10. Density functional theory of atoms and molecules, by R. G. Parr and W. Yang

11. Modern Quantum Chemistry — Introduction to Advanced Electronic Structure Theory, by A. Szabo and N. S. Oslund

12. Materials Modelling using Density Functional Theory Properties and Predictions, by F. Giustino

13. Electronic Structure Calculations for Solids and Molecules Theory and Computational Methods, by Jorge Kohanoff

14. Electronic Structure Basic Theory and Practical Methods, by Richard M. Martin

Unit – IV — Optimization Techniques

Introduction to modeling, simulation, and machine learning concepts

Single variable functions, multivariable function with constraints, Lagrange multipliers,

successive quadratic programming, Newton-Raphson method, Quasi-Newton method, steepest descent, conjugate gradient, genetic algorithm, simulated annealing, Levenberg—Marquardt algorithm.

References

15. Numerical Recipes in C++ (2nd ed.), W. H. Press, S. A. Teukolsky, W. T. Vetterling and B. P
16. H. M. Antia: Numerical methods for scientists and engineers.
17. Iterative Methods for Optimization, C. T. Kelley, North Carolina State University, Raleigh, North Carolina
18. S. S. Sastry: Introductory method of numerical analysis, PHI India 2005
19. P. B. Patil and U. P. Verma: Numerical Computational methods, Narosa Publ.

ELECTIVES-2

Phys-515A: Particle Physics (60 lectures, 4 credits)

UNIT 1: GENERAL CONCEPTS (12 LECTURES + 3 TUTORIALS)

1. Survey of Particle Physics

The four fundamental interactions, classification by interaction strength and decay lifetimes, numerical estimates, use of natural units.

Classification of elementary particles by masses, interactions and conserved quantum numbers, selection rules for particle decays and scattering.

2. Experimental Techniques:

Particle detectors and accelerators: cloud and bubble chambers, emulsion techniques, electronic detectors, proportional counters, fixed target and collider machines, basic idea of cyclotron, synchrotron and linac.

3. Klein Gordon equation

Relativistic energy-momentum relation, Klein-Gordon equation, solutions of the equation, probability conservation problem, relation with negative energy states.

4. Dirac equation

Dirac equation, algebra of γ matrices, conservation of probability, solutions of Dirac equation, helicity and chirality, Lorentz covariance, bilinear covariants, trace relations and similar identities, C, P and T invariance of the Dirac equation.

UNIT 2: QUANTUM ELECTRODYNAMICS (11 LECTURES + 4 TUTORIALS)

5. The QED Lagrangian

Structure of the QED Lagrangian, gauge invariance and conserved current, scalar electrodynamics, Feynman rules for QED (no derivation).

6. Basic Processes in QED

Feynman diagram calculation

for $e^+e^- \rightarrow \mu^+\mu^-$

, phase space integration, Møller and Bhabha scattering, polarisation vectors, Compton scattering and pair creation/annihilation, Klein-Nishina formula.

7. Higher Orders in QED

Concept of multi-loop diagrams (no computation), momentum integral, UV and IR singularities, idea of regularisation, running coupling constant.

UNIT 3: QUARK PARTON MODEL (11 LECTURES + 4 TUTORIALS)

8. The Eightfold Way

Isospin and strangeness, introduction to unitary groups, generators, Casimir invariants, fundamental and adjoint representations, root and weight diagrams, meson and baryon octets, baryon decuplet and the prediction of the

Ω^-

, Gell-Mann-Nishijima formula.

9. Quark Model

Product representations and irreps, symmetry group, Young tableaux, quark model, meson and baryon wavefunctions.

10. Deep Inelastic Scattering

Elastic scattering off a point particle, form factors, Rosenbluth formula, Breit frame, inelastic scattering, structure functions, dimensionless variables.

11. Parton Model

Bjorken scaling, parton model, structure functions in terms of PDFs, Callan-Gross relation, kinematic regions, valence and sea quarks, gluons.

UNIT 4: WEAK INTERACTIONS (11 LECTURES + 4 TUTORIALS)

12. Fermi theory

Beta decay, Fermi and Gamow-Teller transitions, current-current form of weak interactions, Fermi constant, universality, unitarity violation at high energies.

13. Intermediate vector bosons

$W^\pm$

bosons, unitarity, requirement of conserved currents, muon decay, pion decay, form factor.

14. Parity violation

Intrinsic parity, parity conservation in strong and electromagnetic interactions, parity violation in weak interactions, experiments of Wu *et al* and of Goldhaber *et al*, maximal parity violation.

15. Flavour Mixing and CP Violation

FCNC suppression, Cabibbo hypothesis, kaon decays, theta-tau puzzle, K^0 - $\bar{K}^0$

mixing, regeneration experiment, GIM mechanism, CKM matrix and quark mixing.

Suggested reading:

1. *Introduction to Elementary Particles*, by D. Griffiths (Wiley 1987).

2. *Quarks and Leptons*, by F. Halzen and A.D. Martin (Wiley 1984).
3. *Particle Physics*, by B.R. Martin and G. Shaw (Wiley 2008).

Phys-515C: Applied Thermodynamics (60 lectures, 4 credits)

Unit I

First Law of Thermodynamics: Energy, enthalpy, specific heats, first law applied to systems and control volumes, steady and unsteady flow analysis.

Second Law of Thermodynamics: Kelvin-Planck and Clausius statements, reversible and irreversible processes, Carnot theorems, thermodynamic temperature scale, Clausius inequality and concept of entropy, principle of increase of entropy; availability and irreversibility.

Zeroth Law of Thermodynamics: concept of temperature, Overview of techniques in low temperature production

Unit II

Properties of Pure Substances: Thermodynamic properties of pure substances in solid, liquid and vapor phases, P-V-T behaviour of simple compressible substances, phase rule, thermodynamic property tables and charts, ideal and real gases, equations of state, compressibility chart.

Thermodynamic Relations: T-ds relations, Maxwell equations, Liquefaction of gases: Joule-Thomson effect, Joule-Thomson coefficient, coefficient of volume expansion, adiabatic and isothermal compressibilities, Clapeyron equation.

Unit III

Equilibrium Concept in Thermodynamics Unary, binary and multicomponent systems, phase equilibria, evolution of phase diagrams, metastable phase diagrams, calculation of phase diagrams, thermodynamics of defects. solution models,**Some Thermodynamic cycles:** Carnot vapor power cycle, Ideal Rankine cycle, Rankine Reheat cycle, Otto cycle, Diesel cycle,

Unit IV

Thermodynamics of Phase transformation and Heterogeneous Systems:

Melting and solidification, precipitation, eutectoid, massive, spinodal, martensitic, order disorder transformations and glass transition. First and second order transitions..Equilibrium Constants and Ellingham diagrams

References:

1. M. Modell and R.C. Reid, Thermodynamics and its Applications, Prentice-Hall, Englewood Cliffs, New Jersey, 1983.
2. H.B. Callen, Thermodynamics and an Introduction to Thermostatistics, John Wiley & Sons, New York, 1985.
3. R.T. DeHoff, Thermodynamics in Materials Science, McGraw-Hill, Singapore,
4. Physical Chemistry of Metals: L.S. Darken and R.W. Gurry
5. Thermodynamics of Solids: R.A. Swalin
6. Phase Transformations in Metals and Alloys: D.A. Porter and K.E. Easterling
7. Principles of Extractive Metallurgy: H.S. Ray

Phys-515D: Properties of Solids (60 lectures, 4 credits)**Unit 1 Optical and Dielectric properties**

Maxwell's equations and the dielectric function, Lorentz oscillator, the Local field and the frequency dependence of the dielectric constant, Polarization catastrophe, Ferroelectrics

Absorption and Dispersion, Kramers' Kronig relations and sum rules, single electron excitations and plasmons in simple metals, Reflectivity and photoemission in metals and semiconductors

Interband transitions and introduction to excitons, Infrared spectroscopy

Unit 2 Transport Properties

Motion of electrons and effective mass, The Boltzmann equation and relaxation time, Electrical conductivity of metals and alloys, Matthiessen's rule, Thermo-electric effects, Wiedemann-Franz Law, Lorentz number, ac conductivity, Galvanomagnetic effects

Unit 3 Magnetism and Magnetic materials

Review: Basic concepts and units, basic types of magnetic order

Origin of atomic moments, Heisenberg exchange interaction, Localized and itinerant electron

magnetism, Stoner criterion for ferromagnetism, Indirect exchange mechanism: superexchange and RKKY

Magnetic phase transition: Introduction to Ising Model and results based on Mean field theory

Other types of magnetic order: superparamagnetism, helimagnetism, metamagnetism, spin-glasses

Magnetic phenomena: Hysteresis, Magnetostriction, Magnetoresistance, Magnetocaloric and magneto-optic effect

Magnetic Materials: Soft and hard magnets, permanent magnets, media for magnetic recording

Unit 4 Superconductivity

The phenomenon of superconductivity: Perfect conductivity and Meissner effect, Electrodynamics of superconductivity: London's equations, Thermodynamics of the superconducting phase transition: Free energy, entropy and specific heat jump

Ginzburg-Landau theory of superconductivity: GL equations, GL parameter and classification into Type I and Type II superconductors, The mixed state of superconductors

Microscopic theory: The Cooper problem, The BCS Hamiltonian, BCS ground state Josephson effect: dc and ac effects, Quantum interference

Superconducting materials and applications: Conventional and High T_c superconductors, superconducting magnets and transmission lines, SQUIDs

References

1. Solid State Physics, H. Ibach and H. Luth, Springer(Berlin) 2003 (IL)
2. Solid State Physics, Neil Ashcroft and David Mermin (AM)

3. Introduction to Solid State Physics (7th/ 8th ed) Charles Kittel (K)
4. Principles of Condensed Matter Physics, Chaikin and Lubensky (CL)
5. Intermediate theory of Solids, Alexander Animalu (AA)
6. Optical Properties of Solids, Frederick Wooten, Ac Press (New York) 1972 (FW)
7. Electrons and Phonons, J M Ziman
8. Electron transport in metals, J.L. Olsen
9. Physics of Magnetism and Magnetic Materials, K.H.J. Buschow and F.R. de Boer
10. Introduction to Magnetism and Magnetic Materials, D. Jiles
11. Magnetism and Magnetic Materials, B. D. Cullity
12. Solid State Magnetism, J. Crangle
13. Magnetism in Solids, D. H. Martin
14. Superconductivity Today, T.V. Ramakrishnan and C.N.R.Rao
15. Superconductivity, Ketterson and Song
16. Introduction to Superconductivity, Tinkham

PHYS-515E: Polymer Physics (4 Credit)

Course Objective:

- Learn the fundamental knowledge on the physics of polymer materials
 - Develop an understanding of structure-property relationships in polymers
 - knowledge on polymer materials with special properties
 - ability to use analysis techniques to identify the properties of polymer materials of interest in modern applications
 - Understand the societal impacts of polymer processing
- Course Outcome:

- enumerate and discuss different polymer chain models
- predict the phase stability of polymer solutions
- describe polymer properties and enumerate experimental techniques for their determination

Unit I:

Introduction to Polymer, classification based on: source, backbone of polymer chain, structure of polymer, composition of polymer, mode of polymerization, molecular force, Degree of polymerization, types of polymerization reactions, biosynthesis of polymer.

Unit II:

Polymerization processes: bulk polymerization, solution polymerization, suspension polymerization, emulsion polymerization, comparison of polymerization methods.

Molecular weight of polymers: molecular weight distribution and average molecular weight, empirical distribution model, measurement of molecular weight.

Unit III:

Properties of polymer: hardness, density, thermal properties, electrical properties, optical properties, diffusion in polymers.

Polymer elasticity, viscoelasticity, effect of crystallinity, effect of fillers, Failure tests, creep failure, fatigue, heterophase systems: partly crystalline material, fibers, rubber, composites

Unit IV:

Preparation of polymer thin films: Evaporation technique, glow discharge technique, gas phase chemical processes, liquid – phase chemical formation, chemical vapor deposition technique

Solid waste management: Solid waste – plastic, advantages of plastic waste, waste

management and the environment, environmental impact: landfill, thermolysis. Industrial waste plastics

Main References:

1. Introduction of polymer physics, M. DOI, Clarendon press – oxford
2. Polymer Physics, Michael Rubinstein & Ralph H. Colby, Oxford University press, 2003
3. Principles of Polymer system, Ferdinand Rodriguez, Claude Cohen, Christopher K. Ober, Lynde, A. Archer, CRC Press, 2015.
4. Scaling concepts in polymer, Pierre – Gilles de Gennes, Cornell University press, London (1979)
5. Handbook Of Thin film deposition, Processes and technology, second edition, Intel corporation Santa Clara, California
6. Platics waste management: Processing and Disposal, Dr. Muralisrinivasan, Natamai Subramanian, Smithers Group Company, 2016

Phys-515F: Electronic Structures of Solids

Unit – I – Basic Concepts and Theoretical Background

Schrodinger equations, 1D, 2D, and 3D, problem, Vector spaces and Matrices. Approximate methods, Hartree fock methods and its limitations.

Unit – 2 – Density functional Theory

Density functional theory: Thomas-Fermi Model, The Hohenberg-Kohn Theorem, Extension of Hohenberg-Kohn Theorem, Formulation of density functional theory, Various approximations.

Unit – 3 – Determination of Electronic structure

Plane waves and grid, Localized orbitals, Gaussian basis set, slater-type basis set, Augmented Functions, Basis sets and functions, choice of basis functions with examples, Pseudopotentials: Ultrasoft, Norm conserving, Projected Augmented waves.

Unit – 4 –

Applications of Density Functional theory Model Self consistency and non-self consistent field calculations, Quantum Molecular Dynamics, Response functions, Excitation spectra and optical spectra, Property Calculations-Structural, Mechanical, thermal, magnetic, electronic and excited state properties.

References:

1. Electronic Structure Calculations for Solids and Molecules – Theory and Computational Methods, Jorge Kohanoff, Cambridge University Press, 1 edition (2006).
2. Electronic Structure: Basic theory and Practical methods, Richard M. Martin, Cambridge University Press, 2004.
3. Computer Simulation of Liquids, M. P. Allen and D. J. Tildesley, Clarendon Press – Oxford, (1991).
4. Understanding Molecular Simulations, D. Frenkel and B. Smit, Academic Press, (2002).

Phys-515G: Microwave Electronics, Radar and Optical Fiber Communication, (60 lectures, 4 credits)

Unit 1

Waveguides, Resonators and Components: Rectangular waveguides, Circular and other waveguides, Waveguide coupling, matching and attenuation, Cavity resonators, Auxiliary components.

Unit 2:

Microwave Tubes and Circuits: Microwave triodes, Multicavity Klystron, Reflex Klystron, Magnetron, Traveling wave tube.

Microwave Semiconductor Devices and Circuits: *Passive* microwave circuits, Transistors and integrated circuits, parametric amplifiers, Tunnel Diodes and Negative Resistance Amplifier, Gunn effect and diodes, Avalanche effects and diodes. PIN Diode, Schottky barrier diode, backward diode.

Microwave Measurements: Slotted line VSWR measurement- Impedance measurement, insertion loss and attenuation measurements

Unit 3:

Radar Systems: Basic principles; Fundamentals, Radar performance factors Pulsed systems; Basic pulsed radar system, Antennas and scanning, Display methods, Pulsed radar systems, Moving radar systems. Moving target indication, Radar beacons, CW Doppler radar, Frequency modulated CW radar, Phased array radars, Planar array radars.

Unit 4:

Optical Fiber Communication Systems: Introduction to optical fibers, signal degradation in optical fibers, Fiber optical sources and coupling, Fiber optical receivers, System parameters, Analog optical fiber communication links, Design procedure, Multichannel analog systems, FM/FDM video signal transmission, Digital optical fiber systems.

Main References:

[1] Electronic communication systems by George Kennedy and Bernard Davis, 4th ed., Tata McGraw-Hill Publishing Company Ltd., New Delhi.

[2] Optical Fiber Communication by Gerd Keiser; McGraw-Hill International, Singapore, 3rd Ed; 2000.

[3] Electronic Communication Systems Fundamentals through Advanced by Wayne Tomasi; 4th Edition, Pearson education Singapore.

Additional References:

[1] Electronic Communications by Dennis Roddy and John Coolen, (4th ed., Pearson Education).

[2] Modern Electronic Communication by Gary M. Miller, (6th ed., Prentice Hall International, Inc.).

[3] Digital Communications Systems by Harold Kolimbris, (Pearson Education Asia).

Phys-515H: Digital Communication Systems (60 lectures, 4 credits)

Unit 1:

Digital Modulation: Introduction, information capacity, bits, bit rate, Baud and M-Ary encoding , ASK , FSK , PSK , QAM , Bandwidth efficiency , carrier recovery , clock

recovery.

Digital Transmission: Introduction, Pulse modulation, PCM sampling, Signal to quantization noise ratio, Commanding, PCM line speed, Delta modulation PCM, Adaptive delta modulation.

Unit 2:

Telephone Instruments and Signals: Introduction, The subscriber Loop, Standard telephone set, Basic telephone call procedures, Call progress tones and signals, Cordless telephones, Caller ID, Electronic telephones, paging system.

Telephone Circuits: Introduction, Local subscriber loop, Transmission parameters and private line circuits (concepts only), Voice frequency circuit arrangement.

Unit 3:

Study of PC Serial Port: Options and choices, Formats and protocols, The PCs serial port from the connector in, PC programming.

Cellular Phone Concepts: Introduction, Mobile phone service, evolution of cellular phone, frequency reuse, interference, cell Splitting, sectoring, segmentation and dualization, cellular system topology, roaming and handoffs

Cellular Phone Systems: Digital cellular phone, Interim standard 95, CDMA, GSM communication.

Unit 4:

Python Programming language: Introduction, Installing Python, First steps, The basics, operators and expressions, control flow, Functions.

Main References:

- [1] Advanced Electronic Communications Systems (Sixth edition) by Wayne Tomasi (PHI EE Ed)
- [2] Serial Port Complete by Jan Axelson; Penram International Publications.
- [3] A Byte of Python by C. H. Swaroop.

Additional References:

- [1] Electronic Communication Systems Fundamentals Through Advanced by Wayne

Tomasi; 4th Edition, Pearson education Singapore.

- [2] Electronic Communications by Dennis Roddy and John Coolen, (4th ed., Pearson Education).
- [3] Modern Electronic Communication by Gary M. Miller, (6th ed., Prentice Hall International, Inc.).
- [4] Wireless Communication Technology by Roy Blake, (Delmar – Thomson Learning).
- [5] Digital Communications Systems by Harold Kolimberis, (Pearson Education Asia).

Fundamentals of Materials Science, (60 lectures, 4 credits)

Unit 1:

Introduction to Materials Science and Engineering, Types of Materials, Competition among Materials, Future trends In Materials Usage, Atomic Structure and Bonding, Types of Atomic and Molecular Bonds, Ionic Bonding, Covalent Bonding, Metallic Bonding, Secondary Bonding, Mixed Bonding, Crystal Structures and Crystal Geometry, The Space Lattice and Unit Cells, Crystal Systems and Bravais Lattices, Principal Metallic Crystal Structures, Atom Positions in Cubic Unit Cells, Directions in Cubic Unit Cells, Miller Indices For Crystallographic Planes In Cubic Unit Cells, Crystallographic Planes and Directions In Hexagonal Unit Cells, Comparison of FCC, HCP, and BCC Crystal Structures, Volume, Planar, and Linear Density Unit Cell Calculations, Polymorphism or Allotropy, Crystal Structure Analysis

Unit 2 :

Solidification, Crystalline Imperfections, and Diffusion In Solids, Solidification of Metals, Solidification of Single Crystals, Metallic Solid Solutions, Crystalline Imperfections, Rate Processes In Solids, Atomic Diffusion In Solids, Industrial Applications of Diffusion Processes, Effect of Temperature on Diffusion In Solids.

Unit 3:

Mechanical Properties of Metals, The Processing of Metals and Alloys, Stress and Strain In Metals, The Tensile Test and The Engineering Stress-Strain Diagram, Hardness and Hardness Testing, Plastic Deformation of Metal Single Crystals, Plastic Deformation of Polycrystalline Metals, Solid-Solution Strengthening of Metals, Recovery and Recrystallization of Plastically Deformed. Metals, Fracture of Metals, Fatigue of Metals, Creep and Stress Rupture of Metals.

Unit 4:

Phase Diagrams, Phase Diagrams of Pure Substances, Gibbs Phase Rule, Binary Isomorphous

Alloy Systems, The Lever Rule, Nonequilibrium Solidification of Alloys, Binary Eutectic Alloy

Systems, Binary Peritectic Alloy Systems, Binary Monotectic Systems, Invariant Reactions, Phase Diagrams With Intermediate Phases and Compounds, Ternary Phase Diagrams.

Reference:

1. William F Smith, Javad Hashemi, Ravi Prakash, Materials Science and Engineering, Tata- McGraw Hill, 4th Edition.

VLSI Design and Embedded Systems: (60 lectures, 4 credits)

Unit I:

Introduction to VLSI Design: Physics of Field Effect Transistors (FETs): General physical considerations, MOSFET Threshold voltage, flat band conditions, threshold adjustment, linear and saturated operation, FET capacitance mobility saturation and thermal variations, short channel effect and hot electron effects, Electromigration, Aluminum spikes and contact resistance.

Processing, Scaling and Reliability: Silicon Gate NMOS processes, Silicon Patterining, Mask Generation, Active Area definition, Transistor Formation Contacts, Metallization, Chip Scaling tact, Functional limitations of scaling, Scaling of wires and interconnections, Latch up in scaled CMOS circuits, Device reliability, Soft error, Noise margins, Lead inductance, Gate oxide reliability, Polysilicon resistance and Input protection.

Design Rules and Layout: NMOS rules, CMOS design rules, passive load NMOS inverter, active load NMOS inverter, NMOS NAND & NOR gates, CMOS inverter, CMOS NAND & NOR gates, interlayer contacts, butting and buried contacts.

MOS Inverters: MOSFET aspect and inverter ratio, enhancement & depletion mode pull ups, enhancement Vs depletion mode pull ups, standard CMOS inverter, NMOS threshold voltage and inverter ratio transit and switching speed of NMOS & CMOS inverter.

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Unit II

CMOS Digital Gates and Sequential Circuits: NMOS and CMOS Super Buffer, Tri-State buffer and PAD Drivers, CMOS Gates, Dynamic CMOS Design, Charge Sharing, Pseudo-NMOS PMOS, Flip-Flops, Setup

and Hold Time, Race Around Condition, Sequential Digital Circuits, Power Analysis and Estimation, Different Process Corners, Slow and Fast Transistors, High and Low Threshold Voltage Transistors

VLSI Computer Aided Design (CAD) Tools and Methodology: Full-Custom CMOS Design Flow, Semi- Custom Design Flow, Application Specific Integrated Circuit (ASIC) CMOS Design Flow. Resistor transfer level (RTL) simulation, Conformal Mapping and Equivalence Check, Physical Design Verification (DRC/LVS).

RTL-To-GDSII Flow: Floorplanning, Placement, Clock-Tree Synthesis, I/O Pads and I/O Rings, RC extraction, Wire load Models, Routing, Design Rule Checking(DRC), Static Timing Analysis, Dynamic Timing Analysis, Timing Report Generation and Analysis.

Packaging and Testing: Packaging of ICs. Different types of packages. Design for Testability – requirement & cost of testing, test pattern generation, fault models, test generation and methodology.

Unit III:

Introduction to Embedded Systems: Introduction to Embedded Systems, Architecture of Embedded System, Design Methodology, Design Metrics, General Purpose Processor, System On chip.

Embedded System Design and Development: Embedded system design, Life-Cycle Models, Problem solving, The design process, Requirement identification, Formulation of requirements specification. Development tools.

System Design Specifications: System specifications versus system requirements, Partitioning and decomposing a system, Functional design, Architectural design, Functional model versus architectural model, Prototyping, Other considerations, Archiving the project.

Unit IV:

Real-Time Operating System (RTOS) based Embedded System Design: Operating System Basics, Types of OS, Tasks, Process and Threads, Multiprocessing and Multitasking, Task Scheduling, Threads, Processes and Scheduling: Putting them altogether, Task Communication, Task Synchronization, Device Drivers, How to Choose an RTOS.

Android Operating System: Introduction to Android Technology, Structure of Android Applications, Working with activities, Data Stores, Network services and APIs, Intents, Content Providers and Services, Advanced Operations with android, Telephony, SMS, Audio, video using the Camera.

References:

1. Introduction to VLSI Design, E.D.Fabircius
2. Introduction to VLSI Systems, Carver Mead and Lynn Conway, Addison-Wesley.
3. Neil Weste and David Harris, CMOS VLSI Design: A Circuits and Systems Perspective, fourth edition, Addison Wesley, 2011.
4. Principles of CMOS VLSI Design a System Perspective, Neil H.E.Weste, Kamran Eshraghian, Addison-Wesley.

5. Basic VLSI Design, D. A. Pucknell, Kamran Eshraghian, Prentice Hall.
6. Introduction to embedded systems, by Shibu K. V.; Sixth Reprint 2012, Tata McGraw Hill
7. James K Peckol, "Embedded Systems – A contemporary Design Tool", John Wiley, 2008.
8. Steve Furber, "ARM System-on-Chip Architecture", Second Edition, Pearson Education Publication.
9. James K. Peckol, "Embedded Systems: A Contemporary Design Tool", WILEY Student Edition Publication.
10. Tammy Noergaard, "Embedded Systems Architecture", Elsevier Publication

Additional References:

2. VHDL programming by example by Douglas L. Perry, Fourth edition, Tata McGraw-Hill
3. Starting Out with C++ Early Objects Tony Gaddis Judy Walters Godfrey Muganda Seventh Edition Addison-Wesley.
4. Object Oriented Programming with C++ by [Balagurusamy](#), McGraw Hill Education (India) Private Limited, Sixth Edition.
5. A Byte of Python by C. H. Swaroop.

VHDL, C++ and Python Programming: (60 lectures, 4 credits)

Unit I:

VHDL I: Introduction to VHDL: VHDL Terms, Describing Hardware in VHDL, Entity, Architectures, Concurrent Signal Assignment, Event Scheduling, Statement concurrency, Structural Designs, Sequential Behavior, Process Statements, Process Declarative Region, Process Statement Part, Process Execution, Sequential Statements, Architecture Selection, Configuration Statements, Power of Configurations.

Behavioral Modeling: Introduction to Behavioral Modeling, Transport Versus Inertial Delay, Inertial Delay, Transport Delay, Inertial Delay Model, Transport Delay Model, Simulation Deltas, Drivers, Driver Creation, Bad Multiple Driver Model, Generics, Block Statements, Guarded Blocks.

Sequential Processing: Process Statement, Sensitivity List, Process Example, Signal Assignment Versus Variable Assignment, Incorrect Mux Example, Correct Mux Example, Sequential Statements, IF Statements, CASE Statements, LOOP statements, NEXT Statement, EXIT Statement, ASSERT Statement, Assertion BNF, WAIT Statements, WAIT ON Signal, WAIT UNTIL Expression, WAIT FOR time_expression, Multiple WAIT Conditions, WAIT Time-Out, Sensitivity List Versus WAIT Statement, Concurrent Assignment Problem, Passive Processes.

Unit-II:

VHDL II: Data Types: Object Types, Signal, Variables, Constants, Data Types, Scalar Types, Composite Types, Incomplete Types, File Types, File Type Caveats, Subtypes.

Subprograms and Packages: Subprograms Function, Conversion Functions, Resolution Functions, Procedures, Packages, Package Declaration, Deferred Constants, Subprogram Declaration, Package Body.

Predefined Attributes: Value Kind Attributes, Value Type Attributes, Value Array

Attributes, Value Block Attributes, Function Kind Attributes, Function Type Attributes, Function Array Attributes, Function Signal Attributes, Attributes 'EVENT and ,LAST-VALUE Attribute 'LAST-EVENT Attribute, 'ACTIVE and 'LAST-ACTIVE Signal Kind Attributes, Attribute 'DELAYED, Attribute 'STABLE, Attribute 'QUIET, Attribute TRANSACTION, Type Kind Attributes, Range Kind Attributes.

Configurations: Default Configurations, Component Configurations, Lower-Level Configurations, Entity-Architecture Pair Configuration, Port Maps, Mapping Library Entities, Generics in Configurations, Generic Value Specification in Architecture, Generic Specifications in Configurations, Board-Socket-Chip Analogy, Block Configurations, Architecture configurations.

Unit III

Overview of Programming Using C++: Introduction to Computers and programming , Introduction to C++, Expressions and interactivity , Making decisions, Looping , Functions , Arrays , Sorting arrays, Pointers,

Object-Oriented Programming: Introduction to Classes and Object-Oriented Programming, Searching, Sorting, and Algorithm Analysis, Characters, Strings, and the string Class, Recursion, Polymorphism and Virtual Functions.

Unit IV:

Python Programming language: Introduction and Installing Python, Operators and Expressions, Looping, Control Statements, String Manipulation, Lists, Tuple, Dictionaries, Functions, Modules, Input-Output, Exception Handling. Introduction to Advance Python: OOPs concept, Regular expressions, CGI, Database, Networking, Multithreading, GUI Programming, Sending email

References:

3. VHDL programming by example by Douglas L. Perry, Fourth edition, Tata McGraw-Hil
4. Starting Out with C++ Early Objects Tony Gaddis Judy Walters Godfrey Muganda Seventh Edition Addison-Wesley.
5. Object Oriented Programming with C++ by [Balagurusamy](#), McGraw Hill Education (India) Private Limited, Sixth Edition.
6. A Byte of Python by C. H. Swaroop.

Additional References:

- a. Introduction to VLSI Design, E.D.Fabricius
- b. Introduction to VLSI Systems, Carver Mead and Lynn Conway, Addison-Wesley.
- c. Neil Weste and David Harris, CMOS VLSI Design: A Circuits and Systems Perspective, fourth edition, Addison Wesley, 2011.

- d. Principles of CMOS VLSI Design a System Perspective, Neil H.E.Weste, Kamran Eshraghian, Addison-Wesley.
- e. Basic VLSI Design, D. A. Pucknell, Kamran Eshraghian, Prentice Hall.
- f. Introduction to embedded systems, by Shibu K. V.; Sixth Reprint 2012, Tata McGraw Hill
- g. James K Peckol, “Embedded Systems – A contemporary Design Tool”, John Wiley, 2008. Steve Furber, “ARM System-on-Chip Architecture”, Second Edition, Pearson Education Publication.
- h. James K. Peckol, “Embedded Systems: A Contemporary Design Tool”, WILEY Student Edition Publication.
- i. Tammy Noergaard, “Embedded Systems Architecture”, Elsevier Publication
- j. VHDL programming by example by Douglas L. Perry, Fourth edition, Tata McGraw-Hill
- k. Starting Out with C++ Early Objects Tony Gaddis Judy Walters Godfrey Muganda Seventh Edition Addison-Wesley

Embedded C, ARM and Interfacing: (60 lectures, 4 credits)

Unit I

Fundamentals of Embedded Operating System, Embedded Linux, GNU Tools, Dynamic memory allocation, Introduction to Operating System services, Process, memory and I/O management, Embedded C Programming, Review of data types, Introduction to Embedded C, Embedded programming issues, Modeling Language for Embedded Systems,

Unit II

Embedded Applications using Data structures, Linear data structures– Stacks and Queues, Nonlinear structures – Trees and Graphs, Socket programming, Creating a linked list, linked stack and queue, double and circular linked list, sparse matrices, binary tree, Interrupt handling in C, Code optimization issues in Embedded C, Object Oriented programming basics,

Unit III

ARM ((Advanced RISC Machine) **Architecture**: Overview of ARM processors, ARM architectural ((LPC2148 and LPC2378) support for high level language, ARM architectural support for system development, ARM architectural support for operating System, Memory subsystem architecture, Designing a cache system, Memory allocation, Communication protocols.

Unit IV

Communication Interface: Inter Integrated Circuit (I2C), Serial Peripheral Interface (SPI), Universal Asynchronous Receiver Transmitter (UART), Wire Interface, Parallel Interface

External Communication Interfaces: RS-232 & RS-485, USB, IEEE 1394 (Firewire), Infrared (IrDA), Bluetooth, Wi-Fi, ZigBee, GPRS.

References:

1. C Programming language, Kernighan, Brian W, Ritchie, Dennis M
2. "Embedded C", Michael J. Pont, Addison Wesley
3. "Exploring C for Microcontrollers- A Hands on Approach", Jivan S. Parab, Vinod G. Shelake, Rajanish K. Kamot, and Gourish M. Naik, Springer.
4. Daniel W. Lewis, "Fundamentals of embedded software where C and assembly meet", Pearson Education, 2002.
5. Bruce Powel Douglas, "Real time UML, second edition: Developing efficient objects for embedded systems", 3rd Edition 1999, Pearson Education.
6. Steve Heath, "Embedded system design", Elsevier, 2003.
7. David E. Simon, "An Embedded Software Primer", Pearson Education, 2003.
6. The Complete Reference C++, Herbert Schildt, TMH
8. GNU C++ For Linux, Tom Swan, Prentice Hall India
9. . Introduction to embedded systems, by Shibu K. V., Sixth Reprint 2012, Tata McGraw Hill
10. Embedded Systems" Architecture, Programming and Design, by Raj Kamal, 2nd Second Edition, The McGraw-Hill Companies.
11. Wireless Communications and Networks, by William Stallings, 2nd edition Pearson.

Additional References:

1. C Programming language, Kernighan, Brian W, Ritchie, Dennis M
2. "Embedded C", Michael J. Pont, Addison Wesley
3. "Exploring C for Microcontrollers- A Hands on Approach", Jivan S. Parab, Vinod G. Shelake, Rajanish K. Kamot, and Gourish M. Naik, Springer.
4. Daniel W. Lewis, "Fundamentals of embedded software where C and assembly meet", Pearson Education, 2002.
5. Bruce Powel Douglas, "Real time UML, second edition: Developing efficient objects for embedded systems", 3rd Edition 1999, Pearson Education.
6. Steve Heath, "Embedded system design", Elsevier, 2003.
7. David E. Simon, "An Embedded Software Primer", Pearson Education, 2003.
6. The Complete Reference C++, Herbert Schildt, TMH
8. GNU C++ For Linux, Tom Swan , Prentice Hall India
9. Object_Oriented programming in C++, Robert Lafore , Galgotia publications
10. Operating System Concepts, Peter B. Galvin, Abraham Silberschatz, Gerg Gagne, Wiley Publishers
11. GNU/LINUX Application Programming, Jones, M Tims
12. Introduction to embedded systems, by Shibu K. V., Sixth Reprint 2012, Tata McGraw Hill

13. Embedded Systems” Architecture, Programming and Design, by Raj Kamal, 2nd Second Edition, The McGraw-Hill Companies.
14. Wireless Communications and Networks, by William Stallings, 2nd edition Pearson.
15. Biomedical Instrumentation S. Chatterjee and Aubert Miller Cengage Learning
16. Biomedical Instrumentation and Measurements Lesli Cromwell, F J Weibell, Erich Pfeiffer PHI
17. Handbook of Biomedical Instrumentation R S Khandpur TMH
18. Biomedical Digital Signal Processing Willis J Tompkins PHI

Biomedical Physics and Instrumentations:
(60 lectures, 4 credits)

Unit I

Introduction to Biomedical Instrumentation System: Overview of Bioinstrumentation, Biomedical Simulators, Biomedical organizations and Standards; Sources of Bioelectric Potential and Electrodes- Resting and Action potential, Propagation of action potential, The bioelectric potentials: ECG, EEG, EMG, ERG, EOG, EGG; Digital Biosignals, Types of Noise.

Biomedical Electrodes, Sensors and Transducers: Electrode Theory, Goldman and Nernst Equations, Ag-AgCl Reference Electrode; Surface electrodes, Needle electrodes, microelectrodes; Classifications and Characteristics of Sensors and Transducers, Pressure, Flow, Temperature and Optical transducers.

Unit II

Instrumentation in Diagnostic Cardiology: The Heart and cardiovascular system, The Electrocardiogram (ECG), ECG leads, Vectorcardiography, Normal and abnormal ECGs, Block diagram of ECG machine (Electrocardiograph); Blood pressure, Heart sounds, Defibrillators and Pacemakers – Theory and circuits, Types of defibrillators and pacemakers

Electroencephalography and EMG Instrumentation: The Anatomy of the Nervous system, The organization of the Brain and its measurement, The Electroencephalogram (EEG) - EEG electrodes, machines and measurements; EMG Machines and Neuromuscular measurements

Unit III

Artifacts and Noise in Medical Instrumentation: Examples of noise in medical instrumentation and biomedical signals – baseline wander, powerline interference, electrode motion artifacts etc, Noise reduction with digital signal processing; QRS complex detection in ECG- Pan Tompkins Algorithm.

Unit IV

Modern Medical Imaging and Instrumentation Systems: Ultrasound and Ultrasonic imaging system – Ultrasound Doppler and flow detector, Echocardiogram; Physics of X-rays and X-ray machines, X-ray images and data, Computer Tomography (CT) – Principles and scans; Magnetic resonance imaging (MRI) Positron Emission Tomography (PET).

References:

1. Biomedical Instrumentation S. Chatterjee and Aubert Miller Cengage Learning
2. Biomedical Instrumentation and Measurements Lesli Cromwell, F J Weibell, Erich Pfeiffer PHI
3. Handbook of Biomedical Instrumentation R S Khandpur TMH
4. Biomedical Digital Signal Processing Willis J Tompkins PHI

Signal Modulation and Transmission Techniques

(60 lectures, 4 credits)

Unit 1:

Radio wave propagation; Electromagnetic waves, free space propagation, reflection, refraction, and diffraction, ground wave propagation, ionospheric propagation, line of sight propagation, propagation in mobile/portable environment, repeaters and cellular systems, other propagation modes.

Unit 2

Transmission Line Theory: Fundamental of transmission lines, Different types of transmission lines; Telephone lines and cables, Radio frequency lines, Micro strip transmission lines. Definition of characteristics impedance, Losses in transmission lines, Standing waves, Quarter and Half wavelength lines, Reactance properties of transmission lines, Fundamental of the Smith charts and its applications.

Unit 3

Elements of communication system, time and frequency domains, noise in communications, Amplitude modulation, full carrier AM: time and frequency domain, quadrature AM, AM stereo, suppressed carrier AM. Angle modulation, frequency modulation, phase modulation, FM and noise, FM stereo.

Unit 4:

Satellite communication

Satellite orbits, geostationary satellites, applications of geostationary satellites, satellites in low and medium earth orbits, satellite telephone systems using LEO and MEO satellites.

Antennas: Basic considerations, Wire radiators in space, Terms and definitions, Effects of ground on antennas, Antenna Coupling at medium frequencies, Directional high frequency antennas, UHF and Microwave antennas, Wideband and special purpose antennas.

References:

11. Electronic Communications Systems by Blake, 2nd ed. Thomson India.
12. Electronic Communication Systems by George Kennedy and Bernard Davis, 4th ed., Tata McGraw-Hill Publishing Company Ltd., New Delhi.
13. Electronic Communication Systems-*Fundamentals through Advanced* by Wayne Tomasi; 4th Edition, Pearson education Singapore.

14. Additional References:

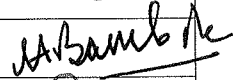
6. Electronic Communications by Dennis Roddy & John Coolen, (4th ed., Pearson Ed.)
7. Modern Electronic Communication by Gary M. Miller, (6th ed., Prentice Hall International Inc.)

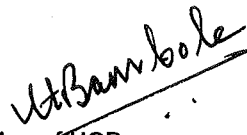
Letter Grades and Grade Points

Semester GPA/Program CGPA	% Marks	Letter Grade Results
9.00-10.00	90-100	O(Outstanding)
8.00≤ 9.00	80.0≤ 90.0	A+(Excellent)
7.00≤ 8.00	70.0≤ 80.0	A(Very Good)
6.00≤ 7.00	60.0≤ 70.0	B+(Good)
5.50≤ 6.00	55.0≤ 60.0	B(Above Average)
5.00≤ 5.50	50.0≤ 55.0	C (Average)
4.00 ≤ 5.00	40.0 ≤ 50.0	P (pass)
Below 4.00		F (Fail)
Ab(Absent		Ab(Absent)

Syllabus
M.Sc.(Physics)
(Sem. I & II)

Team for Creation of Syllabus

Name	College Name	Sign
Prof Vaishali Bambole	University Department of Physics	
Prof Balasaheb J. Nagare	University Department of Physics	
Mr. Nitin Bijewar	University Department of Physics	


Sign of HOD

Prof. Vaishali A. Bambole

Department of Physics

Professor & Head

Department of Physics

University of Mumbai


Sign of Dean

Prof Shivram Garje

Science and Technology

Appendix B

Justification for M.Sc.(Physics)

1.	Necessity for starting the course:	It is basic science program to understand the physical nature.
2.	Whether the UGC has recommended the course:	Yes
3.	Whether all the courses have commenced from the academic year 2023-24	Yes
4.	The courses started by the University are self-financed, whether adequate number of eligible permanent faculties are available?:	Aided Yes
5.	To give details regarding the duration of the Course and is it possible to compress the course?:	PG Diploma in Physics:1 year M.Sc. (Physics): 2 Year
6.	The intake capacity of each course and no. of admissions given in the current academic year:	Intake-68 Admitted-68
7.	Opportunities of Employability / Employment available after undertaking these courses:	Government sector, Industry and self employments, semiconductor and electronics industry.

V. Bambole
Sign of HOD

Prof. Vaishali A. Bambole
Department of Physics

Professor & Head
Department of Physics
University of Mumbai

Garje
Sign of Dean
Prof Shivram Garje
Science and Technology