M.Sc. Physics

Scheme and Syllabus

OUTCOME BASED EDUCATION SYSTEM (OBES)/

Learning Outcomes based Curriculum Framework (LOCF)

Choice Base Credit System (CBCS)

ACADEMIC SESSION

(w.e.f. 2021-2022)

DEPARTMENT OF PHYSICS

FACULTY OF SCIENCES

J C BOSE UNIVERSITY OF SCIENCE AND TECHNOLOGY, YMCA, FARIDABAD HARYANA -121006

J C BOSE UNIVERSITY OF SCIENCE AND TECHNOLOGY, YMCA

VISION

J C BOSE University of Science and Technology, YMCA aspires to be a nationally and internationally acclaimed leader in technical and higher education in all spheres which transforms the life of students through integration of teaching, research and character building.

MISSION

- To contribute to the development of science and technology by synthesizing teaching, research and creative activities.
- To provide an enviable research environment and state-of-the art technological exposure to its scholars.
- To develop human potential to its fullest extent and make them emerge as world class leaders in their professions and enthuse them towards their social responsibilities

DEPARTMENT OF PHYSICS

VISION

A department that can effectively harness its strengths to create an academically stimulating atmosphere; evolving into a well-integrated system that synergizes the efforts of its competent faculty towards imparting intellectual confidence that aids comprehension and complements the spirit of inquiry.

MISSION

- To create well-rounded individuals ready to comprehend scientific and technical challenges offered in the area of specialization.
- To counsel the students so that the roadmap becomes clearer to them and they have the zest to turn the blueprint of their careers into a material reality.
- To encourage critical thinking and develop their research acumen by aiding the nascent spirit for scientific exploration.
- Help them take economic, social, legal and political considerations when visualizing the role of technology in improving quality of life.
- To infuse intellectual audacity that makes them take bold initiatives to venture into alternative methods and modes to achieve technological breakthroughs.

PROGRAM NAME: M.Sc. Physics

The M.Sc. Program in Physics aims to provide students with a sound knowledge of the principles of Physics which form a thorough basis for careers in Physics and related fields. It also aims to enable students to develop insights into the techniques used in current fields and allow an in-depth experience of a particular specialized research area. In addition, the M.Sc Program is meant to develop professional skills in students that play a meaningful role in industrial and academic life and give students the experience of teamwork, a chance to develop presentation skills and learn to work to deadlines. The M.Sc. program includes a number of lecture courses and laboratory courses both relevant to the discipline and forward-looking with respect to recent developments and state-of-the-art achievements. The program has following three specializations:

I Nuclear Physics
II Materials Science
III Electronics

Program Outcomes (POs) for Post Graduate Programs (CBCS) in the Faculty of Sciences, J.C. Bose University of Science and Technology, YMCA, Faridabad

PO1	Knowledge	Capable of demonstrating comprehensive disciplinary knowledge gained during course of study
PO2	Research Aptitude	Capability to ask relevant/appropriate questions for identifying, formulating and analyzing the research problems and to draw conclusion from the analysis

PO3	Communication	Ability to communicate effectively on general and scientific topics with the scientific community and with society at large
PO4	Problem Solving	Capability of applying knowledge to solve scientific and other problems
PO5	Individual and Team Work	Capable to learn and work effectively as an individual, and as a member or leader in diverse teams, in multidisciplinary settings.
PO6	Investigation of Problems	Ability of critical thinking, analytical reasoning and research based knowledge including design of experiments, analysis and interpretation of data to provide conclusions
PO7	Modern Tool usage	Ability to use and learn techniques, skills and modern tools for scientific practices
PO8	Science and Society	Ability to apply reasoning to assess the different issues related to society and the consequent responsibilities relevant to the professional scientific practices
PO9	Life-Long Learning	Aptitude to apply knowledge and skills that are necessary for participating in learning activities throughout life
PO10	Ethics	Capability to identify and apply ethical issues related to one's work, avoid unethical behaviour such as fabrication of data, committing plagiarism and unbiased truthful actions in all

		aspects of work
PO11	Project Management	Ability to demonstrate knowledge and understanding of the scientific principles and apply these to manage projects

Program Specific Outcomes (PSOs)

After successful completion of M. Sc. Physics program, the students will

PSO1: Acquire an in-depth understanding and knowledge of the core areas of Physics encompassing mathematical physics, classical mechanics, quantum mechanics, electrodynamics, and statistical mechanics for explicating physical phenomena covering wide length and time scales.

PSO2: Be capable of applying the core physical laws to unravel a multitude of physical properties, processes, and effects involving radiation, nuclei, atoms, molecules, and bulk forms of matter.

PSO3: Develop hands-on skills for carrying out elementary as well as advanced experiments in different sub-fields of Physics viz. condensed matter physics, nuclear physics, particle physics, materials science, computational physics & electronics, along with enhancing their understanding of physical concepts and theories.

PSO4: Attain abilities of critical thinking, problem mapping & solving using fundamental principles of Physics, systematic analysis & interpretation of results, and unambiguous oral & writing/presentation skills.

PSO5: Have robust foundation in basic and practical aspects of Physics enabling them to venture into research in front-line areas of physical sciences, and career as Physics teachers and scientists.

J C BOSE UNIVERSITY OF SCIENCE AND TECHNOLOGY, YMCA, FARIDABAD
DEPARTMENT OF PHYSICS

SCHEME M.SC. PHYSICS

SEMESTER I

Subject Code	Title	L	T	P	Internal Assessment	End-semester Examination	Total	Credits	Category Code
MPH101	Mathematical Physics	4	0	0	25	75	100	4	DCC
MPH102	Classical Mechanics	4	0	0	25	75	100	4	DCC
MPH103	Quantum Mechanics-I	4	0	0	25	75	100	4	DCC
MPH104	Electronic Devices	4	0	0	25	75	100	4	DCC
MPH105	Physics Laboratory-I	0	0	16	30	70	100	8	DCC
MPH106	Seminar-I	2	0	0	50		50	0	DCC
XXX	MOOC**								MOOC
Total Marks							**550**	**24**	

* DCC – Discipline Core Course; MOOC – Massive Open Online Course
**The students have to pass at least one mandatory MOOC course with 4-6 credits (12-16 weeks) from the list given on the Swayam portal or the list given by the Department/ University from 1st semester to 3rd semester as notified by the University. (Instructions to students overleaf)
L – Lecture; P - Practical

Instructions to the students regarding MOOC

1. Two types of courses will be circulated: branch-specific and general courses from the website https://swayam.gov.in in the month of June and November every year for the forthcoming semester.
2. The department coordinators will be the course coordinators of their respective departments.
3. Every student has to pass a selected MOOC course within the duration as specified below:

Programme	**Duration**
B. Tech.	Sem. I to Sem. VII
M.Sc./M.Tech./M.A./MBA	Sem. I to Sem. III
B.Sc./MCA	Sem. I to Sem. V

The passing of a MOOC course is mandatory for the fulfillment of the award of the degree of concerned programme.

4. A student has to register for the course for which he is interested and eligible which is approved by the department with the help of the course coordinator of the concerned department.
5. A student may register in the MOOC course of any programme. However, a UG student will register only in UG MOOC courses and a PG student will register in only PG MOOC courses.
6. The students must read all the instructions for the selected course on the website, get updated with all key dates of the concerned course, and must inform his/her progress to their course coordinator.
7. The student has to pass the exam (online or pen-paper mode as the case may be) with at least 40% marks.
8. The students should note that there will be a weightage of Assessment/quiz etc. and final examination appropriately as mentioned in the instructions for a particular course.
9. A student must claim the credits earned in the MOOC course in his/her marksheet in the examination branch by forwarding his/her application through the course coordinator and chairperson.

SEMESTER II

Subject Code	Title	L	T	P	Internal Assessment	End-sem Exam	Total	Credits	Category Code
MPH201	Quantum Mechanics - II	4	0	0	25	75	100	4	DCC
MPH202	Nuclear and Particle Physics	4	0	0	25	75	100	4	DCC
MPH203	Solid State Physics	4	0	0	25	75	100	4	DCC
MPH204	Electrodynamics	4	0	0	25	75	100	4	DCC
MPH205	Physics Laboratory-II	0	0	16	30	70	100	8	DCC

MPH206	Seminar-II	2	0	0	50		50	0	DCC
XXX	Audit Course*	2	0	0	25	75	100	2	AUD
Total Marks							**650**	**26**	

- DCC – Discipline Core Course; AUD-Audit Course; L – Lecture; P - Practical
- *provided by the Department/ University along with subject code and syllabus.
- *URL for various department OEC and Audit Courses https://jcboseust.ac.in/postgraduate-programmes

SEMESTER III

Subject Code	Title	L	T	P	Internal Assessment	End-sem Exam	Total	Credits	Category Code
MPH301	Atomic and Molecular Physics	4	0	0	25	75	100	4	DCC
MPH302	Statistical Mechanics	4	0	0	25	75	100	4	DCC
MPX303	*Specialization I/II/III	4	0	0	25	75	100	4	DEC
MPX304	Specialization I/II/III	4	0	0	25	75	100	4	DEC
MPX305	Specialization (I/II/III) Lab	0	0	16	30	70	100	8	DEC
MPH306	Seminar-III	2	0	0	50		50	0	DCC
XXX	**OEC/VAC	3	0	0	25	75	100	3	OEC
Total Marks							**650**	**27**	

- DCC – Discipline Core Course; * Students will have to choose one out three specializations offered by the department. The choice will be granted on merit basis **OEC – Open Elective Course; L – Lecture; T-Tutorial, P – Practical, **VAC- Value Added Course** URL for various department OEC and Audit Courses https://jcboseust.ac.in/postgraduate-programmes

SEMESTER IV

Subject Code	Title	L	T	P	Internal Assessment	End-semester Examination	Total	Credits	Category Code
MPH401	Laser Technology	4	0	0	25	75	100	4	DCC

MPH402	Materials Science	4	0	0	25	75	100	4	DCC
MPX403	*Specialization I/II/III	4	0	0	25	75	100	4	DEC
MPX404	*Specialization I/II/III	4	0	0	25	75	100	4	DEC
MPH405	#Dissertation	2	0	0	30	70	100	6	DCC
Total Marks							**500**	**22**	

- DCC – Discipline Core Course; DEC – Discipline Elective Course; L – Lecture; P - Practical
- * Students will continue with the same specialization as was chosen in Semester III.
- # Students will have to complete a dissertation in the respective specialization under the guidance of the supervisor. Formatting and description for dissertation writing will be provided.

Guidelines for Dissertation

The purpose of the dissertation in M.Sc. (Physics) 4th semester is to introduce research methodology to the students. It may consist of review of some research papers, development of a laboratory experiment, fabrication of a device, working out some problem related to Physics, participation in some ongoing research activity, analysis of data, etc. The work can be carried out in any thrust areas of Physics (Experimental or Theoretical Physics) under the guidance of faculty members of the department. The students must submit their dissertation in the department as per the date announced for the submission.

Internal assessment of the dissertation work will be carried out by respective faculty members assigned to them as mentor/supervisor through power point presentation given by candidates during the semester. External assessment of the dissertation work will be carried out by an external examiner (nominated by the Chairperson of the Department) through power-point presentation given by candidates. This load (equivalent to 2 hours per week) will be counted towards the normal teaching load of the teacher.

1. Dissertation will contain a cover page, certificate signed by student and supervisor, table of contents, introduction, methodology, result and discussion conclusion, and references.

- The paper size to be used should be A-4 size.
- The font size should be 12 with Times Roman font
- The text of the dissertation may be typed in 1.5 (one and a half) space.
- The print out of the dissertation shall be done on both sides of the paper (instead of single side printing)
- The total no. of writing pages should be between 40 to 60 for dissertation.

2. The candidate shall be required to submit two soft bound copies of dissertation along with a CD in the department as per the date announced.

3. Dissertation will be evaluated internally by the supervisor allotted to the student during the semester.

4. The candidate will defend her/his dissertation/project work through presentation before the External examiner at the end of semester and will be awarded marks.

5. In case, a student is not able to score passing marks in the dissertation exam, he/she will have to resubmit her/his dissertation after making all corrections/improvements & this dissertation shall be evaluated as above. The candidate is required to submit the corrected copy of the dissertation in hard bound within two weeks after the viva -voce.

List of Specialization Papers

Specialization-I: Nuclear Physics

Subject Code	Title	L	T	P	Internal Assessment	End-semester Examination	Total	Credits	Category Code
Semester III									
MPN303	Nuclear Reactions	4	0	0	25	75	100	4	DEC
MPN304	Nuclear Detectors	4	0	0	25	75	100	4	DEC
MPN305	Nuclear Physics Spec. Lab	0	0	16	30	70	100	8	DEC
Semester IV									
MPN403	Nuclear Models and	4	0	0	25	75	100	4	DEC

	Astrophysics								
MPN404	Nuclear Techniques and Neutron Physics	4	0	0	25	75	100	4	DEC

Specialization-II: Materials Science

Subject Code	Title	L	T	P	Internal Assessment	End-semester Examination	Total	Credits	Category Code
Semester III									
MPM303	Materials Characterization Techniques	4	0	0	25	75	100	4	DEC
MPM304	Fundamentals and synthesis of nanomaterials	4	0	0	25	75	100	4	DEC
MPM305	Material Science Spec. Lab	0	0	16	30	70	100	8	DEC
Semester IV									
MPM403	Advanced Materials Science	4	0	0	25	75	100	4	DEC
MPM404	Vacuum Science and Thin Films Technology	4	0	0	25	75	100	4	DEC

Specialization-III: Electronics

Subject Code	Title	L	T	P	Internal Assessment	End-semester Examination	Total	Credits	Category Code

Semester III									
MPE303	Analog Electronics	4	0	0	25	75	100	4	DEC
MPE304	Microprocessor	4	0	0	25	75	100	4	DEC
MPE305	Electronics Spec. Lab	0	0	16	30	70	100	8	DEC
Semester IV									
MPE403	Digital Electronics	4	0	0	25	75	100	4	DEC
MPE404	Optical fiber Communicatio n	4	0	0	25	75	100	4	DEC

The Audit course and Open elective courses offered by Department of Physics for PG students are as follows:

Course	Subject	Subject Code	NO OF CREDITS
AUDIT COURSE	RENEWABLE ENERGY RESOURCES	APH101	2
OEC	INTRODUCTION TO ASTROPHYSICS AND COSMOLOGY	OPH101	3
	ENERGY HARVESTING AND STORAGE DEVICES	OPH102	3

- The students have to choose one Audit course (0 credit) from the list provided by the department/University. Only passing of the Audit course will be mandatory.
- The students have to choose one Open Elective Course (03 credits) related to other branch of Science/Engineering/other discipline required for enhancing professional performance as provided by the department/university.

JC BOSE UNIVERSITY OF SCIENCE AND TECHNOLOGY, YMCA, FARIDABAD

DEPARTMENT OF PHYSICS

SYLLABI OF M.SC. PHYSICS

M.Sc. PHYSICS SEMESTER-I

MPH101

SUBJECT NAME: MATHEMATICAL PHYSICS

NO OF CREDITS: 4

		SESSIONAL:	25
L	P	THEORY EXAM:	75
4	0	TOTAL:	100

Note: The question paper will be of two parts. Part I will consist of 10 questions of 2 marks each. It should cover the entire syllabus. Part II will consist of six questions of 10 marks each out of which the student has to attempt any four.

Course Outcomes (COs)

After successful completion of the course on Mathematical Physics, a student will be able to:

MPH101.1 *Derive Cauchy integral theorem and Cauchy integral formula and find Taylor and Laurent series expansion of functions of complex variable.*

MPH101.2 *Understand the calculus of residue and evaluate some typical definite integral using the method of contour integration.*

MPH101.3 *Find explicit expressions of Hermite, Laguerre, Bessel and Legendre polynomials using the corresponding generating functions and derive orthogonality relations and various recurrence relations among these special functions for their applications in solving quantum mechanical systems.*

MPH101.4 *Apply the knowledge of matrices for solving linear algebraic equations and Learn basics of group theory and prepare group multiplication tables for understanding crystallography.*

MPH101.5 *Learn properties of Fourier and Laplace transforms and evaluate the Fourier and Laplace transforms of functions and derivatives.*

Unit I: Theory of Functions of a Complex variable (12hrs)

Function of a Complex variable, Exponential functions, Logarithmic functions, Analyticity and Cauchy condition, Cauchy-Riemann equations, necessary and sufficient conditions for a function to be analytic, Harmonic functions, Cauchy's Integral Theorem, Cauchy's Integral Formula, Taylor's Series and Laurent's series and expansion, Zeroes and Singular Points, Multi valued functions, Residues, Cauchy's Residue Theorem, Jordon's Lemma, Evaluation of real definite integrals.

Unit II: Special Functions (12 hrs.)

Bessel Functions: Bessel functions of the first kind $J_n(x)$, Generating function, Recurrence relations, Expansion of $J_n(x)$ when n is half an odd integer, Integral representation; Legendre Polynomials $P_n(x)$: Generating function, Recurrence relations and special properties, Rodrigues' formula, Orthogonality of $P_n(x)$; Hermite and Laguerre Polynomials: generating function & recurrence relations only.

Unit III: Matrices and Group Theory (12 hrs.)

Matrices: Orthogonal, Unitary and Hermitian Matrices with examples, Independent elements of orthogonal and unitary matrices of order 2, Matrix diagonalization, eigenvalues and eigenvectors; Fundamentals of Group theory: Definition of a group and illustrative examples, cyclic groups.

Unit IV: Integral Transforms (12hrs)

Fourier Integral theorem, Fourier Sine, Cosine and Complex transforms with examples, Properties of Fourier transform, Fourier transforms of Derivatives, Parseval's theorem, Convolution theorem, Fourier transform of Integrals.

Laplace Transforms, Transforms of some Elementary Functions, Properties of Laplacetransform, Transform of Derivatives, Transform of Integrals, Convolution theorem, and its applications, Inverse Laplace Transform by partial fractions method

REFERENCE BOOKS:

1. Mathematical methods for Physicists, Arfken, 4th edition, Academic Press Inc. 1995.

3. Mathematical Physics, AK Ghatak, Trinity Press-Laxmi Publications, 1st Edition, 1995.
4. Mathematical Physics by H.K. Dass, S. Chand Publications, 5th edition, 2017.
5. Schaum's Outlines Complex Variables by M. R. Spiegel, Mc-Graw hill publications, 2015.
6. Group theory and Quantum Mechanics by M. Tinkam, Dover Publications, 2012.
7. Schaum's Outlines Group Theory by B. Baumslag, B. Chandler, Mc-Graw Hills, 2012.

M.Sc. PHYSICS SEMESTER-I

MPH102

SUBJECT NAME: CLASSICAL MECHANICS

NO OF CREDITS: 4

		SESSIONAL:	25
L	P	THEORY EXAM:	75
4	0	TOTAL:	100

Note: The question paper will be of two parts. Part I will consist of 10 questions of 1.5 marks each. It should cover the entire syllabus. Part II will consist of six questions of 15 marks each out of which the student has to attempt any four.

COURSE OUTCOME: On successful completion of classical Mechanics, students should be able to:

MPH102.1	*Demonstrate a basic and advanced knowledge of Lagrangian and Hamiltonian Formulations and solve related problems.*
MPH102.2	*Identify the cyclic coordinates and understand their importance in Hamiltonian formulation.*
MPH102.3	*Acquire knowledge of Poisson and Lagrange Brackets and establish relationships between their properties.*
MPH102.4	*Demonstrate the concept of motion of a particle under central force and apply advanced methods to deal with central force problems.*
MPH102.5	*Use Hamilton-Jacobi theory for finding the solutions of various Classical systems.*

MPH102.6 *Develop a deep understanding to tackle the problems of small oscillations and special theory of relativity.*

Unit I: Lagrangian and Hamiltonian Formulations (12 hrs.)

Types of Constraints on dynamical systems, Generalized Coordinates Hamilton's principle, Derivation of Lagrange's equations from Hamilton's principle, Principle of Least Action and its applications, Canonical Transformation, Legendre Transformation and Hamilton's equation of motion, The physical significance of the Hamiltonian, Cyclic coordinates, Applications of Langrangian and Hamiltonian Formulation.

Unit II: Poisson and Lagrange Brackets (12 hrs.)

Poisson bracket and its properties, Poisson theorem, Poisson bracket and canonical transformation, Jacobi identity and its derivation, Lagrange bracket and its properties, Relationship between Poisson and Lagrange brackets and its properties, Liouville's theorem and its applications.

Unit III: Central Force Problem and Hamilton-Jacobi Theory (12 hrs.)

Two body central force problem: Reduction to the equivalent one-body problem, Equation of motion and first integrals, Classification of orbits, Virial theorem, Differential equation for the orbit, Integrable power law in time in the Kepler's problem,

Hamilton-Jacobi Theory: Hamilton-Jacobi equation, Separation of variables in Hamilton-Jacobi equation. Solution of Harmonic Oscillator problem and Kepler's Problem by Hamilton-Jacobi Method.

Unit IV: Small Oscillations and Special Theory of Relativity (12 hrs.)

Theory of small oscillations: Formulation of the problem, Eigenvalue equation, and the principle axis transformation, Frequencies of free vibrations and Normal coordinates, Free vibrations of a linear triatomic molecule.

Special Theory of Relativity: Postulates of Special Theory of Relativity, Lorentz Transformation, Length Contraction, Time Dilation, Relativistic addition of velocities, variation of mass with velocity, mass-energy equivalence.

REFERENCE BOOKS:

1. Classical Mechanics (3rd ed., 2002), H. Goldstein, C. Poole, and J. Safko, Addison Wesley.

2. Classical Mechanics, J C Upadhyaya, Himalaya Publishing House.

3. Classical Mechanics, G. Aruldhas, PHI Learning Pvt. Ltd., New Delhi.

4. Classical Mechanics, John R. Taylor, University Science Books, USA.

M.Sc. PHYSICS SEMESTER-I

MPH103

SUBJECT NAME: QUANTUM MECHANICS - I

NO OF CREDITS: 4

L	P		
		SESSIONAL:	25
L	P	THEORY EXAM:	75
4	0	TOTAL:	100

Note: The question paper will be of two parts. Part I will consist of 10 questions of 1.5 marks each. It should cover the entire syllabus. Part II will consist of six questions of 15 marks each out of which the student has to attempt any four.

Course Outcomes (COs)

After successful completion of the course on Quantum Mechanics - I, a student will be able to:

MPH103. 1	*Realize the basic quantum-mechanical view point, and learn its wave mechanical formulation for a non-relativistic situation, Solve the 3 dimensional Schrödinger wave equation for eigenfunctions and eigenvalues for harmonic oscillator and Hydrogen atom.*
MPH103. 2	*Construct matrices for observables and wave functions in different representations, and apply the matrix theory for calculating eigenvalues and eigenfunctions*
MPH103. 3	*Describe the time-development of a quantum system in Schrödinger, Heisenberg and Interaction pictures, and to envisage the same in Hilbert space.*
MPH103. 4	*Calculate the eigenvalues and eigenfunctions for the orbital and general angular momenta, along with the matrix representation of angular momentum.*
MPH103. 5	*Have an understanding of the perturbation theory and apply the same for degenerate and non-degenerate systems.*
MPH103. 6	*Apply the time-dependent perturbation theory to deal with atom-em radiation interaction and calculate explicitly the transition probability for the induced absorption and emission processes.*

UNIT-I: Fundamentals of Quantum Mechanics (12hrs)

Need of Quantum Mechanics, Two slit experiment with radiation and matter particles, Ehrenfest theorem, Postulates of quantum mechanics, Wave function and Schrödinger wave equation, Orthonormality of eigenfunctions, Reality of eigenvalues, Closure property, Probability density, Expectation values, Uncertainty principle for two arbitrary observables, Solution of Schrödinger equation for three dimensional problems: Harmonic oscillator, Hydrogen atom Problem (radial wave functions and energy eigenvalues).

UNIT-II: Matrix formalism of Quantum Mechanics (12hrs)

Overview of Linear Vector Space, Basis, Operators, Dirac Notations of Bra and Ket, Matrix Representation of Observables and States, Determination of Eigenvalues and Eigenfunctions of Observables, orthogonality, closure, completeness. Matrix theory of the harmonic oscillator: Spectrum of eigenvalues and eigenfunctions, Hilbert space representation, Change of Representation, Hermitian and Unitary Transformation, Time-development of quantum system: Schrödinger, Heisenberg and Interaction pictures

UNIT-III: Theory of Angular Momentum (12hrs)

Orbital angular momentum operator **L**, Cartesian and spherical polar coordinate representation, Commutation Rules for Angular Momentum, Eigenvalues and Eigenfunctions of $\mathbf{L}^2$ and $\mathbf{L}_z$, General angular momentum operator **J**, Eigenvalues and Eigenfunctions of $\mathbf{J}^2$ and $\mathbf{J}_z$ Matrix Representation of Angular Momentum Operators, Spin angular momentum, Wavefunction including spin (Spinor), Spin one half: Spin eigenfunctions and Pauli Spin Matrices.

UNIT-IV: Perturbation Theory (12hrs)

Perturbation Theory of Non-degenerate Systems with first and second order corrections to energy eigenvalues and eigenfunctions, Application to He Atom, Zeeman Effect without electron spin, Perturbation Theory for Degenerate Systems, First order correction, First Order Stark Effect in H-Atom, Time Dependent Perturbation Theory (First Order), Transition probability for constant and harmonic perturbations, Fermi Golden Rule.

REFERENCE BOOKS:

1. Quantum Mechanics by L. I. Schiff, McGraw-Hill Education
2. Quantum Mechanics - A Modern Introduction by A. Das and A. C.Melissinos, Gordan and Breach Science Publishers
3. Modern Quantum Mechanics by J. J. Sakurai, Pearson publishers.
4. Principles of Quantum Mechanics by P. Dirac, Oxford University Press.
5. Principles of Quantum Mechanics by R. Shankar, Plenum Press.

6. Quantum Mechanics by A. K. Ghatak & S. Lokanathan, Kluwer Publications.

M.Sc. PHYSICS SEMESTER-I

MPH 104

SUBJECT NAME: ELECTRONIC DEVICES

NO OF CREDITS: 4

L	P			
			SESSIONAL:	25
L	P		THEORY EXAM:	75
4	0		TOTAL:	100

Note: The question paper will be of two parts. Part I will consist of 10 questions of 2 marks each. It should cover the entire syllabus. Part II will consist of six questions of 10 marks each out of which the student has to attempt any four.

COURSE OUTCOMES:

After successful completion of the course on Electronics Devices, a student will be able to:

MPH104.1 Understand the fabrication process for devices and ICs like crystal growth, Oxidation, pattern transfer, diffusion, etching, ion-implantation and epitaxial growth.

MPH104.2 Gain Knowledge of inter-connection, packaging and the processing of compound semiconductor.

MPH104.3 Obtain a fair understanding of the steps involved in the fabrication of electronic devices like BJT, MOSFET, FET, Schottky diodes IC diodes capacitors and resistors.

MPH104.4 Gain a fair understanding of the operation and application of decoders, multiplexers, encoders and flip-flops.

MPH104.5 Comprehend the operation and application of RAMs, ROMs, 555 IC timer, D/A and A/D Converters.

MPH104.6 Explain operation and important adders, shift resistor and Counters.

COURSE OBJECTIVES:

The students should be able to understand various semiconductor devices the fabrication of ICs, understand the working and characteristics of BJT and FET, understand the working and applications of Op-Amp (IC-741) and 555 Timer.

Unit I: Bipolar Junction Transistor and Field Effect Transistor (12 hrs)

PNP and NPN transistors, basic transistor action, emitter efficiency, base transport factor, current gain, input and output characteristics of CB, CE and CC configurations and amplifiers, Construction of JFET, MOSFET, Idea of channel formation, pinch off and saturation voltage, current voltage output characteristics.

Unit II: Semiconductor Devices and Fabrication of ICs (12 hrs)
Metal/Semiconductor Contact, MOS Junction (Accumulation, Depletion and Inversion), Interface States and Their Effects, Fabrication of ICs, monolithic Integrated Circuit Technology, planar process, Fabrication of Bipolar Transistor, Resistor, capacitor, FET and MOSFET.

Unit III: Op-Amp (IC-741) and 555 Timer (12 hrs)

DC coupled amplifiers, common mode rejection ratio, Block Diagram of Op-Amp, Input offset voltage, Input bias current, Slew Rate, Frequency Response, and Compensation, Feedback in amplifiers, Inverting and non-inverting amplifiers, Linear application of op-amp: summing, difference, Integration, differentiator, Non-Linear application of op-amp: Comparator, Zero crossing detector, Schmitt trigger

555 Timer: 555 Timer – Description and block diagram - Monostable operation, Astable operation

Unit IV: Digital Circuits and Systems (12 hrs)

Binary Adders, full adder, and half adder, serial and parallel adders, binary subtractor, Digital comparator, BCD to decimal Decoder, multiplexer, Demultiplexer, Memory Concept, RAM, ROM, PROM, EPROM, EEPROM, Flip-Flops: SR, JK, Master Slave, D Type, T Type, Shift register, Asynchronous counter, Up-Down counter, Divided by N counter.

REFERENCE BOOKS:

1. Integrated Electronics by jacob millman and christos c halkias, Mcgraw Hill Higher Education, (1 January 2002)
2. Gayakwad: OP-AMPS and Linear Integrated Circuits , 4th Edition, Prentice Hall / Pearson.
3. Jacob Millman and Arvin Grabel: Microelectronics, McGraw Hill Education; 2nd edition (1 July 2017)

M.Sc. PHYSICS SEMESTER-I

MPH105

SUBJECT NAME: PHYSICS LAB I

NO OF CREDITS: 8

SESSIONAL: 30

L	P		
		END SEM EXAM:	70
0	16	TOTAL:	100

Course Outcomes (COs)

After successful completion of creative work about 'Lab Experiments', student will be able to learn

MPH105.1 *Designing and working of diodes, transistors, and their applications.*

MPH105.2 *Build a common emitter/base/collector amplifier and measure its voltage gain.*

MPH105.3 *Understand the use of CRO for various applications.*

MPH105.4 *Explore the operation and advantages of operational amplifiers*

MPH105.5 *Learn to design different types of filters and apply the same to oscillators and amplifiers.*

MPH105.6 *Learn and understand about different types of IC's.*

MPH105.7 *Exploring the circuitry which converts an analog signal to a digital signal.*

MPH105.8 *Understand fundamentals of various physical phenomena and physical concepts*

COURSE OBJECTIVE

This course is designed to provide students with fundamental concepts of Electronic Circuits for lab experiences such as the study of the operation of Oscillators and Waveform generators like multivibrators and Schmitt trigger. This lab will also give students a preview of the various applications of op-amp and flip-flops. This course is designed to provide students with fundamental concepts of general physics lab experience.

Students assigned the electronic laboratory work will perform at least 8 experiments of the following sections

Section A: Electronics Lab

1. To study Zener diodes as a voltage regulator.
2. To study the common emitter transistor using NPN transistors.
3. To design basic comparator and Zero crossing detector using 741 op-amp.
4. Application of op-amp as an integrator/differentiator amplifier.
5. To study negative feedback in op-amp (summing/difference.
6. To design a full adder and full subtractor and verify its truth table using logic gates.
7. To design a JK Flip flop and realize an up-down counter using it.
8. To design a 4-bit shift register using JK Flip flop.
9. To construct an astable multivibrator using a transistor and to determine the frequency of oscillation.
10. To design an astable and monostable multivibrator using a 555 timer.
11. To design a multiplexer/demultiplexer.

SECTION B: General Physics lab

1. To verify the existence of different harmonics and measure their relative amplitudes in a complex wave using CRO (square, clipped sine wave, triangular wave, etc.)
2. Determination of Energy Band Gap of Silicon, Germanium, etc. using light-emitting diodes (LED's).
3. Demonstration of energy quantization using the Franck-Hertz Experiment
4. To determine wavelength, spot size, a divergence of LASER, Power distribution within the beam, Grating element of the grating.
5. To determine the wavelength of laser light using Michelson interferometer experiment.
6. To study the Magnetostriction effect in a metallic rod.
7. To determine the charge to mass ratio of an electron by using Magnetron.
8. To determine the Dielectric constant of dielectric material by varing frequency.
9. To find out the g-value using Electron spin resonance(ESR).
10. UJT – Characteristics, and its application as a relaxation oscillator.

10\. SCR – Characteristics and its application as a switching device.

Note: More experiments may be added from time to time as per the requirement.

M.Sc. PHYSICS SEMESTER-II
MPH201

SUBJECT NAME: QUANTUM MECHANICS II

NO OF CREDITS: 4

L	P		
		SESSIONAL:	25
		THEORY EXAM:	75
4	0	TOTAL:	100

Note: The question paper will be of two parts. Part A will consist of 10 short answer type questions of 1.5 marks each. It should cover the entire syllabus. Part B will consist of five questions of 15 each out of which the student has to attempt any four.

Course Outcomes (COs)

After successful completion of the course on Quantum Mechanics - II, a student will be able to:

MPH201.1 Use the WKB method to understand tunneling through a barrier and spherically symmetric potentials

MPH201.2 Perform quantum-mechanical addition of two general angular momenta, and calculate Clebsch-Gordan coefficients for some simple situations.

MPH201.3 Grasp the concepts of identity, indistinguishability, and see how eigenstates of a system of identical particles bifurcate into totally symmetric and anti-symmetric ones.

MPH201.4 Find the spin and total wave functions for a system of two identical spin ½ particles, and comprehend connection among spin, symmetry and statistics of identical particles.

MPH201.5 Have an understanding of the basics of non-relativistic quantum scattering theory, learn the theory of partial waves, calculate and analyse Born scattering cross-sections for finite square well and screened Coulomb potentials.

MPH201.6 Have knowledge of basic laws of relativistic quantum mechanics and *ability to solve Klein - Gordan equation and Dirac equation.*

Unit I: WKB approximation and Addition of Angular Momentum: (12hrs)

The WKB Approximation: The WKB solutions, The connection formulae and their derivation, Application of the WKB solutions to (i) eigenvalue problems, (ii) the tunnelling probability calculations and (iii) spherically symmetric potentials, Addition of two angular momenta, Clebsch-Gordan coefficients, their properties and calculation for $j_1 = j_2 = 1/2$, $j_1 = 1$, $j_2 = 1/2$ and $j_1 = j_2 = 1$.

Unit II: Identical Particles (12hrs)

Introduction, The principle of indistinguishability, Symmetrical and Antisymmetric wave function, Symmetrization postulate, Particle Exchange operator, Distinguishability of Identical particles, Connection among spin, symmetry and statistics of identical particles, Fermions and bosons; Spin and total wave functions for a system of two spin ½ particles, The Pauli's Exclusion principle, Slater determinant, Application to Helium atom, para- and ortho- Helium.

UNIT-III: Scattering (12hrs)

Laboratory and center of mass frame, Scattering amplitude, Differential scattering cross section and total scattering cross section, The optical theorem, Scattering by Spherically symmetric potential, Theory of Partial Wave and Calculation of Phase Shifts in Simple Cases, Integral Form of Scattering Equation, The first Born approximation, Scattering of an electron by a screened Coulomb potential in Born approximation and validity criterion. Scattering of identical Particles.

Unit IV: Relativistic Quantum Mechanics (12hrs)

Klein Gordon Equation and its interpretation , Klein Gordon equation in Electromagnetic field, Dirac's relativistic equation, Dirac Matrices, Covariant form of Dirac Equation, Charge and Current Densities, Electromagnetic potentials: Magnetic moment of the electron, Dirac equation for a central field, The Hydrogen atom, Negative energy solution, Anti-particles.

REFERENCE BOOKS:

1. Quantum Mechanics: John. L. Powell & Bernd Crasemann, Narosa Publishing House.
2. Quantum Mechanics Concepts and Applications: Nouredine Zettili, Wiley(Second Edition).
3. Quantum Mechanics : A.P.Messiah, Dover Publications.
4. Modern Quantum Mechanics : J.J.Sakurai, Cambridge University Press.

5. Quantum Mechanics-Theory And Applications : Ajoy Ghatak, S Lokanathan, Laxmi Publications.

M.Sc. PHYSICS SEMESTER-II

MPH202

SUBJECT NAME: NUCLEAR AND PARTICLE PHYSICS

NO OF CREDITS: 4

L	P		
		SESSIONAL:	25
4	0	THEORY EXAM:	75
		TOTAL:	100

Note: The question paper will be of two parts. Part I will consist of 10 questions of 1.5 marks each. It should cover the entire syllabus. Part II will consist of six questions of 15 marks each out of which the student has to attempt any four.

Course Outcomes (COs)

After successful completion of the course on Nuclear and Particle Physics, a student will be able to:

MPH202.1 *Understand the energy loss processes of different energetic particles in a medium and mechanisms of interaction of gamma photon with matter.*

MPH202.2 *Learn about the basic properties and characteristics of Nuclear forces, and their mediating particle.*

MPH202.3 *Know and learn about various type of detectors used in nuclear physics experiments, unique properties of different detectors and their applications in the field of nuclear physics.*

MPH202.4 *Differentiate between different types of nuclear reactions, relevant aspects associated with nuclear reactions and kinematics of such reactions.*

MPH202.5 *Describe certain properties associated with nuclei, models governing different aspects of nuclear behaviour and detailed understanding of the deuteron problem.*

MPH202.6 *Understand the phenomenon of radioactive decays of alpha and beta particles, their detailed formalism.*

MPH202.7 *Know about different elementary particles, their quark content and quark model.*

MPH202.8 *Learn about decay of some elementary particles and laws governing such decays.*

Unit I: Nuclear Properties and Nuclear decay (12 hrs)

Properties of Nuclei (Charge, Mass, size, binding energy, spin, parity), Basic parameters of radioactivity (Decay constant, Activity, Half-life, Average life time), Laws of radioactive decay (Soddy-Fajans, radioactive disintegration and successive transformation), Types of decay: Alpha decay (Properties, charge to mass ratio, range, Geiger Nuttall law, energy, Gamow's Theory of Alpha-Decay), Beta decay (Types, energetics, Fermi's Theory of Beta-Decay), Neutrino theory: origin of continuous beta spectrum, and Gamma decay (Energetics of Gamma decay, selection rules), Internal conversion.

Unit II: Nuclear Forces and Models (12 hrs)

Properties of nuclear forces, Deuteron problem (Binding energy, spin parity, magnetic dipole moment, electric quadrupole moment); Nucleon-nucleon scattering (General formalism) neutron-proton scattering at low energies (Partial wave analysis, scattering length and effective length); proton-proton scattering at low energies. Types of Nuclear Models, liquid drop model (Basics, semi empirical mass formula, Binding energy, Asymmetry energy, Odd-Even effect) Shell model (Basics, success and failure), Unified model (General Idea).

Unit III: Interaction of Radiation with Matter and Nuclear Detectors (12 hrs)

Types of Nuclear Radiations and their interaction processes, Interaction of light charged Particles, Interaction of heavy charged Particles (Bohr's formula for Stopping power of heavy charged particles, Bethe-Bloch relation, Range and Straggling), Interaction of Gamma-Rays (Photoelectric effect, Compton effect and Pair production), Absorption of gamma rays and its applications, linear and mass absorption coefficients of gamma rays. Neutron interaction (basic concepts), classification of detectors on basis of interaction and operation. Construction and working of Gas filled detectors, Ionization chambers, Proportional counters (MWPC), GM counter.

Unit IV: Particle Physics (12 hrs)

Classification and properties of elementary particles, Fundamental interactions, conservation laws (Energy, charge, mass, angular momentum and linear momentum) and properties of elementary particles, Gell-Mann Nishijima Scheme, SU(2) and SU(3) symmetries, Properties of quarks and their classifications.

REFERENCE BOOKS:

1. Nuclear Physics by D.C. Tayal., (Himalaya Publishing House, 2009)
2. Introductory Nuclear Physics. By Kenneth S. Krane. (John Wiley & Sons, 1989)
3. Fundamentals of Nuclear physics by Jahan Singh (Pragati Prakashan)
4. Theory of Nuclear Structure by M. K. Pal (Affiliated East-West Press,1982).
5. Nuclear Reaction and Nuclear Structure by P.E. Hodgson (Clarendon Press, 1971)
6. Nuclear Physics by R. Prasad, (Pearson, 2014)

M.Sc. PHYSICS SEMESTER-II

MPH203

SUBJECT NAME: SOLID STATE PHYSICS

NO OF CREDITS: 4

L	P		
		SESSIONAL:	25
L	P	THEORY EXAM:	75
4	0	TOTAL:	100

Note: The question paper will be of two parts. Part I will consist of 10 questions of 2 marks each. It should cover the entire syllabus. Part II will consist of six questions of 10 marks each out of which the student has to attempt any four.

MPH203.1 *Analyze the structure of a crystalline solid in terms of lattice, basis, unit cell, reciprocal lattice, Brillouin zone and symmetry elements.*

MPH203.2 *Deduce the structure of a crystalline solid from an analysis of the XRD pattern and the theoretically calculated crystal structure factor.*

MPH203.3 *Calculate the dispersion of lattice waves for crystals with mono- and diatomic basis, and understand the principle underlying its experimental measurement using neutron scattering.*

MPH203.4 *Acquire an understanding of the concept of phonon and use it to determine the lattice heat capacity in the Einstein and Debye models.*

MPH203.5 *Learn Bloch's theorem, its application to the KP model, solve the one-electron Schrödinger equation for a periodic potential to see the emergence of energy bands, and classify materials into conductors, semiconductors and insulators.*

MPH203.6 *Learn and apply the tight binding and Wigner-Seitz methods for calculating the energy bands.*

Unit I: Symmetry and Reciprocal Lattice (12 hrs.)
Crystal symmetry elements, Miller indices, Direct lattice type, fundamental type of direct lattices i.e. 2 dimensional and 3 dimensional lattice, Diffraction of Waves by Crystal: The Bragg law, Fourier Analysis, Reciprocal lattice Vectors, Diffraction Condition. Brillouin Zones, Reciprocal lattice (example of sc, bcc, fcc, hcp lattices), Crystal structure factor (bcc, fcc), Atomic form factor, Scattering factors, Intensity of diffraction maxima, extinction due to lattice centering.

Unit II: Lattice Vibration (12 hrs.)
The concept of lattice modes of vibration, Elastic vibrations of continuous media, Vibration of one dimensional monoatomic and diatomic linear lattice, Particle displacement in two branches, Wavelength limit of acoustic phonons, Quantization of lattice waves: Phonons, Phonon momentum, Inelastic scattering of photons and phonons, Inelastic scattering of X rays by phonons, Inelastic scattering of neutrons by phonons, Electron-Electron Interaction, Electron-Phonon Interaction: Polarons.

Unit III: Electronic Properties of Solids (12 hrs.)

Electrons in periodic potential, Kronig-Penny model for band theory, brillouin zone, Effective mass, Physical interpretation of effective mass, Distinction between metals, Semiconductors and insulators, Density of state function, Density of electrons in conduction band, Density of holes in valence bands, Donor and acceptor impurities in n-type and p-type semiconductors, Metal-Semiconductor junctions.

UNIT IV: Fermi Surfaces and Metals (12 hrs.)

Reduced Zone Scheme, Periodic Zone Scheme, Construction of Fermi Surfaces: Tight Binding Method of Energy Bands: Wigner-Seitz Method, Cohesive Energy. Pseudopotential Methods, Experimental Methods in Fermi Surface Studies, Quantization of Orbits in a Magnetic Field, De Haas-van Alphen Effect, Fermi Surface of Copper, Magnetic Breakdown, Quantum Hall effect.

REFERENCE BOOKS:

1. C. Kittel, Introduction to Solid State Physics. 7th ed., Wiley, 1996
2. Adrianus J. Dekker., Solid State Physics. Front Cover. Prentice-Hall, 1957
3. SM Sze, Physics of semiconductor devices, 2nd ed. New york, Wiley, 1981
4. SO Pillai, Solid State Physics, New Academic Science Ltd; 6th edition (30 October 2009)

M.Sc. PHYSICS SEMESTER-II

MPH204

SUBJECT NAME: ELECTRODYNAMICS

NO OF CREDITS: 4

		SESSIONAL:	25
L	P	THEORY EXAM:	75
4	0	TOTAL:	100

Note: The question paper will be of two parts. Part I will consist of 10 questions of 2 marks each. It should cover the entire syllabus. Part II will consist of six questions of 10 marks each out of which the student has to attempt any four.

Course Outcomes (COs)

After successful completion of the course on electrodynamics, a student will be able to:

MPH204.1 *Enhance skills for solving Boundary value problems especially using Method of images.*

MPH204.2 *Understand the fundamental concepts of electrodynamics and describe the propagation of electromagnetic waves through different media.*

MPH204.3 *Understand the laws of reflection and transmission of electromagnetic waves at the interfaces of different media for normal and oblique incidence.*

MPH204.4 *Learn the basic concepts of dispersion and scattering of electromagnetic waves through different media.*

MPH204.5 *Understand the Non-uniqueness of Electromagnetic potentials with concept of Gauge and get familiarize with concept of retarded time for charges undergoing acceleration and evaluate fields and power corresponding to Lienard-Wiechert Potentials.*

MPH204.6 *Understand the basic concepts of Plasma Physics and wave guides and propagation of electromagnetic waves through plasma and through rectangular waveguide.*

Unit I: Introduction to Electrodynamics (12 hrs.)

Electrostatics: Method of Images, Point charge near an infinite Grounded Conducting Plane, Point charge in the presence of Grounded Conducting Sphere, Point charge in the presence of Charged, Insulated Conducting sphere, Point charge near a Conducting Sphere held at Fixed Potential, Conducting sphere in a Uniform Electric Field.
Electrodynamics: Energy stored in an electric and magnetic field. Continuity Equation, Displacement Current, Maxwell's equations, power flow in an electromagnetic field and poynting theorem. Electromagnetic waves in a homogeneous medium-solution for free-space conditions. Uniform plane waves, the wave equations for a conducting medium, Sinusoidal time variations, Maxwell's equations using phasor notation. Wave propagation in a lossless medium, wave propagation in a conducting medium, wave propagation in a good dielectric.

Unit II: Electromagnetic Waves (12hrs)

Reflection & Refraction of Plane waves:- Boundary Conditions, Laws of reflection and refraction of plane waves, Reflection by a perfect dielectric – normal and oblique incidence, Fresnel relations, Brewster's angle, Reflection by a perfect conductor – normal incidence, Power loss in a plane conductor.
Dispersion and Scattering:- Radiative reaction force, Abraham Lorentz formula, scattering and absorption of radiation, Thompson scattering and Rayleigh

Scattering, Normal and anomalous dispersion, Dispersion relation of EM waves in Solids, Liquids and gases.

Unit III: Electromagnetic fields and Radiation by Moving Charges (12 hrs.)
Electromagnetic scalar and vector potentials, Maxwell's equations in terms of scalar and vector potentials, Non-uniqueness of Electromagnetic potentials and concept of Gauge. Lorentz gauge and coulomb gauge.

Moving point charges: Retarded time, Retarded potentials, Lienard-Wiechart potentials for a point charge, the potentials and fields of a charged particle moving with variable velocity and constant velocity, Total power radiated by a point charge: Larmor's formula and its relativistic generalization.

Unit IV: Plasma Physics & Waveguides(12 hrs.)

Elementary Concepts: Plasma as fourth state of matter, Various kinds of Plasma, Debye Shielding, Plasma Parameters, applications of Plasma, EM Wave propagation through plasma. Plasma production and heating of the plasma.

Waveguides:- Maxwell's equations in waveguides, TE, TM and TEM waves, TE and TM modes in rectangular waveguides, concept of cut-off frequency, dielectric waveguides.
Polarization of electromagnetic waves:-Linear, elliptical and circular Polarization

REFERENCE BOOKS:
1.Classical Electrodynamics by J.D. Jackson, John Wiley & Sons, New York, 1962.
2. Introduction to Electrodynamics by D. J. Griffiths, Prentice-Hall Inc., 3rd edition, 1999.
3. Introduction to Plasma Physics (Vol.-I) by Francis F. Chen, Plenum Press New York, 1984.
4. Introduction to Plasma Theory by D. R. Nicholson,John Wiley & Sons, New York 1983.
5. Introduction to Electrodynamics by A. Z. Capri and P. V. Panat, Alpha Science International Ltd; 2002.

M.Sc. PHYSICS SEMESTER-II

MPH205

SUBJECT NAME: PHYSICS LAB II

		SESSIONAL:	30
L	P	END SEM EXAM:	70
0	16	TOTAL:	100

COURSE OBJECTIVE

To develop basic experimental knowledge in physics by extending knowledge and processes used by physics which produce new and exciting technologies in everyday use.

Course Outcomes (COs)

After successful completion of creative work about 'Lab Experiments' student will be able to learn

MPH105.1 *Utilize scientific methods for formal investigation of physical laws.*

MPH105.2 *Understand the fundamentals of various physical phenomena and physical concepts.*

MPH105.3 *Know and learn about various type of detectors used in nuclear physics experiments.*

MPH105.4 *Understand the phenomenon used in GM counter for estimating the range of different radioactive sources.*

MPH105.5 *Demonstrate competency with experimental methods that are used to discover and verify the concepts related to content and research knowledge.*

MPH105.6 *Analyze the structure of a crystalline solid in terms of lattice, basis, unit cell, reciprocal lattice, brillouin zone and symmetry elements*

MPH105.7 *Deduce the structure of a crystalline solid from an analysis of the XRD pattern and the theoretically calculated crystal structure factor.*

MPH105.8 *Learn about generation of energy by solar PV module.*

Students will perform at least 8 experiments of each of the following sections:

SECTION A:

1. To determine the Ionization potential of Lithium.
2. Determination of range of Beta-rays from Ra and Cs using GM Counter.
3. Measurement of resistivity of a semiconductor by four-probe method at different temperatures and determination of bandgap.
4. Determination of Lande's factor of DPPH using ESR spectrometer.
5. Determination of Hall coefficient of a given semiconductor and estimation of charge carrier concentration.
6. Study of Faraday effect using He-Ne Laser. To determine the angle of rotation as a function of the mean flux density using different colour filters.
7. To calculate the corresponding Verdet′s constant in each case and to evaluate Verdet′s constant as a function of the wavelength.
8. Determination of dislocation energy of Iodine molecule by photography the absorption bands of I_2 in the visible region.
9. Determination of the wavelengths of the most intense spectral lines of He and Hg (two-electron Systems).
10. Determination of e/m of electron by normal Zeeman Effect using Febry Perot Etalon.
11. To verify the Compton scattering formula, derived from the quantum theory of electromagnetic radiation, and as a consequence, the mass of the electron will be determined.
12. To understand how electric and magnetic fields impact an electron beam and experimentally determine the electron charge-to-mass ratio.
13. To determine the hysteresis loss by C.R.O, use a hysteresis curve to measure the power loss of an iron core transformer • for comparison, measure the loss for a ferrite core transformer • estimate the Curie point for ferrite.

SECTION B:

1. To study the dispersion of lattice vibrations using an electrical analog of the real lattice.
2. To determine Lattice parameter and Miller Indices using XRD.
3. To find out the Magnetic susceptibility of hydrated copper sulfate.
4. To determine the Transition temperature of ferrites.
5. To study the phenomenon of magneto-resistance.
6. To study and perform Electron paramagnetic resonance(EPR) experiment.
7. To study glow curves by performing Thermo-luminescence studies.
8. To study the properties of High temperature superconductor.

9. To determine the Dielectric constant of benzene and dipole moment of acetone.
10. To study Solar cell characteristics.
11. To estimate the effect of sun tracking on energy generation by solar PV module.

Note: Addition and deletion in the list of experiments may be made from time to time by the department.

M.Sc. PHYSICS SEMESTER-III

MPH301

SUBJECT NAME: ATOMIC AND MOLECULAR PHYSICS

NO OF CREDITS: 4

L	P	
		SESSIONAL: 25
		THEORY EXAM: 75
4	0	
		TOTAL: 100

Note: The question paper will be of two parts. Part I will consist of 10 questions of 1.5 marks each. It should cover the entire syllabus. Part II will consist of six questions of 15 marks each out of which the student has to attempt any four.

Course Outcomes (COs)

After successful completion of the course on Atomic and Molecular Physics, a student will be able to:

MPH 301.1 Understand the fundamental aspects of origination of atomic physics, analysis of spectral lines.

MPH 301.2 Capable of understanding the change in behavior of atoms in external applied electric and magnetic field on atomic spectral lines, their selection rule.

MPH 301.3 Construct and analyze the rotational, vibrational spectra of molecules.
MPH 301.4 Understand the experimental and theoretical aspects of Raman spectra.

MPH 301.5 Understand electronic energy spectroscopy, its rule, spectral range, analysis of the electronic transitions in molecules.

MPH 301.6 Grasp about the knowledge of the nucleus interaction with external fields and effect on their spectrum to understand the molecule.

COURSE OBJECTIVE

To understand the fundamentals of atomic and molecular physics. To provide a coherent and concise coverage of traditional atomic and molecular physics.

UNIT-1: Basics of Atomic Spectra (12 hrs)

Magnetic Dipole moments, Electron spin and vector model, Fine structure of hydrogen and hydrogen-like atoms-mass correction, Spin-orbit term, Darwin term, Intensity of fine structure lines, the ground state of two-electron atoms-perturbation theory and variation method. Many electron atoms- LS and JJ coupling schemes, Lande interval rule. Terms for equivalent & non-equivalent electron atom.

UNIT-II Atomic Spectra (12 hrs)

Space Quantization: stern Gerlach experiment, normal & anomalous Zeeman effect, Stark effect, Paschen-Back effect; Intensities of spectral line: General selection rule, Hyperfine Structure, Isotope Shifts and Nuclear Size Effects. X-ray spectra, X-ray emission, and Absorption spectra Auger effect, Spectra of Alkali elements

UNIT-III: Molecular Structure (12 hrs)

Born-Oppenheimer separation for diatomic molecules, rotation, vibration and electronic structure of diatomic molecules. Description of Molecular Orbital and Electronic Configuration of Diatomic Molecules: H2, H2+. Co-relation diagram for hetero-nuclear molecules.

UNIT-IV: Molecular Spectra (12 hrs)

Rotation, Vibration-rotation and electronic spectra of diatomic molecules. The Franck Condon Principle. Raman Spectroscopy: Introduction, pure rotational Raman Spectra, vibrational Raman spectra, Nuclear spin and intensity alternation in Raman spectra, Isotope effect and Raman spectrometer. Dissociation and predissociation, Dissociation energy, Rotational fine structure of electronic bands.

REFERENCE BOOKS:

1 Concept of Modern Physics by Arthur Beiser (McGraw-Hill Book Company, 1987).
2 Atomic spectra & atomic structure, Gerhard Hertzberg: Dover publication, New York.
3 Molecular structure & spectroscopy, G. Aruldhas; Prentice – Hall of India, New Delhi.
4 Fundamentals of molecular spectroscopy, Colin N. Banwell & Elaine M. McCash, Tata McGraw –Hill publishing company limited.
5 Introduction to Atomic spectra by H.E. White
6 Spectra of diatomic molecules by Gerhard Herzberg
7 Principles of fluorescence spectroscopy by Joseph R. Lakowicz

M.Sc. PHYSICS SEMESTER-III

SUBJECT NAME: STATISTICAL MECHANICS
MPH302
NO OF CREDITS: 4

		SESSIONAL:	25
L	P	THEORY EXAM:	75
4	0	TOTAL:	100

Note: The question paper will be of two parts. Part I will consist of 10 questions of 1.5 marks each. It should cover the entire syllabus. Part II will consist of six questions of 15 marks each out of which the student has to attempt any four.

Course Outcomes (COs)

After successful completion of the course on Statistical Mechanics, a student will be able to:

MPH302.1 Realize the fundamental connection between statistical mechanics and thermodynamics.

MPH302.2 Learn the ensemble formulation of statistical mechanics, and apply these to calculate important thermodynamical quantities for simple systems.

MPH302.3 Formulate the quantum mechanical ensemble theory and use it to derive the laws of quantum statistics, viz. Fermi-Dirac (FD) and Bose-Einstein (BE) statistics.

MPH302.4 Apply the laws of quantum statistics to determine the equation of state for ideal Bose and Fermi gases, and understand the origin of Bose-Einstein condensation.

MPH302.5 Grasp the basics of cluster expansion method for a classical real gas to obtain its equation of state and simple cluster integrals.

MPH302.6 Construct and solve the Ising model, along with the Landau theory of phase transition and understand fluctuations.

PHY302.7 Understand fluctuations, their spectral analysis and connection with spatial correlations.

PHY302.8 Describe the theoretical basis of Brownian motion on the basis of Enistein-Smoluchowski, and Langevin approaches.

COURSE OBJECTIVE The course aims to train the students in Classical Statistical Mechanics, Quantum Statistical Mechanics, Non-ideal Systems and Fluctuations. Furthermore, to develop the understanding to an extent that these can be used in the Bose Einstein Condensation and Phase transitions.

Unit I: Classical Statistical Mechanics (12 hrs.)

Foundations of Statistical Mechanics: The macroscopic and microscopic states, Postulate of equal a priori probability, Contact between statistics and thermodynamics; Ensemble theory: Concept of ensemble, Phase space, Density function, Ensemble average, Liouville's theorem, Stationary ensemble; The microcanonical ensemble, Application to the classical ideal gas; The canonical and grand canonical ensembles, Canonical and grand canonical partition functions, Calculation of statistical quantities; Thermodynamics of a system of non-interacting classical harmonic oscillators using canonical ensemble, and of classical ideal gas using grand canonical ensemble, Energy and density fluctuations; Entropy of mixing and the Gibbs paradox, Sackur-Tetrode equation.

Unit II: Quantum Statistical Mechanics (12 hrs.)

Quantum-mechanical ensemble theory: Density matrix, Equation of motion for density matrix, Quantum-mechanical ensemble average; Statistics of indistinguishable particles, Two types of quantum statistics- Fermi-Dirac and Bose-Einstein statistics, Fermi-Dirac and Bose-Einstein distribution functions using microcanonical and grand canonical ensembles (ideal gas only), Statistics of occupation numbers; Ideal Bose gas: Internal energy, Equation of state, Bose-Einstein Condensation and its critical conditions; Bose-Einstein condensation in ultra-cold atomic gases: its detection and thermodynamic properties; Ideal Fermi gas: Internal energy, Equation of state, Completely degenerate Fermi gas.

Unit III: Non-Ideal Systems (12 hrs.)

Cluster expansion method for a classical gas, Simple cluster integrals, Mayer-Ursell relations, Virial expansion of the equation of state, Van der Waal's equation, Validity of cluster expansion method; Phase transitions: Construction of Ising model, Solution of Ising model in the Bragg-William approximation, Exact solution of the one-dimensional Ising model; Critical exponents, Landau theory of phase transition, Scaling hypothesis.

Unit IV: Fluctuations (12 hrs.)

Thermodynamic fluctuations and their probability distribution law, Spatial correlations in a fluid, Connection between density fluctuations and spatial correlations; Brownian motion, the Langevin theory of the Brownian motion (derivations of mean square displacement and mean square velocity of Brownian particle), Auto-correlation function and its properties, The fluctuation-dissipation theorem, Diffusion coefficient; the Fokker-Planck equation; Spectral analysis of fluctuations: the Wiener-Khintchine theorem.

REFERENCE BOOKS

1. Statistical Mechanics by R. K. Pathria and P. D. Beale (2011), United States: Elsevier/Academic Press. (3rd edition)
2. Statistical and Thermal Physics by F. Reif (2010) Waveland Press.
3. Statistical Mechanics by K. Huang (1963). New York: Wiley.
4. Statistical Mechanics by L. D. Landau and I. M. Lifshitz (1980), USSR Academy of Sciences.
5. Statistical Mechanics by R. Kubo (1965) Amsterdam: North-Holland.

M.Sc. PHYSICS SEMESTER-IV

MPH401

SUBJECT NAME: LASER TECHNOLOGY

NO OF CREDITS: 4

		SESSIONAL:	25
L	P	THEORY EXAM:	75
4	0	TOTAL:	100

Note: The question paper will be of two parts. Part I will consist of 10 questions of 2 marks each. It should cover the entire syllabus. Part II will consist of six questions of 10 marks each out of which the student has to attempt any four.

COURSE OUTCOMES (COs)

After successful completion of course on Laser Technology, students will be able to:

MPH401.1 Understand the basic principles of a laser system and conventional sources.

MPH401.2 Learn *about the basic properties and characteristics of laser light.*

MPH401.3 Learn principle and working of various lasers including gas, liquid and solid-state.

MPH401.4 Know principle and working of semiconductor lasers and its type, p-n junction laser.

MPH401.5 Understand the nonlinear optics and brief about harmonic generation.

MPH401.6 Generate phase matching conditions and self-focusing in nonlinear optics.
MPH401.7 Learn about Raman scattering and types of Raman Scattering in nonlinear optics
MPH401.8 *Describe certain applications like laser c*ooling and trapping of atoms along with Bose Condensation.

COURSE OBJECTIVE

To understand the basic laser fundamentals, unique properties of the laser, types of practical lasers and laser safety, and industrial applications of high and low power lasers. Apart from this, topics of current research interest will also be discussed, such as laser cooling and trapping which play an important role in the realization of Bose-Einstein condensate in atomic vapors.

Unit-I: Basic Principle and Different Lasers (12hrs)

Laser characteristics: Spontaneous and Stimulated Emission, Absorption, Laser Idea, Pumping Schemes, Properties of Laser Beams: Monochromaticity, Coherence, Directionality, Brightness, radiative transition and Amplified Spontaneous Emission, Non-radiative delay, Resonator, rate equations, Methods of Q-switching

Unit-II: Types of Lasers (12hrs)

Principle and Working of CO_2 Laser, Semiconductor Laser. Homo-structure and Hetero-structure P–N Junction Lasers, Nd-YAG Lasers. Principle of Excimer Laser. Principle and Working of Dye Laser. Free Electron Laser. Photo detector p-n diode, nano laser, Ultrafast laser

Unit-III: Non-Linear Processes (12hrs)

Propagation of Electromagnetic Waves in Nonlinear Medium, Self-Focusing, Phase Matching Condition, Raman Scattering: Stimulated Raman Scattering, Hyper Raman Scattering and CARS, Two-Photon Absorptions process.

Unit IV: Novel Applications of Laser (12hrs)

Cooling and Trapping of Atoms, Principles of Doppler and Polarization Gradient Cooling, Qualitative Description of Ion Traps, Optical Traps and Magneto-Optical Traps and Bose Condensation.

REFERENCE BOOKS:

1. Laser Spectroscopy and Instrumentation, Demtroder, Springer
2. Principles of Lasers, Svelto, Orazio, Fifth edition, Springer
3. Atom, Laser and Spectroscopy, 2nd Edition, Kindle Edition, S. N. Thakur, D. K. Rai,PHI Publication
4. Laud: Laser and nonlinear optics, B.B. Laud, New Age International Pvt Ltd Publishers.

5. Lasers:Fundamentals and Applications, Thyagarajan, K., Ghatak, Ajoy, Springer

M.Sc. PHYSICS SEMESTER-IV

MPH402
SUBJECT NAME: MATERIAL SCIENCE

NO OF CREDITS: 4

L	P		
		SESSIONAL:	25
L	P	THEORY EXAM:	75
4	0	TOTAL:	100

Note: The question paper will be of two parts. Part I will consist of 10 questions of 2 marks each. It should cover the entire syllabus. Part II will consist of six questions of 10 marks each out of which the student has to attempt any four.

Course Outcomes (COs)

After successful completion of the course on Material Science-I, a student will be able to:

MPM303.1 *Understand the basic concepts and properties of Materials.*

MPM303.2 *Describe how and why defects (point, line and planar) in materials greatly affect engineering properties and limit their use in service*

MPM303.3 *Understand strengthening and grasp the importance of various strengthening mechanisms.*

MPM303.4 *Describe various parameters involved in elastic deformation, plastic deformation, inelastic deformation etc.*

MPM303.5 *Grasp the concept of magnetization in materials.*

MPM303.6 *Comprehend magnetic, dielectric, optical and ferroelectric materials.*

MPM303.7 Elucidate the polarizability in materials and analysis of dielectric materials for various applications.

MPM303.8 Develop structure-property correlation for design of materials.

Course Objectives: The course targets to make the students understand the various types of defects/imperfections in materials. The course will also expose the students to mechanical, electrical, magnetic, optical and dielectric properties of materials.

Unit I: Imperfections in Solids (12 hrs.) Point Defects: Vacancy, Substitutional, Interstitial, Frenkel and Schottky Defects, Equilibrium Concentration of Frenkel and Schottky Defects; Line Defects: Slip Planes and Slip Directions, Edge and Screw Dislocations, Burger‘s Vector, Cross-slip, Glide and Climb, Jogs, Dislocation Energy, Super & Partial dislocations, Dislocation Multiplication, Frank Read Sources; Planar Defects: Free Energy, Grain Boundaries, Twin Interfaces, and Stacking Fault; Volume Defects: Precipitates and Dispersants.

Unit II: Mechanical Properties (12 hrs.) Stress-Strain Curve; Stress: tensor and concentration; stress in two dimensions, Elastic Deformation: Isotropic and Anisotropic; Anelastic and Viscous deformation; Plastic Deformation: True stress and Strain, Critically resolved shear stress; Slip theory: Perfect and real crystal; Strengthening Mechanisms: work hardening, recovery, recrystallization, strengthening from grain boundaries, strain aging, solid solution strengthening; Creep & its Mechanism, Fracture: Introduction.

Unit III: Magnetic Materials (12 hrs.)

Magnetic Processes: Larmor frequency; Diamagnetism, magnetic susceptibility, Langevin's diamagnetism equation; Paramagnetism, Curie constant, the density of states curves for a metal; Ferromagnetism, Curie temperature, Curie-Weiss law, exchange interactions, domain structure; Antiferromagnetism and magnetic susceptibility of an antiferromagnetic material; Ferrimagnetism and Ferrites; Paramagnetic, ferromagnetic and cyclotron-resonance.

Unit IV: Dielectrics, Optical, and Ferroelectric Materials (12 hrs.)

Polarization, Macroscopic electric field, Dielectric susceptibility, Local electric field at an atom, Dielectric constant and polarizability, Clausius-Mossotti relation, Electronic polarizability, Classical theory of electronic polarizability; Structural phase transitions; Ferroelectric crystals and their classification; Landau theory of the phase transition; Optical absorption, transmission and reflection.

REFERENCES:

1. J.C. Anderson, K.D. Leaver, P. Leevers and R.D. Rawlings, Materials Science for Engineers, CRC Press, London.
2. V. Raghavan, Materials Science and Engineering: A First Course, PHI Learning, New Delhi.
3. C. Kittel, Introduction to Solid State Physics, Wiley, India.
4. A.J. Dekker, Solid State Physics, Macmillan Press, London.
5. W.D. Callister, Materials Science and Engineering : An Introduction, John Wiley, New York.
6. G.E. Dieter, Mechanical Metallurgy, McGraw Hill, New York.
7. Milton Ohring, Engineering Materials Science, Academic Press, USA.

SPECIALIZATION-I: NUCLEAR PHYSICS

M.Sc. PHYSICS SEMESTER-III

MPN303

SUBJECT NAME: NUCLEAR REACTIONS

NO OF CREDITS: 4

		SESSIONAL:	25
L	P	THEORY EXAM:	75
4	0	TOTAL:	100

Note: The question paper will be of two parts. Part A will consist of 10 short answer type questions of 1.5 marks each. It should cover the entire syllabus. Part B will consist of five questions of 15 each out of which the student has to attempt any four.

Course Outcomes (COs)

After successful completion of the course on Nuclear Reactions, a student will be able to:

MPH303.1 *Differentiate between different types of nuclear reactions, relevant aspects associated with nuclear reactions and kinematics of such reactions.*

MPH303.2 *Acquire conceptual understanding of nuclear cross section*

MPH303.3 *Know and learn about the theory of Deuteron and explore it's applications*

MPH303.4 *Understand the neutron-proton scattering and concept of scattering length*

MPH303.5 *Understand the quantum formulation of nuclear reaction*

MPH303.6 *Know concept of cross section and apply it to resonances in quantitative way*

MPH303.7 *Learn nuclear fission and its related theories*

MPH303.8 *Understand nuclear fusion its reaction rates and cross section*

Unit - I: Basics of Nuclear Reactions (12 hrs)

Type of nuclear reactions, Q-value of nuclear reactions and its determination. Collision between subatomic particles, elastic collision in L-system, elastic collision in C-system (Non-relativistic), Invariance in nuclear reactions. Basic concepts of cross section: Total cross section, Partial cross section, differential cross section. Cross section in terms of partial wave analysis.

Unit - II: Two Body Problem (Deuteron - $^{1}H_{2}$)(12 hrs)

Physical properties of Deuteron: Mass, binding energy, spin or total angular momentum, parity, magnetic moment and electric quadrupole moment. Ground state of Deuteron (square well potential), Range depth relationship for square well potential. Concept of scattering length and significance of its sign. Spin dependence of neutron- proton scattering, Effective range theory of neutron-proton scattering.

Unit – III: Quantum Formulation of Nuclear Reaction (12 hrs)

Breit-Wigner dispersion formula for s-wave neutrons of low energy, compound nucleus, Form of the optical potential: Square well, Woods-Saxon and spin dependent optical potential. Elastic scattering and reaction cross section with optical model. Kapur-Peierls dispersion formula for potential scattering, Limitations of the optical model. Stripping and pick-up reactions.

Unit – IV: Fission & Fusion reactions (12 hrs)

Nuclear Fission: Types of fission, energy released in fission, nature of fission fragments, neutron emission in fission process, Bohr & Wheeler theory of nuclear fission and it's limitations, four factor formula, conditions for controlled chain reactions, Nuclear Fusion: Basic introduction of Plasma, fusion reactions, energy balance & Lawson criterion, cross section of fusion, reaction rates.

REFERENCE BOOKS:

1. Nuclear Physics: Principle and Application by John Lilley (Wiley Pub.).
2. Concepts of Nuclear Physics by Bernard L. Cohen (TMH).
3. Nuclear Physics: Theory and Experiment by R. R. Roy and B. P. Nigam (New Age Int.)
4. Nuclear Physics Experimental and Theoretical by H. S. Hans (New Age Int.).
5. Introduction to nuclear reactions G R Satchler (Oxford university Press)
6. Introductory Nuclear Physics. By Kenneth S. Krane. (John Wiley & Sons, 1987)
7. Nuclear & Particle physics, by S. L. Kakani & S. Kakani (Viva Books)
8. Nuclear Physics by S. N. Ghoshal (S. Chand Pub.)

M.Sc. PHYSICS SEMESTER-III

MPN304

SUBJECT NAME: NUCLEAR DETECTORS

NO OF CREDITS: 4

		SESSIONAL:	25
L	P	THEORY EXAM:	75
4	0	TOTAL:	100

Note: The question paper will be of two parts. Part A will consist of 10 short answer type questions of 1.5 marks each. It should cover the entire syllabus. Part B will consist of five questions of 15 each out of which the student has to attempt any four.

Course Outcomes (COs)

After successful completion of the course on Nuclear Detectors, a student will be able to:

MPH304.1 *Learn about the theoretical aspects of design and usage of various nuclear detectors and their applications in the field of nuclear physics.*

MPH304.2 *Learn about the concept, working, types and properties of various gas filled detectors.*

MPH304.3 *Understand various operation regions in different gas filled detectors.*

MPH304.4 *Know the Solid state detectors (Basics, construction, working, advantages, disadvantages)*

MPH304.5 *Understand the types and characteristics of Solid State detectors*

MPH304.6 *Understand the classification, mechanisms, and properties of scintillator detectors.*

MPH304.7 *Describe the factors affecting performance of scintillator detectors*

MPH304.8 *Learn about the other miscellaneous detector types*

Unit-I: Gas Detectors (12 hrs)

Ionization Chamber (Ionization in gas, Charge migration and collection, Design and operation of DC Ion chambers, Exposure and dose measurements, Pulse mode operation), Proportional counter (Gas multiplication, design of proportional counter, Counting curve and applications, Gas electron multiplier), Geiger-Muller Counters (The Geiger discharge, Geiger plateau, Counting efficiency).

Unit-II: Solid State Detectors (12 hrs)

Basics of semiconductors, Solid state detectors (Basics, construction, working, advantages, disadvantages), Types of semiconductor detectors (Diffused junction, surface barrier, Lithium-Drifted Silicon Si(Li), Lithium-Drifted Germanium detectors, Ge(Li), High purity Germanium detectors), Characteristics of semiconductor detectors (Average energy, Linearity, leakage current, Intrinsic efficiency and sensitivity), Compound semiconductor detectors.

Unit-III: Scintillation Detectors (12 hrs)

Principle, Properties and types of scintillator detectors, Factors affecting performance of scintillator detectors, Inorganic scintillators (Mechanism and characteristics of Thallium activated sodium iodide-NaI(Tl) scintillator), Organic scintillators (Mechanism, Types and Response of Organic scintillators), Basics of Fiber scintillators and Noble gas scintillators, Photo and electron multipliers: Photomultiplier tubes and Channel electron multipliers.

Unit-IV: Miscellaneous Detector Types (12 hrs)

Statistics of counting: Normal, Poisson and Gaussian distribution, Solid state nuclear track detectors (Visualization of the tracks of ionizing radiations, mechanism of formations of tracks, etching and advantages), Construction, operation, applications, merit and demerits of the Spark Chamber , The Bubble chamber, Cloud chamber, Chernokov detectors.

REFERENCE BOOKS:

1. Radiation Detection and Measurement by G. F. Knoll (John Wiley & Sons, Inc. 3rd Ed., 2000)
2. Nuclear Radiation Detectors by S. S. Kapoor and V. S. Ramamurthy (New Age Int.).
3. Techniques for Nuclear and Particle Physics Experiments by W. R. Leo (Springer-Verlag)
4. Nuclear Radiation Detection, Measurements and Analysis by K. Muraleedhara Varier (Narosa)

M.Sc. PHYSICS SEMESTER-III

MPN305

SUBJECT NAME: NUCLEAR PHYSICS SPECIALIZATION LAB

NO OF CREDITS: 8

		SESSIONAL:	30
L	P	END SEM EXAM :	70
0	16	TOTAL:	100

Course Outcomes (COs)

After successful completion of the course on Nuclear Detectors, a student will be able to:

MPN305.1 *Understand the working of GM Counter and measure the end point energy and resolving time of source of given sample.*

MPN305.2 *Learn to verify inverse square law and find the Linear & mass attenuation coefficient using gamma source*

MPN305.3 *Understand the various scattering processes*

MPN305.4 *Able to determine the operating voltage of a photomultiplier tube*

MPN305.5 *Acquire practical knowledge on calibrating a gamma ray spectrometer and to determine the energy of a given gamma ray source.*

MPN305.6 *Analyze half life of radioactive nuclei*

MPN305.7 *Learn to determine the beta ray spectrum of a beta source (like Cs-137) and to calculate the binding energy of the K-shell electron of a given source.*

MPN305.8 *Understand few experiments using computation codes & Simulations*

COURSE OBJECTIVE

To develop basic experimental knowledge in nuclear physics through performing experiments. Students will perform at least 8 experiments of each of the following sections:

Experiments for specializations in Nuclear Physics

Section A

1. To study the characteristics of G.M. Counter.
2. To find the end point energy of a given source using G.M. Counter.
3. To find the absorption coefficient of given material using G.M. counter.
4. To study the Solid State Nuclear Track Detector.
5. To determine the mass absorption coefficient for beta rays.
6. To study Nuclear counting statistics.
7. To measure the short half-life of a radioactive nuclei.
8. To verify the inverse square law using gamma rays.
9. To estimate the efficiency of GM detector for (a) gamma source (b) beta source
10. To find the Linear & mass attenuation coefficient using gamma source.
11. To study the counting statistics for radioactive decay using SSNTD.
12. To determine the operating voltage of a photomultiplier tube.
13. To find the efficiency of a NaI (Tl) detector.
14. To determine the range and energy of alpha particles using spark counter
15. To study the Compton Scattering experiment.
16. To study the Rutherford backscattering experiment.
17. To study Poisson and Gaussian distributions using a GM Counter.
18. To calibrate a gamma ray spectrometer and to determine the energy of a given gamma ray source.
19. To determine the beta ray spectrum of a beta source (like Cs-137) and to calculate the binding energy of the K-shell electron of a given source.
20. To study the various modes in a multichannel analyzer and to calculate the energy resolution, energy of gamma ray.

Section B

Experiments using computation codes & Simulations

1. To study Compton scattering using computer code
2. To study the Rutherford scattering through code
3. To study energy losses by light and heavy ions passing through matter using code
4. To find the radial part of wave function of deuteron in its ground state using Runge- Kutta Method
5. To solve the s-wave Schrodinger equation for the ground state of the hydrogen atom.
6. Simulation of nuclear radioactivity by Monte Carlo technique.

M.Sc. PHYSICS SEMESTER-IV

MPN403

SUBJECT NAME: NUCLEAR MODELS AND ASTROPHYSICS

NO OF CREDITS: 4

		SESSIONAL:	25
L	P	THEORY EXAM:	75
4	0	TOTAL:	100

Note: The question paper will be of two parts. Part A will consist of 10 short answer type questions of 1.5 marks each. It should cover the entire syllabus. Part B will consist of five questions of 15 marks each out of which the student has to attempt any four.

Course Outcomes (COs)

After successful completion of the course on Nuclear Models and Astrophysics, a student will be able to:

MPN403.1 *Learn basics of nuclear liquid drop model, nuclear fission process and nuclear shell model.*

MPN403.2 *Predict ground state properties like spin, parity, magnetic dipole moment, electric quadrupole moment of nuclei by employing nuclear shell model.*

MPN403.3 *Understand types of multipole deformations and surface vibrations in heavy nuclei.*

MPN403.4 *Apply nuclear collective model in predicting low lying rotational and vibrational excited states of nuclei.*

MPN403.5 *Acquire conceptual understanding of the general theory of nuclear scattering and reactions.*

MPN403.6 *Analyze the cross sections for compound and direct nuclear reactions.*

MPN403.7 *Understand the key features of nuclear reactions involving weakly bound nuclei and heavy induced ion reactions.*

MPN403.8 *Appreciate the importance of recent research activities being carried out by using beams of rare isotopes.*

Unit-I : Nuclear Models (12 hrs)

Fermi gas model, Liquid Drop Model, merits and limitations of liquid drop model. Evidence for nuclear shell structure, Concept of magic numbers, Three-dimensional central Schrodinger equation, square-well potential: the energy eigenvalue problem for bound states, The harmonic oscillator potential, Nuclear spin orbit interaction, Qualitative idea about the Nilsson model, superfluid model

Unit-II: Application of Nuclear Models (12 hrs)

Applications of extreme single particle shell model and its predictions regarding ground state spin parity, magnetic moment and electric quadrupole moments, Schmidt lines, Collective model, Rotational mode, Rotational energy spectra and the nuclear wave function for even-even and odd-A nuclei, Vibrational mode, Potential energy and total Hamiltonian in vibration mode.

Unit-III: Exotic Nuclei (12 hrs)

Nuclear landscape and drip lines, qualitative idea of production of exotic nuclei, structure and properties of exotic nuclei and their application in astrophysics, evidence of breakdown of magic numbers, Halo & Skin structure, GDR and soft dipole resonance (reaction point of view)

Unit-IV: Nuclear Astrophysics (12 hrs)

Evolution of stars, Nuclear synthesis of elements in stars, hydrogen chain, carbon chain, energy liberation rate, Neon cycle, emission of neutrino from the core of stars, Chandrasekhar limit and white dwarfs, introduction of neutron star, basic introduction of r-process, supernova, cosmic rays, types and properties of primary cosmic rays, qualitatively idea of interaction of primary cosmic rays with atom.

REFERENCE BOOKS:

1. Theory of Nuclear Structure by M. K. Pal (Scientific and Academic Editions(1983)
2. Nuclear Physics: Theory and Experiment by R. R. Roy and B. P. Nigam (New Age Int.)
3. Nuclear Physics Experimental and Theoretical by H. S. Hans (New Age Int.).
4. Basic ideas and concepts in Nuclear Physics by K. Heyde (Second Edition Overseas Press)
5. Nuclear Structure Vol. 1& 2 by A. Bohr and Ben R. Mottelson (world Scientific)
6. Nuclear shell theory by Amos de- Shalit and I. Talmi (New York Academic press)
7. Fundamental of Nuclear Physics by Jahan Singh (Pragati Publication)
8. Nuclear Physics by S. N. Ghoshal (S Chand)
9. Halo Nuclei by Jim Al Khalili (A Morgan & Claypool Publication)
10. Physics of radioactive beam by C. A. Bertulani, M.S. Hussian, G. Munzenberg(Nova Science Publishers)
11. Nuclear Astrophysics by Md A. Khan (CRC Press, Taylor & Francis Group)

M.Sc. PHYSICS SEMESTER-IV

MPN404

SUBJECT NAME: NUCLEAR TECHNIQUES AND NEUTRON PHYSICS

NO OF CREDITS: 4

		SESSIONAL:	25
L	P	THEORY EXAM:	75
4	0	TOTAL:	100

Note: The question paper will be of two parts. Part A will consist of 10 short answer type questions of 1.5 marks each. It should cover the entire syllabus. Part B will consist of five questions of 15 marks each out of which the student has to attempt any four.

Course Outcomes (COs)

After successful completion of the course on Nuclear Techniques and Neutron Physics, a student will be able to:

MPN404.1	*Understand the resonance and non-resonance method.*
MPN404.2	*Understand the concept of high energy accelerators.*
MPN404.3	*Realize the relativistic kinematics and its importance in calculations at relativistic energies.*
MPN404.4	*Construct Analysis of the decay energy in various high energy reactions.*
MPN404.5	*Understand the interaction of charged particles with matter and will be able to calculate the dynamics of high energy particles.*
MPN 404.6	*Learn the basics of Neutron Physics, their classification and their methods of production*
MPN404.7	*Understand radiation mechanism at relativistic velocities.*
MPN404.8	*Grasp details of particle accelerators for the creation of high energy particles*

Unit-I: Determination of Nuclear Properties (12 hrs)

Mass measurement using ion optics, Dempster's semicircular focusing, Aston's, Bainbridge, atomic beam method of nuclear magnetic moment determination, non-resonance & resonance method, electron paramagnetic resonance, nuclear induction method, determination of electric quadrupole moment.

Unit-II: Radiofrequency Accelerators (12 hrs)

Basic principles and components of accelerators, Linear accelerators - Resonance acceleration and phase stability, electron and proton Linacs. Circular accelerators-Cyclotron, Frequency Modulated Synchrocyclotron, AVF Cyclotron, Alternating-gradient accelerators.

Unit-III: Electrostatic and Heavy Ion Accelerators (12hrs)

Van de Graaff voltage generator, Cockcroft-Walton voltage generator, insulating column, voltage measurement, Acceleration of heavy ions, Tandem electrostatic accelerator, Production of heavy negative ions, Pelletron and Tandetron. Qualitative idea about Storage ring accelerators and large hadron collider (LHC).

Unit-IV: Neutron Physics (12 hrs)

Basic properties of neutron, classification of neutrons, methods for neutron production: Radioactive sources as (**α,n**) reactions, photo neutron sources, interaction of neutrons with nuclei and with matter in bulk, general properties of neutron detection, Different types of nuclear fission reactors, Plasma, critical temp confinement of hot plasma, Magnetic confinement of plasma, plasma lose. Qualitative idea about fusion reactor (Tokamak).

REFERENCE BOOKS:

1. Techniques for Nuclear and Particle Physics Experiments by W R Leo (Springer-Verlag)
2. Nuclear Radiation Detection, Measurements and Analysis by K Muraleedhara Varier (Narosa)
3. Particle Accelerator Physics, Vol I and II, H.J. Wiedman, Springer Verlag (1998)
4. Particle Accelerators, M.S. Livingston and J.P. Blewel, McGraw-Hill Book Press.
5. Nuclear Spectroscopy and Reactions Part-A, Ed. J. Cerny, Academic Press, 1974.
6. Theory of Resonance Linear Accelerators by I.M. Kapchenkey, Harwood, Academic Publishers.
7. Nuclear physics: Principles and applications by John Lilley (Wiley-India)
8. Fundamental of Nuclear Physics by Jahan Singh (Pragati Publication)
9. Nuclear Physics by Dr. S N Ghoshal (S Chand)
10. Fundamental of Nuclear Physics by Jahan Singh (Pragati Publication)

SPECIALIZATION-II: MATERIALS SCIENCE

M.Sc. PHYSICS SEMESTER-III

MPM303

SUBJECT NAME: MATERIALS CHARACTERIZATION TECHNIQUES

NO OF CREDITS: 4

L	P		
		SESSIONAL:	25
4	0	THEORY EXAM:	75
		TOTAL:	100

Note: The question paper will be of two parts. Part I will consist of 10 questions of 2 marks each. It should cover the entire syllabus. Part II will consist of six questions of 10 marks each out of which the student has to attempt any four.

COURSE OUTCOMES (COs):

After successful completion of course on Material Characterization Techniques, students will be able to:

MPH402.1 Know brief about the techniques to characterize the materials.

MPH402.2 Explain classification of characterization techniques and determination of crystal structure of specimen

MPH402.3 Estimate crystallite size and stress of crystalline materials by using X-ray diffraction methods.

MPH402.4 Apply appropriate characterization techniques for microstructure examination at different magnification level and use them to understand the microstructure of various materials.

MPH402.5 Choose appropriate electron and atomic microscopy techniques to investigate microstructure of materials at high resolution.

MPH402.6 Use appropriate optical technique to measure vibrational / electronic transitions to estimate parameters like energy band gap, elemental concentration, etc.

MPH402.7 Know thermal analysis techniques to determine thermal stability of and thermodynamic transitions of the specimen.

MPH402.8 Understand the magnetic material characterization and its analysis.

COURSE OBJECTIVE

The goal of this course is to introduce the materials characterization techniques to the students and Help them to understand the instrumentation aspects. It will provide a detailed understanding of data interpretation and hands on experience of the characterization technique To introduce the students to the principles of optical and electron microscopy, X-ray diffraction and various spectroscopic techniques

Unit-I: Structural Characterization and Analysis (12hrs):

Introduction to materials characterization, Bragg's Law, Generation and detection of X-rays, X-ray diffraction methods (XRD), Determination of crystal structure, Lattice Parameter, Crystallite Size, Lattice Strain measurements, Williamson Hall Plot; Electron diffraction.

Unit-II: Electron Microscopy and Surface Analysis (12hr):

Interaction of electrons with solids, Scanning electron microscopy(SEM), Transmission electron microscopy(TEM), Scanning transmission electron microscopy(STEM), Scanning Probe Microscope (SPM): Atomic force microscopy (AFM), scanning tunneling microscopy(STM).

Unit-III: Optical and Thermal Characterization (12hrs):

Optical Microscopy, UV/Visible spectroscopy, Fourier Transform Infrared spectroscopy(FTIR), Atomic absorption spectroscopy(AAS), Raman spectroscopy. Thermo gravimetric analysis(TGA), Differential thermal analysis(DTA), Differential Scanning Calorimetry (DSC),.

Unit-IV: Magnetic Characterization (12hrs):

Spectroscopy Techniques: Basic of nuclear magnetic resonance (NMR) and electron spin resonance (ESR) spectroscopy, Magnetic Measurements: Vibrating Sample Magnetometer (VSM), Superconducting Quantum Interference Device (SQUID), Magnetic Force Microscopy, Mössbauer Spectroscopy.

REFERENCE BOOKS:

1. Introduction to Nanotechnology, Charles P. Poole, Jr. and Frank J. Owens, Wiley, (2003)
2. MEMS/NEMS: micro electro mechanical systems/nano electro mechanical systems Volume 1, Design Methods, Cornelius T. Leondes, Springer, (2006).
3. Instrumental methods of Chemical Analysis, G. Chatwal & Sham Anand, Himalaya
4. Introduction to Infrared and Raman spectroscopy, Norman D Colthup, Lawrence H Daly and Stephen E Wiberley, Academic press, NY.

5. Instrumental methods of analysis, H.H. Willard, L.L. Merrit, J.A. Dean & F.A. Settle, CBS Pub.
6. Principles of Instrumental analysis, Skoog and West – Hall – Sanders Int.
7. Instrumental methods of chemical analysis, G W Ewing, MGH
8. Scanning Tunnelling Microscopy, R. Wiesendanger & H.J. Guntherodt, Springer
9. Nanotechnology: Principles and Practices – *Sulabha K Kulkarni.* Capital Publishing Company, New Delhi.

M.Sc. PHYSICS SEMESTER-III

MPM304

SUBJECT NAME: FUNDAMENTALS AND SYNTHESIS OF NANOMATERIALS

NO OF CREDITS: 4

		SESSIONAL:	25
L	P	THEORY EXAM:	75
4	0	TOTAL:	100

Note: The question paper will be of two parts. Part I will consist of 10 questions of 2 marks each. It should cover the entire syllabus. Part II will consist of six questions of 10 marks each out of which the student has to attempt any four.

COURSE OUTCOMES (COs):
After successful completion of course on Fundamentals and Synthesis of Nanomaterials, students will be able to:

MPM304.1 Understand the basics of nanotechnology and its implications in modifying the properties of materials at the nanoscale.

MPM304.2 Learn with quantum phenomena used in nanostructured materials.

MPM304.3 Concept of Quantum confinement, 3D,2D,1D and 0D nanostructure with examples.

MPM304.4 Know about the role of carbon family in nanotechnology with its applications.

MPM304.5 Different synthesis techniques including top down and bottom up approaches and able to apply appropriate Non Lithographics for development of nanomaterials

MPM304.6 Develop nano devices using Lithographic techniques.

MPM304.7 Use Chemical synthesis techniques to growth of Nanomaterials.

MPM304.8 Understand the coating techniques to prepare the thin film.

COURSE OBJECTIVE

To develop a fundamental knowledge of nanomaterials and able to acquire an understanding of the quantum phenomena used in nanostructured materials. Moreover, by this course, students are capable of selecting the synthesis processes viz. physical, chemical, and biological methods in creating exotic nanostructured materials.

Unit I: **Introduction and Quantum mechanical concepts at Nanoscale (12hrs)**: Introduction to nanomaterials, Band Structure, Density of states of nanoscale Size, Applications of Schroedinger equation, confined particle in 1D, potential step: reflection and tunneling. penetration of barrier, potential box: trapped particle in 3D;Nanodot, electron trapped in 2D plane; Nano sheet, electron moving in 1D; Nanowire/rod/belt. Quantum confinement in nanomaterials, Surface to volume ratio.

Unit-II: Carbon based Nanomaterials (10hrs)
Introduction to Carbon Clusters, CNTs and synthesis of carbon nanotubes. Growth mechanism, electronic structure of carbon nanotubes, preparation and characterization of fullerenes and graphene. Nanodiamond, Defects and purifications in CNT(Brief).

Unit III: **Synthesis of Nanomaterials-I (14 hrs):**
Physical Methods: Top-down vs. Bottom-up Technique, Nonlithographic Techniques: Plasma Arc Discharge, Sputtering, Electron Beam and Thermal Evaporation , Pulsed Laser Deposition, Molecular Beam Epitaxy. Lithographic Process and its Limitations: Electron beam lithography, Ion beam lithography, Photo lithography, x-ray lithography.

Unit IV: **Synthesis of Nanomaterials-II (12 hrs):**
Chemical Methods: Chemical Vapor Deposition (CVD), Sol-gels techniques, Co-precipitation, Hydrothermal, Spin and Dip coating techniques and Spray pyrolysis, Chemical Etching Techniques, Electroplating, Langmuir Blodgett(L-B) method, microemulsions.

REFERENCE BOOKS:

1. Introduction to Nanoscience and Nanotechnology – K.K. *Chatopadhyay and A.N. Benerjee,* PHI
2. Nanotechnology: Principles and Practices – *Sulabha K Kulkarni.* Capital Publishing Company, New Delhi.
3. Nanostructured Materials and Nanotechnology – *Hari Singh Nalwa.* AP.

4. Nanostructures and Nanomaterials-Synthesis, Properties and Applications – *Cao,* Guozhong. World Scientific Series in Nanoscience and Nanotechnology: Volume 2
5. Biological Synthesis of Nanoparticles and Their Applications Edited by L Karthik, A. Vishnu Kirthi, Shivendu Ranjan, V. Mohana Srinivasan, CRC Press
6.Introduction to Nanoscience and Nanomaterials, https://doi.org/10.1142/8433, Dinesh C Agrawal (Indian Institute of Technology, India) World Scientific.

M.Sc. PHYSICS SEMESTER-III

MPM305

SUBJECT NAME: MATERIAL SCIENCE LAB

NO OF CREDITS: 8

L	P			
			SESSIONAL:	30
			END SEM EXAM:	70
0	16		TOTAL:	100

COURSE OUTCOME (COs):

After successful completion of course on Material Science Lab, students will be able to:

MPM305.1 Synthesis the nanomaterial by using Physical and Chemical methods

MPM305.2 Develop the nano tin films by using sputtering method

MPM305.3 Demonstrate the optical properties through a Spectrophotometer

MPM305.4 Demonstrate the structural properties through XRD

MPM305.5 Analyze the material properties through Dynamic light scattering

MPM305.6 Demonstrate the electrical properties using IV and CV Characteristics

MPM305.7 Characterize the nanomaterials Demonstrate the morphology through SEM

MPM305.8 Handle the equipments and Interpret the results through graphs and calculations

COURSE OBJECTIVE:

- To impart practical knowledge on practical skills to analyze nanomaterials.
- Analyzing the results for the properties of nanomaterials
- Practical training on the operation of the characterization equipment

Students assigned the general laboratory work will perform at least 8 experiments of the following:

List of Experiments Material Science Laboratory

1. To study the magneto resistance behavior of Ge crystal at room temperature
2. Synthesis of nanoparticles using Sol-Gel Method
3. Fabrication of thin film using spin coating technique.
4. Preparation of Thin film by Sputtering method
5. Fabrication of Nano/micro pores in Silicon Wafer through Chemical etching technique of porous silicon.
6. Determination of lattice parameters using XRD Technique.
7. Determine the crystallite size of nanomaterial using Debye Scherer method.
8. Determination of band gap energy of metal-oxide nanoparticles using UV Spectrophotometer.
9. To understand the microstructural features of ceramics/metals by optical microscopy.
10. Study and analysis of FTIR spectra of material.
11. To study the I-V characteristics of semiconductor material.
12. To study the C-V characteristics of materials for electrochemical applications
13. Study of surface morphology of a material by scanning electron microscopy (SEM) technique

Experiments may be added or deleted

The faculty conducting the laboratory will prepare a list of 8 experiments and get the approval of the HoD/Director and notify it at the beginning of each semester.

M.Sc. PHYSICS SEMESTER-IV

MPM403

SUBJECT NAME: ADVANCED MATERIALS SCIENCE

NO OF CREDITS: 4

		SESSIONAL:	25
L	P	THEORY EXAM:	75
4	0	TOTAL:	100

Note: The question paper will be of two parts. Part I will consist of 10 questions of 2 marks each. It should cover the entire syllabus. Part II will consist of six questions of 10 marks each out of which the student has to attempt any four.

Course Outcomes (COs)

After successful completion of the course on Material Science-II, a student will be able to:

MPM403.1 *Gain knowledge of the microstructure of the materials.*

MPM403.2 *Grasp the concepts of phase diagrams and phase transformations and correlate these with growth kinetics and microstructure evolution in materials.*

MPM403.3 *Analyze the diffusion process in materials.*

MPM403.4 *Understand superconductivity properties of materials.*

MPM403.5 *Elucidate the different types of composite materials and develop state of art in hybrid and advanced composite materials.*

MPM403.6 *Comprehend the importance of smart and composite materials as futuristic materials.*

MPM403.7 *Grasp the concept, working and applications of smart materials for energy harvesting.*

MPM403.8 *Design the materials for various industrial applications.*

Unit I: Phase diagrams and phase transformations (12 hrs.)

Solid Solutions and Intermediate Phases: phase rule, unitary & binary phase diagrams, Lever rule, Hume-Rothery rule; Free Energy and Equilibrium Phase Diagrams: Complete Solid Miscibility, Partial Solid Miscibility-Eutectic, Peritectic and Eutectoid reactions, Eutectoid mixture; Diffusion: Fick‘s law, Kirkendall Effects, Atomic Model of Diffusion, Nernst-Einstein relation Phase Transformation: Nucleation, Growth and Overall Transformation Kinetics

Unit-II: Superconductivity (12 hrs.)

Superconductivity and its Occurrence, Meissner effect, Type I and type II Superconductors, London Equation, Coherence Length, Flux Quantization in a Superconducting Ring, Microscopic theory: Qualitative features of the BCS theory; Single Particle Tunneling; DC and AC Josephson Effects; High T_c Superconductors (introduction only).

Unit-III: Composite Materials (12 hrs.)

Agglomerated Composites, Cermets, Laminates, Reinforced Composite Materials, Classification of Reinforced Composite Materials, Flakes Composite, Whisker Reinforced Composites, Hybrid Composites, Sandwich Composites, Fiber-reinforced Glass and Glass-ceramic Composites, Polymer Concrete, Fiber Reinforced Concrete, Metal Matrix Composites and Wood Composites, Nanocomposites, Advantages and Limitations of Composites.

Unit-IV: Smart Materials (12 hrs.)

Introduction to Smart Materials, Principles of Piezoelectricty, Perovskite Piezoceramic Materials, Piezoelectric Polymers, Multiferroics and Magnetoelectrics, Smart Actuators, Principles of Magnetostriction, Rare earth Magnetostrictive materials, Giant Magnetostriction and Magneto-resistance Effect, Shape Memory Alloys.

REFERENCES:

1. J.C. Anderson, K.D. Leaver, P. Leevers and R.D. Rawlings, Materials Science for Engineers, CRC Press, London.
2. V. Raghavan, Materials Science and Engineering: A First Course, PHI Learning, New Delhi.
3. C. Kittel, Introduction to Solid State Physics, Wiley, India.
4. A.J. Dekker, Solid State Physics, Macmillan Press, London.
5. M. Tinkham, Introduction to Superconductivity, Dover Publication, New York.
6. W.D. Callister, Materials Science and Engineering : An Introduction, John Wiley, New York.
7. K.K. Chawla, Composite Materials: Science and Engineering, Springer, New York.
8. M. Balasubramaniam, Composite Materials and Processing, CRC Press, New York.
9. D. Hull and T.W. Clyne, Introduction to Composite Materials, Cambridge University Press, U.K.
10. I.A. Parinov, S.H. Chang and V.Y. Topolov, Advanced Materials: Manufacturing, Physics, Mechanics and Applications, Springer, New York.

M.Sc. PHYSICS SEMESTER-IV

SUBJECT NAME: VACUUM SCIENCE AND THIN FILMS TECHNOLOGY

MPM404

NO OF CREDITS: 4

L	P		
		SESSIONAL:	25
4	0	THEORY EXAM:	75
		TOTAL:	100

Note: The question paper will be of two parts. Part I will consist of 10 questions of 2 marks each. It should cover the entire syllabus. Part II will consist of six questions of 10 marks each out of which the student has to attempt any four.

COURSE OUTCOMES:

After successful completion of course on Material Science Lab, students will be able to:

MPM404.1 Understand the fundamentals of vacuum science & Technology

MPM404.2 Develop the knowledge of vacuum production and its measurement.

MPM404.3 Acquitant with various vacuum pumps and leak detection.

MPM404.4 Evolution and fundamentals of thin film technology

MPM404.5 Provide the knowledge about various methods of thin films deposition.

MPM404.6 Fabricate the thin films of materials via various techniques

COURSE OBJECTIVE: The course aims to acquaint the students with the understanding of fundamentals of vacuum technology and to learn the operational principles of different vacuum pumps. The course also targets to familiarize the students with some common techniques used in the fabrication of thin films.

UNIT–I: Vacuum Fundamentals and Its Production (12 hrs.)
Kinetic theory of gases, Mean free path, Mass flow, Pumping speed, Importance of Vacuum, Design, Principles, Construction, Operational Characteristics and the uses of Rotary pump, Roots pump, Turbomolecular pump, Diffusion pumps, Cryogenic-pump, Sputter-ion pump.

UNIT-II: Vacuum Measurement and Detection (12 hrs.)
Importance of measurement of Pressure, Concept of different gauges: McLeod gauge, thermal conductivity gauges, spin rotor gauge, Ionization gauges, hot

cathode, cold cathode gauges; Pirani, Penning and pressure control, Flow Meters and Residual Gas Analyzer, Leak Detection.

UNIT-III: Introduction and preparation of thin film (12 hrs.)
Environment for Thin Film Deposition, Evolution of Thin Film: Absorption (Physisorption), Surface Diffusion, Chemical Bond Formation (Chemisorption), Nucleation, Microstructure Formation, Deposition Parameters and their effects on Film Growth, Epitaxy–homo, hetero and coherent epilayers, lattice misfit and imperfections.

UNIT-IV: Thin Film Deposition techniques (12 hrs.)
Thermal evaporation, Electron beam evaporation, DC and RF Sputtering Technique: Bias sputtering, magnetically enhanced sputtering systems, reactive sputtering, Chemical Vapour Deposition (CVD), Pulsed Laser Deposition (PLD), Atomic layer deposition (ALD), Spin Coating, Spray pyrolysis, Molecular beam epitaxy.

REFERENCE BOOKS:

1. Vacuum Science and Engineering, CM Van Atta, Tata McGraw Hill, New York.
2. Vacuum Technology, Andrew Guthrie, Wiley, New York.
3. Vacuum Technology – An introduction by LG Carpenter
4. Thin Film Phenomenon, K. L. Chopra, McGraw Hill, New York.
5. Vacuum Physics and Techniques, T. A. Delchar, Chapman & Hall.

SPECIALIZATION-III: ELECTRONICS

M.Sc. PHYSICS III SEM

MPE303

SUBJECT NAME: ANALOG ELECTRONICS

NO OF CREDITS: 4

L	P		
		SESSIONAL:	25
		THEORY EXAM:	75
4	0	TOTAL:	100

Note: The question paper will be of two parts. Part I will consist of 10 questions of 1.5 marks each. It should cover the entire syllabus. Part II will consist of six questions of 15 marks each out of which the student has to attempt any four.

COURSE OUTCOMES: *After successfully completing of the course, students will be able to,*

MPE303.1 Describe and explain working of microwave tubes and solid state devices..

MPE303.2 Explain the operation of RADAR systems and recite their applications.

MPE303.3 Undetrstand various modulation and demodulation techniques.

MPE303.4 Learn the communication satellite mechanics

COURSE OBJECTIVE

The course introduces the students to concept of properties, generation, detection and application of microwave. Further analog signal communication and is use in satellite communication is also being introduced to the students.

UNIT –I Microwave Electronics (12 hrs)

Microwave characteristic features & applications, Waveguide and cavity resonators, Two cavities Klystron, Reflex Klystron, Gunn diode characteristics, microwave antenna, Detection of microwave, Dielectric constant measurement, Isolator and circulator, PIN diode modulator, Directional coupler, Avalanche Transit Time Devices: IMPATT Diode-Physical structure, Principle of operation, breakdown voltage, Avalanche and Drift region.

UNIT –II Radar Communication (12 hrs)

Basic Radar systems, Radar range equation and performance factor, Radar Cross-section, Pulsed Radar system, Duplexer, Radar display, Doppler Radar, CWIF Radar, FMCW Radar, Moving Target Indicator (MTI), Blind Speeds.

UNIT –III Analog Signal Transmission (12 hrs)

Introduction, Amplitude, Frequency & phase modulation; AM, FM modulating and demodulating circuits; AM, FM Receivers functioning (Block Diagram) and characteristic features; Pulse modulation; Sampling Processes, PAM, PWM and PPM modulation and demodulation, Quantization noise, PCM, Differential PCM and Delta modulation systems, Comparison of PCM and PDM, Time division multiplexing.

UNIT –IV Satellite Communication (12 hrs)

Principle of Satellite communication, Satellite frequency allocation and band spectrum, Satellite orbit, trajectory and its stability, Satellite link Design, Elements of Digital Satellite Communication, Multiple Access Technique, Antenna system, Transponder, Satellite Applications.

REFERENCE BOOKS:

1. Digital and Analog Communication Systems : K. San Shanmugam, John Wiley and Sons.
2. Communication Systems : Simon Haykin, John Wiley and Sons
3. Principles of Communication System, H. Taub and D.L. Schilling, TMH
4. Electronic Communication System, G. Kennedy, B. Davis and S.R.M. Prasanna, TMH
5. Microwave and Radar Engineering : M.Kulkarni.
6. Satellite Communication : Pratt and Bosterin.
7. Microwave : K.C. Gupta.

M.Sc. PHYSICS SEMESTER-III

MPE 304

SUBJECT NAME: MICROPROCESSOR

NO OF CREDITS: 4

L	P		
		SESSIONAL:	25
		THEORY EXAM:	75
4	0	TOTAL:	100

Note: The question paper will be of two parts. Part I will consist of 10 questions of 2 marks each. It should cover the entire syllabus. Part II will consist of six questions of 10 marks each out of which the student has to attempt any four.

COURSE OUTCOMES:

After successful completion of the course, student shall be able to

MPE304.1 Understand the basics of microprocessor and 8085 microprocessor.

MPE304.2 Understand of the Intel 8086 architecture. Knowledge of the 8086 instruction set and ability to utilize it in programming.

MPE304.3 Learn addressing modes (Immediate, direct, extended, indexed modes).

MPE304.4 Understand the Intel 8086 real mode memory addressing.

MPE304.5 Ability to interface various devices to the microprocessor. Introduction to the microcontroller.

COURSE OBJECTIVE

The objective of this course is to familiarize the students with the architecture and the instruction set of an Intel microprocessor 8086. Assembly language programming will be studied as well as the design of various types of digital and analog interfaces. The student will be able to draw a block diagram of a simple computer consisting of a processor, RAM and ROM memory, ports, and the buses that interconnect these components

UNIT I : Introduction to Microprocessor and 8085 Microprocessor (12hrs)

Microprocessor evolution and types, Architecture, Microprocessor and computer languages: machine language, assembly language and high level language, advantage of assembly language, introduction to 8085 microprocessor, internal architecture, Timing and control unit, registers, data and address bus, status flags, pin configuration, Applications of microprocessors.

UNIT II: 8086 Microprocessor (12hrs)

Introduction to 8086, overview of 8086 microprocessor family, 8086 internal Architecture, stack segment register, stack pointer registers, Accessing data in memory, Introduction to programming for 8086 microprocessor, program development steps, constructing the machine code for 8086 instructions, assembly language program development tools, writing simple program for use with an assembler.

UNIT III: 8086 Microprocessor System Hardware (12hrs)

Basic 8086 microcomputer system, pin diagram of 8086, minimum and maximum modes, timing diagram, physical memory organization, addressing memory (RAM, ROM) and ports in microcomputer system, 8086 addressing and addressing decoding, programmable parallel ports and handshake input and output, 8255 A internal block diagram, 8255 A operational modes and initialization, pin diagram of 8255 A

UNIT IV: Digital interfacing (12hrs)

Interfacing to keyboards, alphanumeric displays, interfacing microcomputer ports to high power devices Direct Memory Access (DMA) Data Transfer, Timing diagram of 8237 DMA, brief introduction of microcontroller, difference between microprocessor and microcontroller, pin diagram of 8051 microcontroller.

REFERENCE BOOKS:

1. Liu and Gibson: Microprocessor System the 8086 / 8088 Family
2. D.V. Hall: Microprocessor and Interfacing, 3rd edition, McGraw-Hill Education - Europe
3. B. Ram: Fundamentals of Microprocessor, Dhanpat Rai Publications

M.Sc. PHYSICS SEMESTER-III

MPE305

SUBJECT NAME: ELECTRONICS SPECIALIZATION LAB

CREDIT: 8

L	P		
		SESSIONAL:	30
L	P	END SEM EXAM:	70
0	16	TOTAL:	100

COURSE OUTCOME:

After successful completion of this course, students should be able to:

MPE305.1 understand the operation and design of digital system.

MPE305.2 work on microprocessor, interfacing & programming on pc.

MPE305.3 Have practical knowledge and develop skill in digital system & microprocessor.

MPE305.4 Have working knowledge of microwave test bench & measurements.

MPE305.5 Understand modulation and demodulation

COURSE OBJECTIVE: To provide practical knowledge and develop skill in digital system & microprocessor, the practical knowledge of microwave test bench & measurement, modulation and demodulation.

Students assigned the laboratory work will perform at least 8 experiments of the following:

1. Microwave Characteristics and Measurements.
2. Nonlinear Applications of Op Amp.
3. PLL Characteristics and its Applications.
4. PAM, PWM and PPM Modulation and Demodulation

5. PCM / Delta Modulation and Demodulation.
6. Fibre Optic Communication.
7. Arithmetic Operations Using Microprocessors 8085 / 8086.
8. D/A Converter Interfacing and Frequency / Temperature Measurement with Microprocessor 8085 / 8086.
9. A/D Converter Interfacing and AC/DC Voltage / Current Measurement using Microprocessor 8085/8086.
10. PPI 8251 Interfacing with Microprocessor for Serial Communication.
11. Assembly Language Program on PC
12. Resonant circuits
13. Filters: Active and passive (All pass)
14. Power supply regulation and stabilisation
15. Oscillator : design and study
16. Multivibrator: astable, monostable, bistable
17. Design and study of triangular wave generator.

Note: Addition and deletion in the list of experiments may be made from time to time by the department.

M.Sc. PHYSICS SEMESTER-IV

MPE403

SUBJECT NAME: DIGITAL ELECTRONICS

NO OF CREDITS: 4

		SESSIONAL:	25
L	P	THEORY EXAM:	75
4	0	TOTAL:	100

Note: The question paper will be of two parts. Part I will consist of 10 questions of 1.5 marks each. It should cover the entire syllabus. Part II will consist of six questions of 15 marks each out of which the student has to attempt any four.

Course Outcomes (COs)

After successful completion of the course on Digital Electronics, a student will be able to:

MPE403.1 Understand mathematical description and representation of discrete and continuous time signal and systems.

MPE403.2 Understand the basics of information and coding theories.

MPE403.3 Understand the signal flow in digital communication system.

MPE403.4 Understand basic elements of optical fiber transmission, fiber modes and various optical detectors.

UNIT - I Signals, System and Noise (12 hrs)

Basics Elements of Communication Systems, Fourier Representation of Periodic and Non-Periodic Signals, Impulse And Step Response of Systems, Time and Frequency Domain Analysis of Systems, Ideal and Real Filters, Noise in Communication Systems, Signal To Noise Ratio, Noise Equivalent Bandwidth and Noise Figure.

UNIT – II Information Technology and Coding (12 hrs)

Introduction, Amount of Information, Average Information, Shannon Encoding Algorithm, Communication Channels, Rate of Information And Capacity of Discrete Memory less Channels, Shanon-Hartley Theorem. Linear Block Cyclic Codes.

UNIT – III Digital Signal (Data) Transmission (12 hrs)

Introduction, Optimum Receiver For Binary Digital Modulation Schemes, Binary ASK, Binary FSK, Binary PSK And Differential PSK Signaling Schemes, Serial Data Communication in Computers USART 8251, Basics Communication Networks(LAN,WAN,MAN) And Its Topology

UNIT – IV Fibre Optic Communication (12 hrs)

Basic Optical Communication System, Wave Propagation in Optical Fibre Media, Step and Graded Index Fiber, Material Dispersion And Mode Propagation, Losses in Fibre, Optical Fibre Sources (LEDs and LASERs) And Detectors (PIN Photodiode, APD Photodiode), Optical Joints And Couplers

REFERENCE BOOKS:

1. Digital and Analog Communication Systems: K. San Shanmugam.
2. Communication Systems: Simon Haykin.
3. Optical Fibre Communication: Kaiser.

M.Sc. PHYSICS SEMESTER-IV

MPE404

SUBJECT NAME: OPTICAL FIBER COMMUNICATION

NO OF CREDITS: 4

		SESSIONAL:	25
L	P	THEORY EXAM:	75
4	0	TOTAL:	100

Note: The question paper will be of two parts. Part I will consist of 10 questions of 1.5 marks each. It should cover the entire syllabus. Part II will consist of six questions of 15 marks each out of which the student has to attempt any four.

Course Outcomes: *After the successful completion of the course, students will be able to*

MPE 404.1: Understand optical fiber waveguides and their applications.

MPE 404.2: Comprehend the use of input/output devices in optical fiber communication.

MPE 404.3 Understand the transmission characteristics of optical fibers.

MPE 404.4 Develop a clear understanding of optical fiber communication, fiber technology and Sensor devices.

MPE 404.5 Analyse the difference between different optical sources.

MPE 404.6 Construct designs for PCFs, OFCSD.

Unit I : Optical Fiber Waveguides (12hrs)

Introduction: Principle of Light Transmission in a fiber, Ray theory transmission, Total Internal Reflection, Numerical Aperture, Skew rays and meridional rays: Electromagnetic mode theory for optical propagation: Modes in a planar waveguide, Group velocity and phase velocity, group index; Fiber index profiles: multi-mode step-index fibers, multi-mode graded index fibers, single mode step index fibers; Photonic Crystal fibers: Index guiding micro-structures and Photonic Band gap fibers.

Unit II: Input / Output Devices (12hrs)

Optical sources; the Laser, Basic concepts, Absorption and Emission of radiation, Einstein's coefficients, semiconductor laser, light emitting diode, the semiconductor junction diode; non-semiconductor lasers: Nd:Yag laser, Ruby laser He-Ne laser; Optical detectors: principle, important parameters of ODs, Absorption coefficient, Quantum efficiency efficiency and responsivity, long wavelength cut-off; semiconductor photodiodes without internal gain: pn photo diode, PIN photodiode; semiconductor photodiodes with internal gain; Avalanche Photo diode

Unit III: Transmission characteristics of Optical Fibers (12hrs)

Attenuation, Material absorption losses in optical fibers; Intrinsic and Extrinsic absorption losses, fiber bend losses, linear scattering losses, Rayleigh scattering, Mie scattering, non-linear scattering losses: Stimulated Brillouin Scattering (SBS), Stimulated Raman Scattering (SRS), Dispersion: Chromatic dispersion, Material dispersion, Wave guide dispersion, inter-modal dispersion in Multimode step index fibers and graded index fibers, Intra-modal dispersion, modal noise.

Unit IV : Fiber Technology, Characterization and Optical Communication (12hrs)

Fiber materials, glass fibers, active glass fibers, plastic clad fibers, plastic optical fibers (POF), Preparation of optical fibers, Fiber fabrication: Liquid phase melting techniques, fiber drawing Outside Vapor- phase oxidation, Vapor-phase Axial deposition, modified chemical vapor deposition, Plasma activated chemical vapor deposition; Principle components of an Optical Fiber Communication System: optical sources, optical detectors, optical amplifier, fiber couplers, directional couplers, Elementary idea of Optical Fiber Sensors

REFERENCE BOOKS:

1. Ghatak and Thyagrajan: Introduction to Fiber Optics: Cambridge University Press
2. Keiser: Optical Fiber Communication: McGraw Hill Education, edition 2017
3. Gowar: Optical Communication System; Prentice Hall International
4. Sapna Katiyar: Optical Fiber Communication: S.K. Kataria and Sons, 2013
5. Senior: Optical Fiber Communication: Principles and Practices: Pearson, Edition 3, 2010

AUDIT COURSE

APH101

SUBJECT NAME: RENEWABLE ENERGY RESOURCES

NO OF CREDITS: 2

L	P			
			SESSIONAL:	25
L	P		THEORY EXAM:	75
2	0		TOTAL:	100

Note: The question paper will be of two parts. Part I will consist of 10 questions of 1.5 marks each. It should cover the entire syllabus. Part II will consist of six questions of 15 marks each out of which the student has to attempt any four.

COURSE OUTCOMES (COs)

After the successful completion of the course, the students will be able to:

APH 101.1: Learn the importance of alternate energy sources.

APH 101.2 : Understand the fundamentals of renewable energy resources.

APH 101.3 : Understand the principles of solar energy and its environmental impact.

APH 101.4 : Learn the basics of solar energy collection and storage.

APH 101.5 : Study the basics of wind energy and geothermal energy.

APH 101.6 : Comprehend the use of ocean energy as an alternate source of energy.

UNIT I: Principles of Solar radiation

Limitation of conventional energy sources, need and growth of alternative energy sources, basic scheme and application of direct energy conservation, Role and potential of new and renewable source, the solar energy option, Environmental impact of solar power, physics of the sun, the solar constant, extraterrestrial and terrestrial solar radiation, solar radiation on titled surface, instruments for measuring solar radiation and sun shine, solar radiation data.

UNIT II: Solar Energy Collection, storage and applications

Flat plate and concentrating collectors, classification of concentrating collectors, orientation and thermal analysis, advanced collectors; Different methods of storage: Sensible, latent heat and stratified storage, solar ponds. Solar Applications- solar heating/cooling technique, solar distillation and drying, photovoltaic energy conversion.

UNIT III: Wind Energy and Geothermal Energy

Wind energy: Sources and potentials, horizontal and vertical axis windmills, performance characteristics, Betz criteria; Geothermal energy: Resources, types of wells, methods of harnessing the energy, potential in India.

UNIT IV: Ocean Energy

OTEC, Principles utilization, setting of OTEC plants, thermodynamic cycles. Tidal and wave energy: Potential and conversion techniques, mini-hydel power plants, and their economics.

REFERENCE BOOKS:

1. Renewable energy resources/ Tiwari and Ghosal/ Narosa.

2. Renewable Energy Technologies /Ramesh & Kumar /Narosa

3. Non-Conventional Energy Systems / K Mittal /Wheeler

4. Renewable energy sources and emerging technologies by D.P.Kothari,K.C.Singhal, P.H.I.

5. Non-Conventional Energy Sources /G.D. Rai, Khanna Publishers

6. Renewable Energy Resources – Twidell & Wier, CRC Press(Taylor & Francis)

OPEN ELECTIVE COURSE

OPH101

SUBJECT NAME: INTRODUCTION TO ASTROPHYSICS AND COSMOLOGY

NO OF CREDITS: 3

		SESSIONAL:	25
L	P	THEORY EXAM:	75
3	0	TOTAL:	100

Note: The question paper will be of two parts. Part I will consist of 10 questions of 1.5 marks each. It should cover the entire syllabus. Part II will consist of six questions of 15 marks each out of which the student has to attempt any four.

COURSE OUTCOMES (COs):

After the successful completion of the course, the students will be able to:

OPH 101.1 : Understand how the properties of astronomical objects and the Universe relate to simple physical laws and processes

OPH 101.2 : Understand the role and physics of detectors and telescopes including geometric optics and understand how distances are measured.

OPH 101.3 : Know how basic laws of physics determine the properties and evolution of stars.

OPH 101.4 : Know Kepler's Laws and how they relate to extrasolar planet detection.

OPH 101.5 : Construct the dynamics of galaxies, the presence of dark matter

OPH 101.6 : Understand the evolution of our Universe.

UNIT I :The Universe and its physics

A tour of the Universe, its scale and contents; Gravity; Pressure; Radiation Observational astronomy**:** the electromagnetic spectrum; Geometrical optics; resolving power, and the diffraction limit; telescopes and detectors; gravitational waves; Distances**:** parallax measurements, standard candles

UNIT II: Physics of the Sun and Stars

Blackbody radiation, Planck, Stefan-Boltzmann and Wien laws, Effective temperature, interstellar reddening; hydrogen spectral lines and Doppler effect; Hertzprung-Russell diagram; Freefall and Kelvin-Helmholtz time; nuclear fusion; basic stellar structure (hydrostatic equilibrium, equation of state); white dwarfs, neutron stars and black holes

UNIT III: Planetary systems:

Kepler's laws; Detection methods of extrasolar planets; search for life elsewhere.

UNIT IV: Star formation:

The interstellar medium; stellar populations; the interstellar medium; galaxy rotation curves, mass and dark matter; Galaxy collisions; central engines; Cosmology**:**Olber's paradox, Hubble's Law; the age of the Universe; Evolution of the Universe: Madau diagram; Evidence for the Big Bang (blackbody radiation, nucleosynthesis); dark energy and the accelerating Universe.

REFERENCES:

1. Carroll, B.W. & Ostlie, D.A., *An Introduction to Modern Astrophysics* (Pearson)

OPEN ELECTIVE COURSE

OPH102

SUBJECT NAME: ENERGY HARVESTING AND STORAGE DEVICES

NO OF CREDITS: 3

		SESSIONAL:	25
L	P	THEORY EXAM:	75
3	0	TOTAL:	100

Note: The question paper will be of two parts. Part I will consist of 10 questions of 1.5 marks each. It should cover the entire syllabus. Part II will consist of six questions of 15 marks each out of which the student has to attempt any four.

COURSE OUTCOMES (COs):

After the successful completion of this course, the students will be able to:

OPH 102.1:Understand the use of nanomaterials in energy generation and storage devices.
OPH 102.2: Exhibit understanding of the sources of energy and the methods of energy conversion and storage.
OPH 102.3 :Comprehend the principles behind energy storage mechanisms.

OPH 102.4 :Gain a broad understanding of concepts and applications of Solar and renewable energy.
OPH 102.5 Design and fabricate solar cells, hydroelectric cells and electrochemical storage devices.
OPH 102.6 Fabricate energy storage devices e.g. Supercapacitors and Batteries.

UNIT-I: Introduction

Energy challenges, Energy consummation, Current sources of energy, Status of energy map, Energy policies, Conservation of energy, Alternative energy sources, Development and implementation of renewable energy technologies, role of renewable energy sources, Energy transport, conversion and storage, Sustainable Energy.

UNIT-II: Solar Energy

Fundamentals of solar cells, Types of solar cells, Photovoltaic effect, Semiconducting materials bandgap theory, Band gap engineering, Solar cell properties and design, p-n junction, Photodiodes, electron and hole transports, charge carrier generation, recombination, I-V characteristics, Tandem structure, Single junction and triple-junction, solar panels, thin film solar cells, solar cell applications, solar cell manufacturing process.

UNIT-III: Thermoelectric, Piezoelectric and Hydroelectric Energy

Thermoelectric and Piezoelectric materials, Fabrication and characterization of thermoelectric devices, Bulk thermoelectric materials performance, Thermoelectric modules, Piezoelectric harvester design, Micro and nanoscale energy harvesting, Fabrication and characterization of piezoelectric devices, Principal and working of Hydroelectric cell, Future prospects of Hydroelectric cell.

UNIT-IV: Electrochemical Energy Storage Devices

Primary and secondary cells, Chemistry and material used for various components (electrode, electrolytes, separator and binders) of different types of batteries: Ni-Hydrogen battery, Sodium-sulfur battery, Lithium-ion/Lithium-polymer battery, Metal-air batteries and its applications., Fundamentals of Electrochemical supercapacitors,, Electrostatic Double Layer Capacitor, Pseudocapacitor, Fabrication of Hybrid supercapacitor, Electrode and electrolytes interfaces and their capacitances, Charge-Discharge characteristics, Energy and Power density, Design, Fabrication and operation, Future prospects of batteries and supercapacitors.

REFERENCE BOOKS

1. Energy for a sustainable world by L. Freris, D. Infield, Wiley, 2008.
2. Nanomaterials for Sustainable Energy by Quan (Ed.), Springer, 2016.
3. Nanomaterials in Energy Devices by Jun Hieng Kait CRC Press, 2017.
4. Advanced nanomaterials and their applications in renewable energy by J. Louise, L. S. Bashir, 2015.
5. Energy Storage and Conversion Devices: Supercapacitors, Batteries, and Hydroelectric Cells by A. Gaur, AL Sharma, A Arya, CRC Press Taylor & Francis Group, 2021.

MODE OF TRANSACTION: Lecture, demonstration, E-tutoring, discussion, assignments, quizzes, case study, power point; **LMS/ICT Tools:** Digital Classrooms, DLMS, ZOOM, G-Suite, MS Power-Point, Online Resources.

Mapping: Mapping is a process of representing the correlation between COs and POs, Cos and PSOs in the scale of 1 to 3 as follows (Table-1)

Table -1: Scale of mapping between COs and POs

Scale	Correlation Type
1	**If the content of the course have low correlation (i.e. in agreement with the particular PO to a small extent) with the particular program outcome.**
2	**If the contents of course have medium correlation (i.e. in agreement with the particular PO to a reasonable extent) with the particular program outcome.**

3	**If the contents of course have strong correlation (i.e. in agreement with the particular PO to a large extent) with the particular program outcome.**

CO-PO matrix for the course MPH101 (Mathematical Physics)

COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PSO1**	**PSO2**	**PSO3**	**PSO4**	**PSO5**
MPH 101.1	3	2	2	3	2	3	3	3	3	2	3	3	2	1	2	2
MPH101.2	3	2	2	3	2	3	3	3	3	2	3	3	1	1	3	3
MPH101.3	3	2	2	3	2	3	3	3	3	2	2	3	2	1	2	2
MPH101.4	3	2	2	3	2	3	3	3	3	2	3	3	2	1	2	3
MPH101.5	3	2	2	3	2	3	3	3	3	2	3	3	2	1	2	3
Average	3	2	2	3	2	3	3	3	3	2	3	3	2	1	2.2	2.8

CO-PO matrix for the course MPH102 (Classical Mechanics)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
MPH 102.1	3	2	2	3	3	3	2	3	3	3	3	3	3	3	3	2
MPH 102.2	3	3	2	3	3	3	2	3	2	2	3	3	2	2	3	3
MPH 102.3	3	3	2	3	3	3	2	3	3	3	2	3	2	2	3	2
MPH 102.4	3	3	2	3	2	3	3	3	3	3	3	3	2	1	2	2
MPH 102.5	3	3	1	3	2	3	2	2	2	3	2	3	2	1	3	2
MPH 102.6	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3
Average	3	2.83	2	3	2.67	3	2.33	2.83	2.67	2.83	2.67	3	2.33	1.83	2.83	2.33

<u>CO-PO matrix for the course MPH103 (Quantum Mechanics-I)</u>

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
MPH103.1	3	3	2	3	3	3	2	3	3	3	3	3	2	2	3	2
MPH103.2	3	3	3	3	3	3	2	3	3	3	2	3	2	2	3	2
MPH103.3	3	3	3	3	3	3	2	2	3	2	2	3	1	1	2	2
MPH103.4	3	2	2	3	3	3	3	2	2	3	3	3	2	2	3	3
MPH103.5	3	3	3	2	2	3	2	2	2	2	2	3	3	2	3	2
MPH103.6	3	3	2	3	2	3	2	3	3	3	2	3	3	3	3	3
Average	3	2.83	2.5	2.83	2.67	3	2.17	2.5	2.67	2.67	2.34	3	2.167	2	2.83	2.33

<u>CO-PO matrix for the course MPH105 (Physics Lab I)</u>

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
MPH102.1	3	2	2	3	3	3	2	3	3	3	3	3	3	3	3	2
MPH102.2	3	3	2	3	3	3	2	3	2	2	3	3	2	2	3	3
MPH102.3	3	3	2	3	3	3	2	3	3	3	2	3	2	2	3	2

MPH102.4	3	3	2	3	2	3	3	3	3	3	3	3	2	1	2	2
MPH02.5	3	3	1	3	2	3	2	2	2	3	2	3	2	1	3	2
MP 102.6	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3
Average	3	2.83	2	3	2.67	3	2.33	2.83	2.67	2.83	2.67	3	2.33	1.83	2.83	2.33

CO-PO matrix for the course MPH201 (Quantum Mechanics-II)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
MPH201.1	3	2	2	3	3	3	2	3	2	2	2	3	2	2	3	2
MPH201.2	3	3	3	3	3	3	2	3	3	3	3	3	2	2	3	2
MPH201.3	3	3	3	2	2	3	3	3	2	2	2	3	1	1	2	2
MPH201.4	3	2	3	2	2	3	3	2	3	3	2	3	2	2	3	3
MPH201.5	3	1	2	3	3	3	2	3	2	2	3	3	3	2	3	2
MPH201.6	3	2	3	2	3	3	2	2	2	3	2	3	3	3	3	3
Average	3	2.17	2.67	2.5	2.67	3	2.34	2.67	2.34	2.5	2.34	3	2.167	2	2.83	2.33

CO-PO matrix for the course MPH202 (Nuclear and Particle Physics)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
MPH202.1	3	3	3	3	3	3	2	3	3	2	3	3	3	2	3	3
MPH202.2	3	3	3	3	2	3	2	3	3	2	3	3	3	3	3	3
MPH202.3	3	3	3	3	2	3	2	2	3	2	2	3	3	3	3	3
MPH202.4	3	3	3	3	2	3	2	2	3	2	2	3	3	3	3	3
MPH202.5	3	3	2	3	2	3	2	2	3	2	3	3	3	3	2	2
MPH202.6	3	3	2	3	2	3	2	2	3	2	2	3	3	3	2	2
MPH202.7	3	3	2	3	2	3	2	2	3	2	2	3	2	2	2	2

MPH202.8	3	3	2	3	1	3	2	2	3	2	1	3	2	2	3	2
Average	3	3	2.5	3	2	3	2	2.25	3	2	2.25	3	2.75	2.63	2.63	2.5

CO-PO matrix for the course MPH 203 (Solid State Physics)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
MPH203.1	3	3	1	3	2	3	2	1	1	2	2	3	2	1	2	2
MPH203.2	3	3	1	3	2	3	2	1	1	2	1	3	2	1	3	3
MPH203.3	3	3	1	2	2	3	2	1	1	2	2	3	2	1	2	2
MPH203.4	3	2	1	2	2	2	2	1	1	2	1	3	2	1	2	3
MPH203.5	3	3	1	3	2	3	2	1	1	2	2	3	2	1	2	3
MPH203.6	3	2	1	2	2	2	2	1	1	2	1	3	2	1	2	3
Average	3	2.66	1	2.5	2	2.66	2	1	1	2	1.5	3	2	1	2	3

CO-PO matrix for the course MPH204 (Electrodynamics)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
MPH204.1	3	2	2	3	2	3	3	3	3	2	3	3	2	1	2	2
MPH204.2	3	2	2	3	2	3	3	3	3	2	3	3	2	1	3	3
MPH204.3	3	2	2	3	2	3	3	3	3	2	2	3	2	1	2	2
MPH204.4	3	2	2	3	2	3	3	3	3	2	3	3	2	1	2	3
MPH204.5	3	2	2	3	2	3	3	3	3	2	3	3	2	1	2	3
MPH204.6	3	2	2	3	2	3	3	3	3	2	3	3	2	1	2	3
Average	3	2	2	3	2	3	3	3	3	2	3	3	2	1	2	3

CO-PO matrix for the course MPH205 (Physics Lab II)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
MPH205.1	3	2	3	3	3	3	3	2	3	3	2	3	3	2	3	3
MPH205.2	3	2	3	3	3	3	3	3	3	3	2	3	3	3	3	3
MPH205.3	3	3	3	2	2	2	2	2	3	3	2	3	3	3	3	3
MPH205.4	3	2	3	3	3	3	3	3	3	3	2	3	3	3	3	3
MPH205.5	3	2	3	3	3	3	3	3	3	3	3	3	3	3	2	2
MPH205.6	3	3	3	2	2	2	3	2	3	3	2	3	3	3	2	2
MPH205.7	3	2	3	3	3	3	3	3	3	3	2	3	2	2	2	2
MPH205.8	3	3	3	2	2	3	2	3	3	3	2	3	2	2	3	2
Average	3	2.37	3	2.62	2.62	2.75	2.75	2.75	3	3	2.12	3	2.75	2.63	2.63	2.5

CO-POs matrix for the course MPH 301 (Atomic and Molecular Physics)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
MPH301.1	3	3	3	3	3	3	2	3	2	2	2	2	2	2	2	2
MPH301.2	3	3	3	3	3	3	2	3	2	3	3	2	2	1	3	2
MPH301.3	3	3	3	3	3	3	2	3	2	3	2	2	3	2	3	3
MPH301.4	3	3	3	2	3	3	3	3	2	2	1	2	3	1	2	2
MPH301.5	3	2	3	3	3	2	3	2	1	2	2	3	2	1	2	3
MPH301.6	3	3	3	3	3	2	3	3	2	2	1	2	3	2	2	2

Average	3	2.83	3	2.83	3	2.66	2.5	2.83	1.83	2.5	1.83	2.16	2.5	1.5	2.33	2.33

<u>CO-PO matrix for the course MPH302 (Statistical Mechanics)</u>

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
MPH302.1	3	3	3	3	3	3	2	3	3	2	3	3	3	2	3	3
MPH302.2	3	3	3	3	2	3	2	3	3	2	3	3	3	3	3	3
MPH302.3	3	3	3	3	2	3	2	2	3	2	2	3	3	3	3	3
MPH302.4	3	3	3	3	2	3	2	2	3	2	2	3	3	3	3	3
MPH302.5	3	3	2	3	2	3	2	2	3	2	3	3	3	3	2	2
MPH302.6	3	3	2	3	2	3	2	2	3	2	2	3	3	3	2	2
MPH302.7	3	3	2	3	2	3	2	2	3	2	2	3	2	2	2	2
MPH302.8	3	3	2	3	1	3	2	2	3	2	1	3	2	2	3	2
Average	3	3	2.5	3	2	3	2	2.25	3	2	2.25	3	2.75	2.63	2.63	2.5

<u>CO-PO matrix for the course MPH401 (Laser Technology)</u>

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
MPH401.1	3	3	3	3	3	3	2	3	3	2	3	3	3	2	3	3
MPH401.2	3	3	3	3	2	3	2	3	3	2	3	3	3	3	3	3
MPH401.3	3	3	3	3	2	3	2	2	3	2	2	3	3	3	3	3
MPH401.4	3	3	3	3	2	3	2	2	3	2	2	3	3	3	3	3
MPH401.5	3	3	2	3	2	3	2	2	3	2	3	3	3	3	2	2
MPH401.6	3	3	2	3	2	3	2	2	3	2	2	3	3	3	2	2
MPH401.7	3	3	2	3	2	3	2	2	3	2	2	3	2	2	2	2

MPH401.8	3	3	2	3	1	3	2	2	3	2	1	3	2	2	3	2
Average	3	3	2.5	3	2	3	2	2.25	3	2	2.25	3	2.75	2.63	2.63	2.5

CO-PO matrix for the course MPH402 (Materials Science)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
MPH402.1	3	2	-	1	-	1	1	-	-	-	1	3	3	2	3	3
MPH402.2	3	2	1	2	1	2	1	1	1	-	1	3	3	3	3	3
MPH402.3	3	2	-	1	-	1	1	-	-	-	1	3	3	3	3	3
MPH402.4	3	2	-	2	-	2	1	-	1	-	1	3	3	3	3	3
MPH402.5	3	2	-	1	-	1	1	-	-	-	1	3	3	3	2	2
MPH402.6	3	3	1	3	1	3	1	1	2	-	2	3	3	3	2	2
MPH402.7	2	3	1	3	1	3	1	1	2	-	2	3	2	2	2	2
MPH402.8	1	3	-	3	2	3	1	2	2	-	3	3	2	2	3	2
Average	2.625	2.375	1	2	1.25	2	1	1.25	1.6	-	1.5	3	2.75	2.63	2.63	2.5

CO-PO matrix for the course MPN303 (Nuclear Reactions)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
MPN303.1	3	2	-	1	-	1	1	-	-	-	1	3	2	-	3	1
MPN303.2	3	2	1	2	1	2	1	1	1	-	1	3	3	-	3	1
MPN303.3	3	2	-	1	-	1	1	-	-	-	1	3	3	-	2	1
MPN303.4	3	2	-	2	-	2	1	-	1	-	1	3	3	-	3	1
MPN303.5	3	2	-	1	-	1	1	-	-	-	1	3	2	-	3	1
MPN303.6	3	3	1	3	1	3	1	1	2	-	2	3	3	-	3	1
MPN303.7	2	3	1	3	1	3	1	1	2	-	2	3	3	-	3	1

MPN303.8	1	3	-	3	2	3	1	2	2	-	3	3	3	-	3	1
Average	2.625	2.375	1	2	1.25	2	1	1.25	1.6	-	1.5	3	2.75	-	2.875	1

CO-PO matrix for the course MPN304 (Nuclear Detectors)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
MPN304.1	3	2	-	1	-	1	1	-	-	-	1	3	2	-	1	3
MPN304.2	3	3	1	3	1	3	1	1	2	-	2	3	3	1	3	3
MPN304.3	3	2	-	2	-	2	-	-	2	-	2	3	3	-	2	3
MPN304.4	3	2	-	1	-	2	-	-	1	-	1	3	3	1	3	3
MPN304.5	3	3	-	3	1	3	1	2	2	1	2	3	2	-	2	3
MPN304.6	1	3	-	3	1	3	1	3	3	1	3	3	3	1	3	3
MPN304.7	3	3	-	2	1	2	1	2	2	1	2	3	3	-	3	3
MPN304.8	1	3	-	3	1	3	1	3	3	1	3	3	3	1	3	3
Average	2.5	2.625	1	2.25	1	2.375	1	2.2	2.143	1	2	3	2.75	0.5	2.5	3

CO-PO matrix for the course MPN305 (Nuclear Physics Specialization Lab)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
MPN305.1	3	2	-	1	-	1	1	-	-	-	1	3	2	3	2	3
MPN305.2	3	3	1	3	1	3	1	1	2	-	2	3	3	3	3	3
MPN305.3	3	2	-	2	-	2	-	-	2	-	2	3	3	3	2	3
MPN305.4	3	2	-	1	-	2	-	-	1	-	1	3	3	3	3	3
MPN305.5	3	3	-	3	1	3	1	2	2	1	2	3	2	3	2	3
MPN305.6	1	3	-	3	1	3	1	3	3	1	3	3	3	3	3	3

MPN305.7	3	3	-	2	1	2	1	2	2	1	2	3	3	3	3	3
MPN305.8	1	3	-	3	1	3	1	3	3	1	3	3	3	3	3	3
Average	2.5	2.625	1	2.25	1	2.375	1	2.2	2.143	1	2	3	2.75	3	2.625	3

CO-PO matrix for the course MPN403 (Nuclear Models and Astro Physics)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
MPN403.1	3	3	3	3	3	3	3	3	2	2	2	3	3	2	3	3
MPN403.2	3	3	3	3	3	3	3	3	2	2	2	3	3	2	3	3
MPN403.3	3	3	3	3	3	2	3	2	2	2	2	3	3	2	3	3
MPN403.4	3	3	3	3	3	2	2	2	2	2	2	3	3	2	3	3
MPN403.5	3	3	3	3	3	2	2	2	2	2	2	3	3	2	3	3
MPN403.6	3	3	3	3	3	2	2	2	2	2	2	3	3	2	3	3
MPN403.7	3	3	3	3	3	2	2	2	2	2	2	3	3	2	3	3
MPN403.8	3	3	3	3	3	1	2	2	2	2	2	3	3	2	3	3
Average	3	3	3	3	3	2.12	2.37	2.25	2	2	2	3	3	2	3	3

CO-PO matrix for the course MPN404 (Nuclear Techniques and Neutron Physics)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
MPN404.1	3	3	3	3	3	3	3	3	2	2	2	3	3	2	3	3
MPN404.2	3	3	3	3	3	3	3	3	2	2	2	3	3	2	3	3
MPN404.3	3	3	3	3	3	2	3	2	2	2	2	3	3	2	3	3
MPN404.4	3	3	3	3	3	2	2	2	2	2	2	3	3	2	3	3
MPN404.5	3	3	3	3	3	2	2	2	2	2	2	3	3	2	3	3

MPN404.6	3	3	3	3	3	2	2	2	2	2	2	3	3	2	3	3
MPN404.7	3	3	3	3	3	2	2	2	2	2	2	3	3	2	3	3
MPN404.8	3	3	3	3	3	1	2	2	2	2	2	3	3	2	3	3
Average	3	3	3	3	3	2.12	2.37	2.25	2	2	2	3	3	2	3	3

CO-PO matrix for the course MPM303 (Materials Science)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
MPM303.1	3	2	-	1	-	1	1	-	-	-	1	3	2	-	1	3
MPM303.2	3	3	1	3	1	3	1	1	2	-	2	3	3	-	3	3
MPM303.3	3	2	-	2	-	2	-	-	2	-	2	3	3	-	2	3
MPM303.4	3	2	-	1	-	2	-	-	1	-	1	3	3	-	3	3
MPM303.5	3	3	-	3	1	3	1	2	2	1	2	3	2	-	2	3
MPM303.6	1	3	-	3	1	3	1	3	3	1	3	3	3	-	3	3
MPM303.7	3	3	-	2	1	2	1	2	2	1	2	3	3	-	3	3
MPM303.8	1	3	-	3	1	3	1	3	3	1	3	3	3	-	3	3
Average	2.5	2.625	1	2.25	1	2.375	1	2.2	2.143	1	2	3	2.75	-	2.5	3

CO-PO matrix for the course MPM304 (Fundamentals and Synthesis of Nanomaterials)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
MPM304.1	3	2	3	3	2	3	2	3	3	2	2	3	3	2	3	3
MPM304.2	3	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3
MPM304.3	3	3	3	3	3	3	2	3	3	2	3	3	3	2	3	3
MPM304.4	3	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3

MPM304.5	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3
MPM304.6	3	3	2	2	3	3	3	3	3	3	3	3	3	3	3	3
MPM304.7	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
MPM304.8	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Average	3	2.9	2.6	2.75	2.9	3	2.6	3	3	2.75	2.88	3	3	2.75	3	3

CO-PO matrix for the course MPM305 (Materials Science Specialization Lab)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
MPM305.1	3	3	1	2	2	2	1	1	2	2	2	3	2	3	2	3
MPM305.2	3	3	1	2	2	3	2	1	1	2	2	3	3	3	3	3
MPM305.3	3	3	-	1	2	2	1	1	2	2	2	3	3	3	2	3
MPM305.4	3	3	1	2	2	2	2	1	1	2	2	3	3	3	3	3
MPM305.5	3	3	-	1	2	1	1	1	2	2	2	3	2	3	2	3
MPM305.6	3	3	1	3	2	3	2	2	2	2	2	3	3	3	3	3
MPM305.7	3	3	1	3	2	3	1	1	2	2	2	3	3	3	3	3
MPM305.8	3	3	-	3	2	3	2	1	2	2	3	3	3	3	3	3
Average	3	3	0.625	0.875	2.375	2.375	1.5	1.125	1.75	2	2.125	3	2.75	3	2.625	3

CO-PO matrix for the course MPM403 (Advanced Materials Science)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
MPM403.1	3	3	1	2	2	2	1	1	2	2	2	3	1	-	1	2
MPM403.2	3	3	1	2	2	3	2	1	1	2	2	3	3	-	3	3
MPM403.3	3	3	-	1	2	2	1	1	2	2	2	3	3	-	3	3

MPM403.4	3	3	1	2	2	2	2	1	1	2	2	3	2	-	2	3
MPM403.5	3	3	-	1	2	1	1	1	2	2	2	3	3	-	3	3
MPM403.6	3	3	1	3	2	3	2	2	2	2	2	3	3	-	3	3
MPM403.7	3	3	1	3	2	3	1	1	2	2	2	3	3	-	3	3
MPM403.8	3	3	-	3	2	3	2	1	2	2	3	3	3	-	3	3
Average	3	3	0.625	0.875	2.375	2.375	1.5	1.125	1.75	2	2.125	3	2.625	-	2.625	2.875

CO-PO matrix for the course MPM404 (Vacuum Science and Thin film Technology)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
MPM404.1	3	2	2	3	2	2	2	2	2	2	2	3	1	-	1	2
MPM404.2	3	3	2	3	2	2	3	3	2	2	2	3	3	-	3	3
MPM404.3	3	2	3	2	2	3	2	2	2	2	2	3	3	-	3	3
MPM404.4	3	2	2	2	3	2	2	2	1	3	2	3	2	-	2	3
MPM404.5	3	3	2	3	3	3	3	3	2	3	3	3	3	-	3	3
MPM404.6	3	3	2	2	3	2	3	2	3	2	3	3	3	-	3	3
Average	3	2.5	2.2	2.5	2.5	2.3	2.5	2.3	2	2.5	2.3	3	2.625	-	2.625	2.875

CO-PO matrix for the course MPE303 (Analog Electronics)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
MPE303.1	3	2	2	3	2	3	3	3	3	2	3	3	1	-	1	2
MPE303.2	3	2	2	3	2	3	3	3	3	2	3	3	3	-	3	3
MPE303.3	3	2	2	3	2	3	3	3	3	2	2	3	3	-	3	3
MPE303.4	3	2	2	3	2	3	3	3	3	2	3	3	2	-	2	3
Average	3	2	2	3	2	3	3	3	3	2	3	3	3	-	3	3

CO-PO matrix for the course MPE305 (Electronics Specialization lab)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
MPE305.1	3	2	2	3	2	2	2	2	2	2	2	3	1	-	1	2
MPE305.2	3	3	2	3	2	2	3	3	2	2	2	3	3	-	3	3
MPE305.3	3	2	3	2	2	3	2	2	2	2	2	3	3	-	3	3
MPE305.4	3	2	2	2	3	2	2	2	1	3	2	3	2	-	2	3
MPE305.5	3	3	2	3	3	3	3	3	2	3	3	3	3	-	3	3
Average	3	2.5	2.2	2.5	2.5	2.3	2.5	2.3	2	2.5	2.3	3	2.625	-	2.625	2.875

CO-PO matrix for the course MPE403 (Digital Electronics)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
MPE403.1	3	2	2	3	2	3	3	3	3	2	3	3	2	-	2	1
MPE403.2	3	2	2	3	2	3	3	3	3	2	3	3	1	-	3	3
MPE403.3	3	2	2	3	2	3	3	3	3	2	2	3	2	-	2	2
MPE403.4	3	2	2	3	2	3	3	3	3	2	3	3	2	-	2	3
Average	3	2	2	3	2	3	3	3	3	2	3	3	2	-	2	3

CO-PO matrix for the course MPE404 (Optical Fiber Communication)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
MPE404.1	3	2	2	3	3	3	2	3	2	2	2	3	3	2	3	3
MPE404.2	3	3	3	3	3	3	2	3	3	3	3	3	3	2	3	3
MPE404.3	3	3	3	2	2	3	3	3	2	2	2	3	3	3	3	3
MPE404.4	3	2	3	2	2	3	3	2	3	3	2	3	3	2	3	3
MPE404.5	3	1	2	3	3	3	2	3	2	2	3	3	3	2	3	3

MPE404.6	3	2	3	2	3	3	2	2	2	3	2	3	3	2	3	3
Average	3	2.17	2.67	2.5	2.67	3	2.34	2.67	2.34	2.5	2.34	3	3	2.16	3	3

CO-PO matrix for the course APH 101 (Renewable Energy Sources)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
APH101.1	3	2	2	3	3	3	2	3	2	2	2	3	3	2	3	3
APH101.2	3	3	3	3	3	3	2	3	3	3	3	3	3	2	3	3
APH101.3	3	3	3	2	2	3	3	3	2	2	2	3	3	3	3	3
APH101.4	3	2	3	2	2	3	3	2	3	3	2	3	3	2	3	3
APH101.5	3	1	2	3	3	3	2	3	2	2	3	3	3	2	3	3
APH101.6	3	2	3	2	3	3	2	2	2	3	2	3	3	2	3	3
Average	3	2.17	2.67	2.5	2.67	3	2.34	2.67	2.34	2.5	2.34	3	3	2.16	3	3

CO-PO matrix for the course OPH101 (Introduction to Astro Physics and Cosmology)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
OPH101.1	3	2	2	3	2	2	2	2	2	2	2	3	3	2	3	3
OPH101.2	3	3	1	3	2	2	3	2	2	2	2	3	3	2	3	3
OPH101.3	3	2	3	2	2	3	2	1	2	2	2	3	3	3	3	3
OPH101.4	3	2	1	2	3	2	2	2	1	3	2	3	3	2	3	3
OPH101.5	3	3	1	3	3	3	3	2	2	3	3	3	3	2	3	3
OPH101.6	3	3	2	2	3	2	3	2	3	2	3	3	3	2	3	3
Average	3	2.5	1.7	2.5	2.5	2.3	2.5	1.8	2	2.5	2.3	3	3	2.16	3	3

CO-PO matrix for the course OPH102 (Energy Harvesting and Storage Devices)

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3	PSO4	PSO5
OPH102.1	3	2	2	3	2	2	2	2	2	2	2	3	3	2	3	3
OPH102.2	3	3	1	3	2	2	3	2	2	2	2	3	3	2	3	3
OPH102.3	3	2	3	2	2	3	2	1	2	2	2	3	3	3	3	3
OPH102.4	3	2	1	2	3	2	2	2	1	3	2	3	3	2	3	3
OPH102.5	3	3	1	3	3	3	3	2	2	3	3	3	3	2	3	3
OPH102.6	3	3	2	2	3	2	3	2	3	2	3	3	3	2	3	3
Average	3	2.5	1.7	2.5	2.5	2.3	2.5	1.8	2	2.5	2.3	3	3	2.16	3	3

Mapping of the subjects with the following

S. No.	Course Name	Course code	Employability	Entrepreneurship	Skill Development
1	Mathematical Physics	MPH101	2	1	2
2	Classical Mechanics	MPH102	2	0	1
3	Quantum Mechanics-I	MPH103	2	0	1
4	Electronic Devices	MPH104	2	2	2
5	Physics Laboratory-I	MPH105	2	1	3
6	Seminar-I	MPH106	2	2	3
7	Quantum Mechanics - II	MPH201	2	0	1
8	Nuclear and Particle Physics	MPH202	2	1	2
9	Solid State Physics	MPH203	2	1	2
10	Electrodynamics	MPH204	2	1	2
11	Physics Laboratory-II	MPH205	2	1	3
12	Atomic and Molecular Physics	MPH301	2	1	2
13	Statistical Mechanics	MPH302	2	1	2
14	Laser Technology	MPH401	2	2	2

15	Materials Science	MPH402	2	2	2
16	Dissertation	MPH405	2	2	3
17	Nuclear Reactions	MPN303	2	1	2
18	Nuclear Detectors	MPN304	2	1	2
19	Nuclear Physics Spec. Lab	MPN305	2	2	3
20	Nuclear Models and Astrophysics	MPN403	2	1	2
21	Nuclear Techniques and Neutron Physics	MPN404	2	1	2
22	Materials Characterization Techniques	MPM303	2	2	3
23	Fundamentals and synthesis of nanomaterials	MPM304	2	2	3
24	Material Science Spec. Lab	MPM305	2	3	3
25	Advanced Materials Science	MPM403	2	2	2
26	Vacuum Science and Thin Films Technology	MPM404	3	3	2
27	Analog Electronics	MPE303	2	2	3
28	Microprocessor	MPE304	2	3	2
29	Electronics Spec. Lab	MPE305	2	2	3
30	Digital Electronics	MPE403	2	1	2
31	Optical fiber Communication	MPE404	2	3	2
32	RENEWABLE ENERGY RESOURCES	APH101	3	3	2
33	INTRODUCTION TO ASTROPHYSICS AND COSMOLOGY	OPH101	2	1	2
34	ENERGY HARVESTING AND STORAGE DEVICES	OPH102	2	2	2

Mapping Scale: 1 to 3 (3: Strong correlation; 2: medium correlation; 1: weak correlation)