Syllabus for Four-Year Undergraduate Programme in Physics

(Revised in July 2025)

Learning Outcomes based Curriculum Framework (LOCF) following NEP 2020

Department of Physics
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Foreword

Education plays an enormously significant role in the building of a nation. The implementation of the National Education Policy (NEP) 2020 has opened new avenues for higher education in India by emphasizing flexibility, interdisciplinarity, and a learner-centric approach. In this context, a **Four-Year Undergraduate Programme in Physics** was designed and implemented in 2022 under **Learning Outcomes based Curriculum Framework (LOCF)** to align with NEP 2020's visionary framework, offering a curriculum that integrates conceptual depth with practical relevance.

However, in course of time, we felt that the situation necessitates transformation and/or redesigning of the syllabus, not only by introducing innovations but by developing a "learner-centric" approach. In order to allow academic flexibility to the students to study the papers of their choice, we focus on papers which are interdisciplinary and multidisciplinary in nature. Further, as the NEP 2020 recommends the incorporation of Indian Knowledge System into the curriculum, presently we have revised the **Syllabus for Four-Year Undergraduate Programme in Physics.**

As a whole, this syllabus aims to nurture scientific temper, analytical thinking, and innovation among students. It offers a multidisciplinary foundation in the initial years, with increasing specialization in advanced topics such as quantum mechanics, electrodynamics, condensed matter physics, and emerging areas like quantum electronics, nanotechnology and computational physics. The curriculum also includes research opportunities, skill enhancement courses, and internships, preparing students for diverse career paths in academia, industry, and beyond.

The program accommodates multiple entry and exit options with appropriate certification at each level, ensuring inclusivity and adaptability. Emphasis on laboratory training, mathematical modelling, digital tools, and project-based learning ensures that students gain hands-on experience and a problem-solving mindset.

We believe this revised syllabus not only meets the academic standards envisioned by NEP 2020 but also instils in students the values of curiosity, critical inquiry, and lifelong learning. We are grateful to the faculty members and subject experts whose dedicated efforts have made this syllabus a reality. We are confident that this comprehensive and forward-looking programme will inspire the next generation of physicists to explore, innovate, and lead.

Prof. Ashis Bhattacharjee
Chairman, Board of Studies
Department of Physics
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Visva-Bharati
15th July, 2025

Profile of the Department

The Department of Physics at Visva-Bharati, Santiniketan, is one of the premier academic departments of the university, known for its commitment to excellence in teaching, research, and academic outreach. Rooted in the ethos of holistic education envisioned by Gurudev Rabindranath Tagore, the department combines scientific rigor with a humanistic perspective to foster curiosity, creativity, and critical thinking among its students and researchers.

Historical Background

Established as part of the Siksha-Bhavana (Institute of Science) in 1963 with a provision for teaching at the B.Sc. (Honours) level while the M.Sc. programme started in 1968, the Department of Physics has grown steadily in stature and scope. From its humble beginnings as an undergraduate teaching unit, it has evolved into a full-fledged department offering comprehensive academic programs at undergraduate, postgraduate, and doctoral levels. Over the years, it has nurtured several generations of scientists, educators, and professionals who have made significant contributions to academia, industry, and society.

Academic Programs

The department offers a Four-Year Undergraduate Programme (FYUP) in Physics under the National Education Policy (NEP) 2020 framework, a Two-Year Master of Science (M.Sc.) in Physics, and a Ph.D. program in diverse research areas. The curriculum is designed to be both rigorous and flexible, blending core theoretical knowledge with hands-on experimental training and emerging interdisciplinary topics. Emphasis is placed on laboratory skills, computational physics, and research-based learning to prepare students for careers in research, teaching, and technology-driven industries.

Research and Collaboration

Research is a cornerstone of the department's identity. Faculty members are actively engaged in cutting-edge research in areas such as Condensed Matter Physics, Nanoscience and Nanotechnology, Quantum Electronics, Materials Science, Nuclear and Particle Physics, Astrophysics, Cosmology, High Energy Physics and Theoretical Physics. The department has received research funding from various national agencies like DST, SERB, CSIR, UGC, MoE and BRNS.

The department maintains collaborative linkages with premier institutions and universities across India and abroad - Max-Planck Institute for Astrophysics (Garching, Germany), Naresuan University (Thailand), Fukushima University (Japan), Osaka University (Japan), University of La Plata (Argentina), International Islamic University of Malaysia (Malaysia), Nicolaus Copernicus University (Poland), University of Silesia (Poland), National University of Uzbekistan (Tashkent, Uzbekistan), University of Yogyakarta (Indonesia), Virginia Commonwealth University (USA), Gerhard Mercator University (Germany), University of Koeln (Germany), etc., facilitating exchange programs, joint research projects, and access to advanced experimental facilities. It regularly organizes conferences, workshops, and seminars that bring together scientists and students to discuss contemporary developments in physics and related fields. The department is an IUCAA Centre for Astronomy Research and Development (ICARD) since 2024

Facilities and Infrastructure

The department boasts well-equipped laboratories for undergraduate and postgraduate teaching, along with specialized research laboratories. Facilities include few advanced instrumentation for material characterization, optical and electronic measurements, and computational resources for simulations and theoretical work. The departmental library houses a substantial collection of textbooks, reference materials, and research journals, supplementing the resources of the central university library.

Faculty and Student Strength

The Department of Physics has a team of dedicated and experienced faculty members who are not only excellent teachers but also active researchers. Their mentorship plays a crucial role in nurturing the academic and professional growth of students. The student community is vibrant, with learners from diverse backgrounds engaged in academic, co-curricular, and outreach activities.

Outreach and Extension

In alignment with Visva-Bharati's commitment to societal development, the department undertakes various outreach initiatives. These include science awareness programs for school students, teacher training workshops, and community engagement through science exhibitions and popular lectures. These initiatives aim to foster a scientific temper and encourage young minds to pursue careers in science.

Vision and Future Directions

The Department of Physics, Visva-Bharati envisions becoming a center of excellence in physics education and research with a global outlook and local relevance. It aims to expand its academic offerings, enhance interdisciplinary research, and build stronger national and international collaborations. The department is committed to fostering an inclusive and intellectually stimulating environment where innovation, inquiry, and integrity are valued above all.

Through its academic and research pursuits, the department continues to contribute to the advancement of science and the realization of Tagore's vision of education as a means of individual and societal transformation.

Objective of Four-Year Undergraduate Programme in Physics

The Four-Year Undergraduate Programme in Physics aims to provide students with a comprehensive, flexible, and multidisciplinary education that fosters a deep understanding of the fundamental principles and applications of Physics. In alignment with the National Education Policy (NEP) 2020, the programme is designed to develop scientific temperament, analytical reasoning, and research aptitude, preparing students for academic, industrial, and societal challenges.

The key objectives of the programme are:

1. **To build a strong foundational understanding** of classical and modern physics.
2. **To promote experiential and skill-based learning** through laboratory experiments, computational methods, scientific modelling, and project-based activities.
3. **To integrate interdisciplinary and multidisciplinary perspectives** by offering elective courses across sciences, humanities, and vocational domains, enabling a broader academic exposure.
4. **To cultivate critical thinking, creativity, and problem-solving abilities** that are essential for research, innovation, and entrepreneurship in scientific and technological fields.
5. **To encourage research and inquiry-oriented learning** by offering research projects, internships, and access to modern scientific tools and methods.
6. **To ensure flexibility and inclusivity** through multiple entry and exit options with appropriate certification, accommodating diverse learner needs and aspirations.
7. **To instill ethical, environmental, and societal awareness**, making students responsible citizens who can apply their knowledge for sustainable development and public welfare.
8. **To prepare students for diverse career pathways** in academia, research institutions, education, industry, civil services, and other emerging sectors.

Through this programme, students will be equipped with a balanced blend of theoretical knowledge, practical skills, and soft skills, in line with the NEP 2020 vision of holistic and multidisciplinary education.

Evaluation of Students

Evaluation is a continuous and integral part of the teaching-learning process. Under the National Education Policy (NEP) 2020, student evaluation aims to assess not only academic knowledge but also conceptual understanding, critical thinking, creativity, and application of skills in real-life situations. A multi-dimensional approach is adopted to ensure comprehensive development. The evaluation scheme for each paper shall contain two parts, namely: ***(a) Continuous Evaluation*** and ***(b) End Semester Evaluation.*** 20% weightage shall be given to the continuous evaluation and 80% weightage shall be for the end semester evaluation for theory and practical papers. For dissertation, 60% and 40% weightages shall be given to the continuous evaluation and end semester evaluation, respectively.

(a) Continuous Evaluation: 20% of the total marks in each paper are for continuous assessment. The continuous evaluation shall be based on a pre-determined transparent system involving any of the following components:

a. At least one written test along with assignment/ quiz /seminar for all theory papers
b. Laboratory participation, keeping of laboratory records, written test / viva voce for all practical papers

To ensure transparency of the evaluation process, the continuous evaluation marks awarded to the students in each paper in a semester shall be displayed after every test/assignment/quiz. The performance of the students in the continuous evaluation shall be communicated to the students for discussion and improvement. The final marks of continuous evaluation shall be displayed on the notice board before commencement of the end semester evaluation.

(b) End Semester Evaluation:
End semester evaluation carries 80% of total marks for each paper. The end semester evaluation in theory papers is to be conducted with question papers set by examiner(s) appointed by the University. All question papers should be approved by a moderation committee constituted by the University. The end semester evaluation in practical papers shall be conducted by a board of examiners appointed by the University.

(c) Internship Evaluation:
Every student of four-year UG programme shall have to do a vocational summer internship project of 4 credits and 120 Credit Hours (approved by the Board of Studies) under the supervision of an *external* mentor. On completion of the internship, an evaluation shall be conducted as per the guidelines framed by the Board of Studies/University.

(d) Dissertation Evaluation:
Dissertation can be opted by students who attain at least *CGPA 75%* at the end of the sixth semester (3rd year) and desire the research degree. The students pursuing B.Sc. Honours (with research) have to secure 12 credits (4 credits in Sem- VII and 8 credits in Semester VIII). However, students pursuing only B.Sc. Honours have to study additional three major papers in physics carrying 12 credits (4 credits in Sem-VII and 8 credits in Sem-VIII) in lieu of the dissertation.

Dissertation evaluation shall be conducted by the guidelines framed by the Board of Studies/University concerned. The evaluation of the project will be done at two stages:

i. Continuous Evaluation: Supervising mentor will assess the project and award the internal marks (*60% weightage of total marks*).

ii. End Semester Evaluation: An external examiner shall be appointed by the University. Evaluation shall be based on the submitted dissertation project report followed by the presentation / viva-voce (*40% weightage of total marks*).

The *total* marks (sum of *continuous evaluation and end semester evaluation marks*) secured for the dissertation project will be awarded to candidates. Submission of the dissertation project report and presentation by the student before a committee are compulsory for continuous/end semester evaluation.

Duration & Question Pattern for Examination of Major Theory / Practical Papers:

Paper (Credits)	**Theory/ Practical (Credits)**	**Full Marks**	**Continuous Evaluation**	**End Semester Evaluation**		
			Marks	**Marks**	**Duration**	**Pattern**
Major **(4)**	Theory **(4)**	100	20	80	3 Hrs.	**Compulsory:** Qs. No. 1, Short Answer Type, 8x2 = 16 marks (Out of 10 Qs.) **Choice-Based:** 4 Qs., each of 16 marks (Out of 6 Qs.)
Major **(3+1)**	Theory **(3)**	75	15	60	2.5 Hrs.	**Compulsory:** Qs. No. 1, Short answer type, 6x2 = 12 marks (Out of 8 Qs.) **Choice-Based:** 4 Qs., each of 12 marks (Out of 6 Qs.)
	Practical **(1)**	25	5	20	3 Hrs.	Each student shall perform 1 experiment. Students will be evaluated by the experiment performed and Viva voce.
Major **(4)**	Practical **(4)**	100	20	80	3+3 Hrs.	Each student shall perform 2 experiments. Students will be evaluated by the experiments performed and Viva voce.

Duration & Question Pattern for Examination of Minor / Multi-Disciplinary / Skill Enhancement Theory / Practical Papers:

Course (Credits)	Theory/ Practical (Credits)	Full Marks	Continuous Evaluation	End Semester Evaluation		
			Marks	Marks	Duration	Pattern
Minor **(3+1)**	Theory **3 Credits**	75	15	60	2:30 Hrs.	**Compulsory:** Qs. No. 1, Short answer type, 6x2 = 12 marks (Out of 8 Qs.) **Choice-Based:** 4 Qs., each of 12 marks (Out of 6 Qs.)
	Practical **1 Credit**	25	5	20	3 Hrs.	Each student shall perform 1 experiment. Students will be evaluated by the experiment (s) performed and Viva voce.
Multi-Discipli-nary **(3)**	Theory **3 Credits**	75	15	60	2:30 Hrs.	**Compulsory:** Qs. No. 1, Short answer type, 6x2 = 12 marks (Out of 8 Qs.) **Choice-Based:** 4 Qs., each of 12 marks (Out of 6 Qs.)
Skill Enhance-ment **(3)**	Theory **3 Credits**	75	15	60	2:30 Hrs.	**Compulsory:** Qs. No. 1, Short answer type, 6x2 = 12 marks (Out of 8 Qs.) **Choice-Based:** 4 Qs., each of 12 marks (Out of 6 Qs.)
Skill Enhance-ment **(3)**	Practical **3 Credits**	75	15	60	3 Hrs.	Each student shall perform 1 experiment/assign-ment. Students will be evaluated by the experi-ment(s) performed and Viva voce.

COURSE STRUCTURE OF FOUR-YEAR UNDERGRADUATE PROGRAMME IN PHYSICS

Sem	Major Courses	Minor Courses	Multi Courses	AECC	SEC	CVAC	Research *	Internship	Total Credits	
I	2x4cr =8	MnA 1x4cr =4	1x3cr =3	ENG/MIL1 1x2cr =2	1x3cr =3	TS 1x3cr =3	---		23	B.Sc. Certificate
II	2x4cr =8	MnB 1x4cr =4	1x3cr =3	ENG/MIL2 1x2cr =2	1x3cr =3	ES 1x3cr =3	---		23	
YEAR 1	2x8 =16cr	2x4 =8cr	2x3 =6cr	2x2 =4cr	2x3 =6cr	2x3 =6cr	---	Sum 4cr	46+4	
After successful completion of ONE YEAR Course (Semesters - I & II) securing 46 credits + 4 credits vocational summer internship, students may exit with B.Sc. Certificate in PHYSICS or continue further.										
III	2x4cr =8	MnA 1x4cr =4	1x3cr=3	MIL/ENG1 1x2cr =2	1x3cr=3	---	---		20	B.Sc. Diploma
IV	4x4cr =16	MnB 1x4cr =4	---	MIL/ENG2 1x2cr =2	---	---	---		22	
YEAR 2	10x4 =40cr	4x4 =16cr	3x3 =9cr	4x2 =8cr	3x3 =9cr	2x3 =6cr	---	Sum 4cr	88+4	
After successful completion of TWO YEAR Course (Semesters - I to IV) securing 88 credits + 4 credits vocational summer internship, students may exit with B.Sc. Diploma in PHYSICS or continue further.										
V	3x4cr =12	MnA 1x4cr =4	---	---	---	---	---		16	B.Sc. Degree
VI	3x4cr =12	MnB 1x4cr =4	---	---	---	---	---		16	
YEAR 3	16x4 =64cr	6x4 =24cr	3x3 =9cr	4x2 =8cr	3x3 =9cr	2x3 =6cr	---	Sum 4cr	120+4	
After successful completion of THREE YEAR COURSE (Semesters - I to VI) securing 120 credits + 4 credits vocational summer internship, students may exit with B.Sc. Degree in PHYSICS or continue further.										
VII	4x4cr=16	MnA 1x4cr =4	---	---	---	---	---		20	B.Sc. Honours Degree
VIII	4x4cr =16	MnB 1x4cr =4	---	---	---	---	---		20	
YEAR 4	24x4 =96cr	8x4=32cr	3x3 =9cr	4x2 =8cr	3x3 =9cr	2x3 =6cr	---	Sum 4cr	160+4	
After successful completion of FOUR YEAR COURSE (Semesters - I to VIII) securing 160 credits + 4 credits vocational summer internship, students may obtain B.Sc. Honours in PHYSICS.										
OR										
VII	3x4 =12cr	MnA 1x4 =4cr	---	---	---	---	1x4 =4cr*		20	B.Sc. Honours (with Research)
VIII	2x4 =8cr	MnB 1x4 =4cr	---	---	---	---	2x4 =8cr*		20	
YEAR 4	21x4 =84cr	8x4 =32cr	3x3 =9cr	4x2 =8cr	3x3 =9cr	2x3 =6cr	3x4 =12cr	Sum 4cr	160+4	
After successful completion of FOUR YEAR COURSE (Semesters - I to VIII) securing 160 credits + 4 credits vocational summer internship, students may obtain B.Sc. Honours (with Research) in PHYSICS.										

***Dissertation can be opted by students who attain at least CGPA 75% in 3 years and desire the Research degree. The students pursuing B.Sc. Honours (with Research) have to secure 12 credits (4 credits in Semester VII and 8 credits in Semester VIII). However, students pursuing only B.Sc. Honours have to study additional three Major Courses in PHYSICS securing 12 credits (4 credits in Semester VII and 8 credits in Semester VIII) in lieu of the Dissertation.**

FOUR-YEAR UNDERGRADUATE PROGRAMME in PHYSICS following NEP 2020

MAJOR COURSES in PHYSICS [Discipline-Specific Core Courses]

Course Code	Course Type	Course Title	Credits	Marks	Hours
SEMESTER I					
MJPH01	Theory	**Mathematical Physics - I**	4	100	60
MJPH02	*Theory*	**Mechanics**	4	100	60
		Total	**8 credits**	**200**	
SEMESTER II					
MJPH03	Theory	**Electricity and Magnetism**	4	100	60
MJPH04	Practical	**Laboratory - I**	4	100	120
		Total	**8 credits**	**200**	
ONE-YEAR CERTIFICATE PROGRAMME	**TOTAL**	**4 MAJOR COURSES**	**16 credits**	**400**	
SEMESTER III					
MJPH05	Theory	**Waves and Optics**	4	100	60
MJPH06	Theory	**Classical Mechanics**	4	100	60
		Total	**8 credits**	**200**	
SEMESTER IV					
MJPH07	Theory	**Thermal Physics**	4	100	60
MJPH08	Theory	**Quantum Mechanics - I**	4	100	60
MJPH09T	Theory	**Analog Electronics**	3	75	45
MJPH09P	Practical	**Analog Electronics**	1	25	30
MJPH10	Practical	**Laboratory - II**	4	100	120
		Total	**16 credits**	**400**	
TWO-YEAR DIPLOMA PROGRAMME	**TOTAL**	**10 MAJOR COURSES**	**40 credits**	**1000**	
SEMESTER V					
MJPH11	Theory	**Quantum Mechanics - II**	4	100	60
MJPH12	Theory	**Solid State Physics - I**	4	100	60
MJPH13T	Theory	**Digital Electronics**	3	75	45
MJPH13P	Practical	**Digital Electronics**	1	25	30
		Total	**12 credits**	**300**	

SEMESTER VI					
MJPH14	Theory	**Statistical Mechanics**	4	75	60
MJPH15	Theory	**Nuclear and Particle Physics**	4	75	60
MJPH16	Practical	**Laboratory - III**	4	100	120
		Total	**12 credits**	**300**	
THREE-YEAR DEGREE PROGRAMME TOTAL 16 MAJOR COURSES			**64 credits**	**1600**	
SEMESTER VII					
MJPH17	Theory	**Mathematical Physics - II**	4	100	60
MJPH18	Theory	**Classical Electrodynamics**	4	100	60
MJPH19	Theory	**Atomic and Molecular Physics**	4	100	60
		Total	**12 credits**	**300**	
MJPH20-1	Theory	**Nanoscience**	4	100	60
MJPH20-2	Theory	**Nuclear Science - Theory and Applications**	4	100	60
MJPH20-3T	Theory	**Physics of Devices and Instruments**	3	75	45
MJPH20-3P	Practical	**Physics of Devices and Instruments**	1	25	30
MJPH20-4	Theory	**Statistical Methods in Physics**	4	100	60
MJPH20-5	Theory	**Quantum Mechanics - III**	4	100	60
		Students have to take one course of 4 credits	**4 credits**	**100**	
SEMESTER VIII					
MJPH21	Theory	**Solid State Physics - II**	4	100	60
MJPH22	Theory	**Laboratory - IV**	4	100	120
		Total	**8 credits**	**200**	
MJPH23-1	Theory	**Advanced Electronics**	4	100	60
MJPH23-2	Practical	**Basics of Machine Learning**	4	100	120
MJPH23-3	Theory	**Advanced Mathematical Methods**	4	100	60
MJPH23-4	Theory	**Laser Physics**	4	100	60
MJPH23-5	Theory	**Particle Physics**	4	100	60
MJPH23-6	Theory	**Introduction to Nonlinear Dynamics**	4	100	60
MJPH23-7	Theory	**Tools and Techniques for Nuclear Physics Experiments**	4	100	60
MJPH23-8	Theory	**Astronomy and Astrophysics**	4	100	60
		Students have to take two courses of 4 credits	**8 credits**	**200**	
FOUR-YEAR HONOURS PROGRAMME TOTAL 21 COURSES + 3 COURSES *(Optional in lieu of Dissertation for Honours students) FOUR-YEAR HONOURS with RESEARCH PROGRAMME TOTAL 21 COURSES + DISSERTATION			**84 credits + 12 credits**	**2100 + 300**	

MINOR COURSES in PHYSICS [Discipline-Specific Minor Courses]

Course Code	Course Type	Course Title	Credits	Marks	Hours
SEMESTER I					
MNPH01T	Theory	**Mechanics**	3	75	45
MNPH01P	Practical	**Mechanics**	1	25	30
SEMESTER II					
MNPH01T	Theory	**Mechanics**	3	75	45
MNPH01P	Practical	**Mechanics**	1	25	30
ONE-YEAR CERTIFICATE PROGRAMME TOTAL 1 MINOR COURSE			**4**	**100**	
SEMESTER III					
MNPH02T	Theory	**Electricity and Magnetism**	3	75	45
MNPH02P	Practical	**Electricity and Magnetism**	1	25	30
SEMESTER IV					
MNPH02T	Theory	**Electricity and Magnetism**	3	75	45
MNPH02P	Practical	**Electricity and Magnetism**	1	25	30
TWO-YEAR DIPLOMA PROGRAMME TOTAL 2 MINOR COURSES			**8**	**200**	
SEMESTER V					
MNPH03T	Theory	**Thermal Physics**	3	75	45
MNPH03P	Practical	**Thermal Physics**	1	25	30
SEMESTER VI					
MNPH03T	Theory	**Thermal Physics**	3	75	45
MNPH03P	Practical	**Thermal Physics**	1	25	30
THREE-YEAR DEGREE PROGRAMME TOTAL 3 MINOR COURSES			**12**	**300**	
SEMESTER VII					
MNPH04T	Theory	**Waves and Optics**	3	75	45
MNPH04P	Practical	**Waves and Optics**	1	25	30
SEMESTER VIII					
MNPH04T	Theory	**Waves and Optics**	3	75	45
MNPH04P	Practical	**Waves and Optics**	1	25	30
FOUR-YEAR HONOURS PROGRAMME TOTAL 4 MINOR COURSES			**16**	**400**	

SKILL ENHANCEMENT COURSES in PHYSICS

Course Code	Course Type	Course title	Credits	Marks	Hours
SEMESTER I					
SECPH01	Practical	**Basic Computer Programming**	3	75	90
SEMESTER II					
SECPH02	Theory	**Basic Instrumentation Skills / Renewable Energy and Energy Harvesting / Radiation Safety** **[Only one paper will be offered each year decided by the department]**	3	75	45
ONE-YEAR CERTIFICATE PROGRAMME		**TOTAL 2 COURSES**	**6 credits**	**150**	
SEMESTER III					
SECPH03	Practical	**Computational Methods in Physics**	3	75	90
TWO-YEAR DIPLOMA PROGRAMME		**TOTAL 3 COURSES**	**9 credits**	**225**	

MULTIDISCIPLINARY COURSE in PHYSICS

Course Code	Course Type	Course title	Credits	Marks	Hours
SEMESTER I					
MDPH01	Theory	**Introduction to Astronomy and Astrophysics**	3	75	45
SEMESTER II					
MDPH02	Theory	**Radiation Safety**	3	75	45
SEMESTER III					
MDPH03	Theory	**Physics in Everyday Life**	3	75	45

PAPER-WISE OBJECTIVES OF TEACHING & LEARNING OUTCOME

MAJOR COURSES in PHYSICS

Course Code	Course Title	Objectives of Teaching	Learning Outcome
MJPH01	**Mathematical Physics - I**	The primary objective of this course is to provide students with a basic foundation in mathematical methods relevant to physics, including vector calculus, differential equations, curvilinear coordinate systems, probability, and Fourier series analysis. The course aims to connect mathematical theory with its practical applications in physics.	Upon completion of this course, students will be able to confidently use mathematical concepts and techniques to analyse and solve problems in physics. Moreover, students will be able to translate physical problems into mathematical formulations. The course will provide the necessary mathematical background for advanced physics courses.
MJPH02	**Mechanics**	A mechanics course aims to provide a deep understanding of the principles governing the motion of objects, from everyday macroscopic objects to celestial bodies. The key objectives include mastering Newtonian mechanics, and applying these concepts to various physical systems. Students should also gain knowledge about concepts like conservation laws, symmetries, and the dynamics of both simple and complex systems, including rigid bodies and central force problems.	A Mechanics course aims to equip students with the ability to analyze and solve problems related to motion and forces in physical systems. Key learning outcomes include understanding fundamental concepts like Newton's laws, energy and momentum conservation, and applying these principles to various mechanical systems. Students should also be able to utilize mathematical tools like calculus and vector analysis to model and solve problems.
MJPH03	**Electricity and Magnetism**	• To enable physics majors to develop a foundational understanding of electrostatics, magnetostatics, electromagnetic induction, Maxwell's equations, and, electrical circuits in a language of vector calculus and differential equations. • To cultivate problem-solving skills through conceptual insight and mathematical techniques	• Upon successful completion of this course, students will be • Able to develop an understanding of electromagnetic phenomena in their daily lives at an appropriate level, and, to perform undergraduate-level experiments. • Prepared to study more advanced topics in this area, such as relativistic electrodynamics.
MJPH04	**Laboratory - I**	To develop practical skills through hands-on experience in different topics of mechanics, properties of matter and basic electrical circuits, reinforcing theoretical concepts through precise measurements.	Students will gain proficiency in setting up and conducting experiments related to mechanics and electricity magnetism by accurately measuring various physical quantities such as moment of inertia, elastic moduli, resistances and circuit responses. This course will also help the students to analyze results to draw meaningful physical conclusions.
MJPH05	**Waves and Optics**	This course covers the various topics related to wave motion and simple harmonic oscillations. It also covers a few topics on wave optics such as interference, diffractions, and polarization. The course	After the successful completion of the course, the students will • understand the underlying features associated with interference,

		has been designed to impart knowledge on the different topics related to wave motion and the different phenomena representing the wave nature of light.	diffraction, and polarization phenomena of light wave; • learn about how to deal with the superposition technique of wave under different conditions in order to generate the different kinds of wave patterns.
MJPH06	**Classical Mechanics**	To develop a clear understanding of the fundamental principles and formulations of classical mechanics and to equip students with a rigorous foundation in advanced classical mechanics, focusing on Lagrangian and Hamiltonian dynamics, canonical transformations.	Students will be able to apply Lagrangian and Hamiltonian mechanics to analyze the motion of particles and systems.
MJPH07	**Thermal Physics**	This course provides an introduction to the basics of thermal physics – laws of thermodynamics, significance of thermodynamic potentials, heat engines, properties of ideal and real gases, transport phenomena, phase transitions, etc. using a phenomenological approach.	Students will learn the basics of thermodynamics and be prepared for a more detailed, theoretical understanding of how thermal systems work.
MJPH08	**Quantum Mechanics - I**	The main objective of this course is to understand the basic of quantum mechanics -- to understand the behaviour of matter and wave at the atomic and subatomic levels. To explain the necessity of studying this new methodology besides classical physics, the course started with the discussion on the historical developments of quantum mechanics. Later, the mathematical formalism of quantum mechanics is designed. At the end to check the understanding of the quantum physics, it is applied to various physical problems like particle in a box, simple harmonic oscillator and to the hydrogen like atom etc.	Upon completion of this course, student will understand the importance of the quantum mechanics as well as the formalism of the quantum mechanics. Students will be able to apply quantum physics into various physical problems like particle in a box, tunnelling phenomena, simple harmonic oscillator and to the hydrogen like atom etc.
MJPH09T	**Analog Electronics**	• To introduce students to the fundamental principles of semiconductor devices and analog circuit design. • To provide theoretical insight into rectifiers, amplifiers, feedback mechanisms, and operational amplifiers. • To enable understanding of analog signal processing and real-world electronic applications.	Students will gain a conceptual and mathematical understanding of analog electronic devices and circuits. They will be able to analyze and design amplifier circuits and evaluate feedback and oscillator configurations. Learners will become proficient in applying operational amplifiers to solve practical engineering problems.
MJPH09P	**Analog Electronics**	• To provide hands-on experience with fundamental analog electronic components and circuits. • To develop skills in designing and analyzing amplifiers, oscillators, and op-amp based circuits. • To reinforce theoretical concepts through practical implementation and circuit testing.	Students will be able to experimentally verify the behavior of diodes, transistors, and operational amplifiers. They will gain proficiency in designing amplifiers, oscillators, and op-amp-based applications. Learners will develop competence in circuit assembly, measurement, and data interpretation.

MJPH10	**Laboratory - II**	This syllabus is framed to develop understanding of fundamental physical principles through laboratory experiments. To reinforce theoretical concepts of optics, wave motion, thermal physics and to encourage scientific inquiry and critical thinking by developing the skills in precise measurement and data handling.	• Students will gain hands-on experience with optical and thermal experiments. • They will learn to operate instruments like spectrometers, thermocouples, and diffraction setups. • They will understand the correlation between theoretical predictions and experimental results. • Students will be able to analyze, interpret, and report experimental data effectively.
MJPH11	**Quantum Mechanics - II**	To advance the understanding of quantum theory through the study of angular momentum, perturbation theory and scattering processes.	Students will be able to apply advanced quantum techniques to analyze systems with time-dependent and time-independent Hamiltonians and understand the principles underlying quantum scattering phenomena.
MJPH12	**Solid State Physics - I**	This course aims to provide a comprehensive understanding of the structural, electronic, thermal, magnetic, and dielectric properties of solids. Students will explore fundamental concepts such as crystal structures, imperfections, lattice dynamics, and X-ray diffraction techniques. The course also introduces semiconductors and their transport phenomena, magnetic behaviours of materials, and the principles of dielectric and ferroelectric materials. Through theoretical insights and experimental techniques, learners will develop a strong foundation in solid-state physics essential for advanced study and applications in materials science, nanotechnology, and electronic device engineering.	Students will be able to analyse and interpret the crystal structure and defects in solids using concepts such as Bravais lattices, Miller indices, and X-ray diffraction techniques. They will understand the principles governing the thermal, electrical, magnetic, and optical behaviours of solids, including phonon dynamics, semiconductor physics, and magnetic phenomena. The students will gain the ability to explain and apply the concepts of dielectric and ferroelectric properties in materials, including polarization mechanisms, hysteresis behaviour, and practical applications in devices.
MJPH13T **MJPH13P**	**Digital Electronics**	Studying digital electronics (Theory and Laboratory) aims to provide students with foundational knowledge of logic circuits. The objectives include enabling students to analyze, design, and implement digital circuits for various applications.	This study prepares students to understand the role of digital electronics in modern technology and systems.

MJPH14	**Statistical Mechanics**	A statistical mechanics course aims to provide an understanding how to bridge the macroscopic world with the microscopic ones by statistical average. The course will cover concepts like ensembles, entropy, and the connection between microscopic and macroscopic descriptions of matter, ultimately enabling students to predict and understand phenomena like heat capacity, phase transitions, and more.	A statistical mechanics course aims to equip students with the ability to understand the connection between microscopic properties of systems and their macroscopic thermodynamic behaviour. Students should be able to apply statistical methods to derive thermodynamic properties, understand different ensemble theories, differentiate between classical and quantum statistics, and analyse systems like ideal Bose and Fermi gases.

MJPH15	**Nuclear and Particle Physics**	The first part gives an introduction to the structure and properties of the nucleus and the second part introduces the properties of the elementary particles. Also, gives a basic understanding of the experimental tools used.	Students will develop an understanding of the basic constituents of the universe and prepare for a detailed study in the later part of the course.
MJPH16	**Laboratory - III**	• To conduct experimental studies on some physical phenomena introduced in the theoretical courses on Modern Physics, Quantum Mechanics and Solid State Physics which include photoelectric effect, magnetic hysteresis (B-H curve), susceptibility of a paramagnetic solution, Hall coefficient of a semiconductor sample etc. • To measure some physical parameters like Planck's constant, e/m of electron by Thomson's method, determination of the charge of electron by Millikan's oil drop method, band gap determination of a semiconductor by measuring its resistivity with temperature, velocity of ultrasonic wave in a liquid etc. and thus to verify the theoretical models / concepts experimentally. • To study the properties of light wave like polarization, optical activity etc.	Upon successful completion of this laboratory course, the students will be able to • Design advanced level experiments involving lights and understand the basic concepts of measurements of different physical parameters of sloid and liquid samples. • Study acousto-optic effects, transducers, modulators etc. • Have a better understanding of the different physical models and concepts put forward in their theory courses.
MJPH17	**Mathematical Physics - II**	• To make physics majors learn the mathematical techniques involving complex calculus, integral transforms and second order linear ordinary differential equations. • To ensure that the students are able to apply such techniques to solve problems arising in various areas of physics.	Upon successful completion of this course, students will be able to • Examine analyticity of complex functions, perform Laurent expansions and do non-trivial integrals and using contour integration. • Apply Fourier transforms to areas such as quantum mechanics, quantum field theory, and, Laplace transforms to electrical circuits. • Solve second order linear ODEs using power series and understand the applications in quantum mechanics. • Grasp allied topics such as conformal mapping, Mellin transforms and partial differential equations.
MJPH18	**Classical Electrodynamics**	This course provides an in-depth understanding of classical electrodynamics, from Maxwell's equations to the dynamics of charged particles in electromagnetic fields. It emphasizes both physical insight and mathematical rigor, incorporating relativistic formulations and radiation theory to prepare students for advanced studies in theoretical physics and related research.	By the end of this course, students will be able to: • Analyze electromagnetic fields using Maxwell's equations in both standard and covariant tensor form. • Understand radiation from accelerating charges, multipole expansions, and antenna theory. • Apply special relativity to electrodynamics using four-vectors and Minkowski space concepts. • Explore charged particle dynamics in electromagnetic and plasma environments. • Appreciate the historical and scientific contributions of J.C. Bose to electromagnetism and beyond.
MJPH19	**Atomic and Molecular Physics**	The course is intended to provide the basic understanding of interaction between	The course is designed so that the students will get the idea of updated

		electromagnetic field and atoms/molecule. In the present course, the students will find the applications of their theoretical understanding of classical electrodynamics and quantum mechanics. The concepts of fine structure and hyperfine structure splitting and their experimental realization are amazing. Additionally, the updated knowledge on the basic principles, the construction and the uses of different types of lasers are certainly interesting.	knowledge on atomic and molecular spectroscopy.
MJPH20-1	**Nanoscience**	The primary objective of this course is to provide students with a basic foundation in nanoscience, nanomaterials and their applications relevant to nanophysics.	The students will develop the basic understanding and foundation of nanomaterials, nanoscience or materials science. The course will certainly build a clear understanding of nanoscale systems, different synthesis of nanostructure materials, a few important characterization techniques and their working principles, the optical properties of nanomaterials and the electron transport through nanomaterials, and finally the applications of nanomaterials.
MJPH20-2	**Nuclear Science - Theory and Applications**	This course covers the various topics related to nuclear models, nuclear level structure, nuclear reactions and neutron physics. The course also emphasizes on a few topics related the detection techniques of nuclear radiations and their subsequent applications for the well-being of human society.	After the successful completion of the course, the students will learn about • various fascinating phenomena associated with the sub-atomic nuclear world; • important usage of nuclear science in everyday life.
MJPH20-3T	**Physics of Devices and Instruments**	• To introduce the fundamental behavior and modeling of semiconductor devices such as JFET, MOSFET, and CMOS. • To build conceptual understanding of power supply circuits, filters, and modulation techniques. • To provide foundational knowledge of integrated circuit (IC) fabrication and communication protocols.	After completing the theory component, students will be able to: • Analyze and interpret the characteristics of electronic devices and their frequency limitations. • Explain the working principles of power supply units, active/passive filters, and amplitude modulation systems. • Describe the fabrication steps of semiconductor devices and the standards in digital communication interfaces.
MJPH20-3P	**Physics of Devices and Instruments**	• To train students in designing and constructing basic electronic circuits using discrete and integrated components. • To enable hands-on learning of filter design, device characterization, and communication circuits. • To introduce basic PC-based interfacing using USB ports and serial communication.	Upon successful completion of the practical, students will be able to: • Construct and test power supplies, filter circuits, and modulation/demodulation setups. • Measure and interpret device characteristics of JFETs and MOSFETs, and build amplifiers using them. • Interface basic electronic circuits with a PC via USB and perform elementary control and sensing operations.
MJPH20-4	**Statistical Methods in Physics**	This course introduces fundamental and advanced statistical tools essential for analysing physical systems and experimental data. Emphasizing both theoretical rigour and practical application, it equips students with techniques in probability, statistical inference, data modelling, and modern machine learning	By the end of this course, students will be able to: • Apply probability theory and probability distributions to physical systems. • Analyze measurement uncertainties and perform rigorous error propagation.

		approaches relevant to contemporary physics research.	• Use methods such as maximum likelihood estimation, least squares, and hypothesis testing for data analysis. • Conduct multivariate statistical analysis and interpret results using regression and MANOVA. • Implement clustering, classification, and dimensionality reduction techniques including PCA, SVD, and neural networks for pattern discovery in complex datasets.
MJPH20-5	**Quantum Mechanics - III**	The course has two parts dealing with elementary topics from modern and advanced quantum mechanics**.** In the first part**,** a few concepts relevant for understanding quantum information theory and quantum computers will be introduced to the students. The second part introduces the basic approach and techniques for analyzing relativistic quantum systems within the framework of Dirac equation and second quantization.	The students will learn subtleties involved in measurement and interpretation of quantum states leading to Bell's inequality. The students will have a fair idea on quantum entanglement and it's quantification, dense coding, quantum teleportation and information entropy. The students will learn Dirac equation, concept of anti-particles and spin, and solutions of relativistic Hydrogen atom. The students will be familiar with the method of second quantization of free fields and computation of scattering cross section for an interacting ϕ^4 field theory of a real scalar field ϕ .
MJPH21	**Solid State Physics - II**	The main objective of this course is to teach students with a comprehensive understanding of the fundamental properties of solids, including their electronic, thermal, magnetic, and superconducting behaviour. It emphasizes theoretical models such as free electron theory, band theory, and quantum magnetism to explain material properties. The course also aims to develop analytical and problem-solving skills relevant to solid-state physics and its applications in advanced materials, electronic devices, and emerging technologies.	Upon successful completion of this course, students will be able to explain the electronic, thermal, magnetic and superconducting properties of solids using theoretical models. They will understand key concepts such as band theory, electron dynamics, magnetism, and superconductivity. Students will also develop problem-solving skills to analyse solid-state systems and apply this knowledge to the design and understanding of advanced materials and modern electronic devices.
MJPH22	**Laboratory - IV**	• To enable the students experimentally study different phenomena like magnetoresistance, electron spin resonance, Hall Effect, temperature dependence of dielectric constant etc. which they have studied mostly in their theory courses. • To introduce the students to the field of precision measurement with optical instruments: Michelson interferometer, Grating spectrometer for studying the vibrational coarse structure of diatomic molecules (iodine molecule), electro-optic rotation (Pockels effect), Zeeman effect etc.	Upon successful completion of this course, the students will be able to: • Understand the basic measurement techniques followed in laboratories – their merits and demerits. • Design an experimental set up based on their experience and exposure to this laboratory. • Develop new measuring instruments in future. • Have a better understanding of the actual physical phenomena which they have studied in theory courses.

MJPH23-1	**Advanced Electronics**	This course aims to provide an in-depth understanding of semiconductor devices, their physical principles, fabrication processes, and high-frequency applications. It covers fundamental topics such as carrier transport in semiconductors, p-n junction behaviour, and the operation of various electronic and optoelectronic devices including LEDs, laser diodes, and MOS capacitors. The course further explores advanced semiconductor processing techniques, microwave diodes, radar systems, filters, and transmission line theory, equipping students with the essential knowledge required for modern electronic and communication technologies.	Students will be able to explain the fundamental physics of semiconductor devices and analyse the behaviour of p-n junctions, diodes, and various electronic components using standard models and equations. They will gain practical understanding of semiconductor fabrication techniques and process technologies such as oxidation, ion implantation, lithography, and etching. The students will develop the ability to evaluate and apply the principles of microwave diodes, radar systems, filter design, and transmission line theory in high-frequency electronic and communication applications.
MJPH23-2	**Basics of Machine Learning**	This lab course introduces students to hands-on machine learning techniques using Python, with a focus on data processing, model implementation, and real-world applications in physics. It aims to build practical skills in regression, classification, clustering, neural networks, and deep learning laying the foundation for computational research and data-driven discovery in physical sciences.	By the end of this course, students will be able to: • Preprocess and analyze real-world data using tools like NumPy, Pandas, and scikit-learn. • Implement and evaluate machine learning models including regression, classification, and clustering algorithms. • Apply dimensionality reduction techniques and visualize high-dimensional data effectively. • Build and optimize artificial neural networks, including CNNs and RNNs, for complex tasks. • Explore physics-specific applications of ML such as particle detection, galaxy classification, and quantum state estimation.
MJPH23-3	**Advanced Mathematical Methods**	The objective of this course is to introduce students to the vector space, matrices, groups and tensors which are extremely essential for studying theoretical aspects of in classical and quantum physics.	After completing this course, students will be able to understand algebraic structures and basic properties of the linear vector spaces and groups. Moreover, they will be able to represent the linear transformations as matrices and to understand the basic properties of matrices. In addition, students will be able to identify different types of tensors and how they transform under coordinate transformations. Students will be able to use tensors in various physical contexts such as mechanics, electromagnetism, and general relativity.
MJPH23-4	**Laser Physics**	• To understand the emission-absorption processes and their classification. • To know about line broadening mechanisms, their roles in emission and absorption line shape. • To understand how to generate coherent electromagnetic radiation through interaction of radiation field with matter (atoms, molecules etc.) – polarization and complex susceptibility of an active medium. • To study the conditions of laser action, single mode and multi-mode operations.	Upon successful completion of the course the students will be able to • Understand how a laser actually works. • Have a clear conception about continuous wave and pulse mode operation of lasers, single mode and multimode operations and what types of lasers are suitable for what kind of operations. • Know about cavity electrodynamics. • Understand wavelength tuning mechanisms of lasers, application in spectroscopy.

		• To know about different types of lasers and their application in science, technology, industries as well as daily life.	
MJPH23-5	**Particle Physics**	Detailed study of the properties of the elementary particles and the underlying theoretical framework.	Students will have an up to date knowledge of the elementary particles, and be prepared to pursue advanced studies in the field.
MJPH23-6	**Introduction to Nonlinear Dynamics**	• To introduce the basic tools and techniques for analysing nonlinear dynamical systems • To familiarize the students with the fascinating nonlinear phenomena pervading in nature and use of nonlinear techniques to analyse real life problems.	The students • will learn phase-portrait and stability analysis of dynamical systems, along with analysing bifurcation patterns; • will have a fair idea on solvability of dynamical systems, chaos and fractals after completing the course.
MJPH23-7	**Tools and Techniques for Nuclear Physics Experiments**	This module is associated with detector systems, accelerators, and various ancillary devices including nuclear electronics, which are required for setting up nuclear physics experiments for detecting nuclear radiation. Although the topics covered are based on a specific laboratory course, the treatment is general and is made without specific reference to any particular experiment.	The students will learn different methods of the experimental techniques for nuclear physics experiments. Moreover, it gives the students an idea of the state of the art and the incredible advances in modern day nuclear physics techniques.
MJPH23-8	**Astronomy and Astrophysics**	The course will give the fundamental concepts of astrophysics and astronomy, including positional astronomy, astronomical techniques, stellar evolution, the solar system, and galaxies. This course will also cover the key principles and techniques used in astronomy and astrophysics.	Students will be able to understand the origin and evolution of the Universe. Students will have the idea of the instruments implemented for astronomical observation, the formation of stars and their evolution with time, the physical properties of the Sun, and the components of the solar system. Students will understand the origin and evolution of galaxies, the presence of dark matter, and the large-scale structures of the Universe.

MINOR COURSES in PHYSICS

MNPH01T	**Mechanics**	This is a course is meant for students of varied background. It is designed to provide the basic understanding of different aspects of mechanics including Newtonian mechanics, oscilllator dynamics, rotational dynamics. It also provides understanding of elastic properties of matter.	This course will help in developing the concept of Inertial and non-inertial frame in the light of Newtonian mechanics, conservative systems and their characteristics, central force fields and the planetary motion, rotational dynamics and so on. Some mathematical tools like vector algebra, methods for solving differential equations are also included; which will help the students in solving mathematical and numerical problems of physics. Thus, this course will help in understanding the physical aspects of other science subjects.
MNPH01P	**Mechanics**	The primary objectives of a mechanics practical course are to provide hands-on experience in applying theoretical concepts of mechanics to real-world scenarios, develop experimental skills, and enhance problem-solving abilities.	Students will learn to use laboratory equipment, collect and analyze data, and interpret results in the context of mechanical systems. Ultimately, the course aims to bridge the gap between theory and practice, preparing students for more advanced studies and professional applications.
MNPH02T	**Electricity and Magnetism**	To give a comprehensive introduction to electromagnetic phenomena at an appropriate level to students majoring mostly in mathematics or chemistry. The topics mainly covered are electrostatics, magnetostatics, and electromagnetic induction.	Upon successful completion of the course, students will be able to develop a basic understanding of electromagnetic phenomena in their daily lives. They shall also be able to correlate the knowledge gained from this course to topics in their respective major subjects.
MNPH02P	**Electricity and Magnetism**	The objective of this practical course is to give an idea about handling common electrical equipment, taking measurements with them, constructing simple electrical circuits and developing practical knowledge of the theoretical aspects they have studied.	In this course students will learn to make simple circuits on breadboard and also do experiments based Wheatstone's Bridge principle. Besides this they will verify various Network theorems, study characteristics of circuits involving non-linear impedance elements like inductors and capacitors. Thus, they will have a fair practical knowledge which will complement their theoretical study and make them more practical-savvy.
MNPH03T	**Thermal Physics**	• To provide students with a solid foundation in kinetic theory, laws of	At the end of the course Students will gain a comprehensive understanding

		thermodynamics, thermodynamic potentials, and radiation and to explain the fundamental principles governing energy, heat, and entropy in physical systems. • To encourage analytical thinking through the application of theoretical concepts to practical situations. Also the course introduce the contributions of Indian scientists, particularly Meghnad Saha in the context of thermal physics.	of gas behavior, thermodynamic laws, and radiation theory. The course will help to apply these concepts to real-world thermodynamic systems and solve related problems. Students will develop problem-solving skills and enhance their ability to analyze thermal processes. Students will get a flavour India's scientific contributions to the field, especially on thermal physics.
MNPH03P	**Thermal Physics**	• To provide hands-on experience in measuring thermal properties such as conductivity, resistance, and heat energy and develop the understanding the practical application of thermal physics laws using standard lab equipment. • To develop experimental skills, data analysis, and scientific reasoning in thermal phenomena.	• Students will accurately perform experiments related to heat, temperature, and thermal conductivity. They will get ability to interpret experimental results and understand the behavior of different materials under thermal conditions. • Students will gain proficiency in using thermal instruments and reporting scientific data effectively.
MNPH04T	**Waves and Optics**	This course (Theory & Practical) covers the various topics related to wave motion and simple harmonic oscillations. It also covers a few topics on wave optics such as interference, diffractions, and polarization. The course has been designed to impart knowledge on the different topics related to wave motion and the different phenomena representing the wave nature of light.	After the successful completion of the course, the students will • understand the underlying features associated with interference, diffraction, and polarization phenomena of light wave; • learn about how to deal with the superposition technique of wave under different conditions in order to generate the different kinds of wave patterns.
MNPH04P	**Waves and Optics**	The primary objective of this practical course is to provide hands-on experience and conceptual understanding of fundamental principles in wave optics and optical instrumentation.	Students will gain practical understanding of wave motion, resonance, and optical interference. They will learn to determine key optical parameters such as wavelength, refractive index, and dispersive power. Hands-on experience with optical instruments like prisms, gratings, and lasers will enhance their experimental skills.

SKILL ENHANCEMENT COURSES in PHYSICS

SECPH01	**Basic Computer Programming**	This course introduces undergraduate physics students to the fundamental principles of computer programming and scientific computation. It aims to develop algorithmic thinking and practical coding skills essential for solving physical problems numerically, using C as the core programming language. Emphasis is placed on numerical methods, error analysis, and real-world applications.	By the end of this course, students will be able to: • Understand basic computer architecture and perform binary and floating-point computations. • Write and debug C programs to solve mathematical and physical problems. • Implement numerical methods like interpolation, integration, and ODE solvers. • Analyze computational errors and apply scientific computing techniques effectively. • Model physical systems such as radioactive decay, electrical circuits, and pendulum motion using code. • Apply Monte Carlo simulations for problems involving random processes.
SECPH02	**Basic Instrumentation Skills**	Students will be introduced to the basic idea of measurement and estimation of uncertainty in a measurement. They will learn the working principles of some common electromechanical, electronic and digital instruments, oscilloscopes, analog to digital conversion and vice-versa.	Students will learn the importance of measurement in Physics and understand the basics of different instruments – their advantages and limitations.
	Renewable Energy and Energy Harvesting	Nowadays, global warming , air, water and land pollution are global issues which are fall out of burning fossil fuels. Moreover, due to depletion of non-renewable resources like petroleum and coal, energy crisis in future is looming large. Hence study of future sources of energy and techniques of harnessing them is the demand of the time. This course is designed	This course gives a comprehensive idea about the renewable energy resources like solar, wind, biomass, geothermal, ocean energy , tidal energy, hydel energy etc. and provides an in depth understanding of the techniques used for producing " Green" power from them. The syllabus also includes the " Photovoltaic" and " Piezoelectric " technologies, their applications and the novel materials exhibiting these effects. Thus, the knowledge of all these technologies will provide a fair idea about the subject thus kindling their interest , and they may take up research in this very interesting field.

		to provide this knowledge and outlook.	
	Radiation Safety	Natural radioactive substances and laboratory-produced ones are hazardous to our health, if we don't handle them with precautions. This course tells about the methodology of handling radioactive sources and the associated safety measures.	• The students will learn about the know-how of the radioactive sources and their controlled use by different techniques. • The students will also understand about the important usage of the nuclear radiation in everyday life, and its safety measures.
SECPH03	**Computational Methods in Physics**	The objective of this course is to develop the skills of the students in using C++ programming for solving physical problems, with emphasis on numerical methods, and efficient algorithm design relevant to physics research and applications.	Upon successful completion of this course, students will be able to design and implement C++ programs to model and solve a range of physical problems. Furthermore, the students will become expert in applying numerical methods for scientific computing and research applications.

MULTIDISCIPLINARY COURSE in PHYSICS

MDPH01	**Introduction to Astronomy and Astrophysics**	The course will give a comprehensive introduction to the measurement of basic astronomical parameters such as astronomical scales, luminosity, and astronomical quantities. It will give an overview of key developments in observational astrophysics.	Upon completion of this course, students will be able to understand the origin and evolution of the Universe. Students will have the idea of the instruments implemented for astronomical observation, the formation of planetary systems and their evolution with time, the physical properties of the Sun and the components of the solar system, and stellar and interstellar components of our Milky Way galaxy. Students will understand the origin and evolution of galaxies, the presence of dark matter, and the large-scale structures of the Universe.
MDPH02	**Radiation Safety**	Natural radioactive substances and laboratory-produced ones are hazardous to our health, if we don't handle them with precautions. This course tells about the methodology of handling radioactive sources and the associated safety measures.	• The students will learn about the know-how of the radioactive sources and their controlled use by different techniques. • The students will also understand about the important usage of the nuclear radiation in everyday life, and its safety measures.
MDPH03	**Physics in Everyday Life**	This course aims to make physics accessible, relevant, and exciting by connecting core physical principles to everyday experiences. It encourages students to appreciate how physics governs the operation of household appliances, natural phenomena, and biological systems, fostering curiosity and scientific literacy.	By the end of this course, students will be able to: • Understand and explain common physical phenomena in daily life using fundamental physics concepts. • Analyze the working principles of everyday devices like refrigerators, microwaves, and smartphones. • Relate physics to natural events such as rainbows, eclipses, and tides with scientific clarity. • Explore the role of physics in biological systems from breathing and blood flow to bird flight and plant processes. • Develop a lifelong appreciation for the presence and power of physics in the world around them.

MAJOR COURSES IN PHYSICS
[Discipline-Specific Core Courses]

PAPER: MATHEMATICAL METHODS - I
PAPER CODE: MJPH01
MARKS: 100; CREDIT: 4
LECTURES: 60 HRS.

Number System in Ancient India: Methods of Indian numerals, Bakshali manuscript and invention of the zero, concept of large and small numbers and scales, Aryabhata and his decimal number system (*dashamik sthanmaan*), concept of Pi, Shulva-sutra, Baudhayana, Brahmagupta and growth of geometry, Vedic Mathematics. **(6 Lectures)**

Vector Calculus: Review of vectors: Properties of vectors under rotations. Scalar product and its invariance under rotations. Vector product, Scalar triple product and their interpretation in terms of area and volume respectively, Vector triple product, Scalar and Vector fields.
Vector Differentiation: Directional derivatives and normal derivative. Gradient of a scalar field and its geometrical interpretation. Divergence and curl of a vector field. Del and Laplacian operators. Vector identities.
Vector Integration: Ordinary Integrals of Vectors. Multiple integrals, Jacobian. Notion of infinitesimal line, surface and volume elements. Line, surface and volume integrals of Vector fields. Flux of a vector field. Gauss' divergence theorem, Green's and Stokes Theorems and their applications. **(12 Lectures)**

Ordinary and Partial Differential Equation: First Order and Second Order Differential equations: First Order Differential Equations and Integrating Factor. Homogeneous Equations with constant coefficients. Wronskian and general solution. Statement of existence and Uniqueness Theorem for Initial Value Problems. Particular Integral.
Calculus of functions of more than one variable: Partial derivatives, exact and inexact differentials. Integrating factor, with simple illustration. Constrained Maximization using Lagrange Multipliers.
Solutions to partial differential equations, using separation of variables: Laplace's Equation in problems of rectangular, cylindrical and spherical symmetry. Wave equation and its solution for vibrational modes of a stretched string, rectangular and circular membranes. Diffusion Equation. **(15 Lectures)**

Orthogonal Curvilinear Coordinates: Orthogonal Curvilinear Coordinates, Derivation of Gradient, Divergence, Curl and Laplacian in Cartesian, Spherical and Cylindrical coordinate Systems. **(7 Lectures)**

Introduction to probability: Independent random variables: Probability distribution functions; binomial, Gaussian, and Poisson, with examples. Mean and variance. Dependent events: Conditional Probability. Bayes' Theorem and the idea of hypothesis testing. **(5 Lectures)**

Some Special Integrals: Beta and Gamma Functions and Relation between them. Expression of Integrals in terms of Gamma Functions. Dirac Delta function and its properties. **(5 Lectures)**

Fourier Series: Periodic functions. Orthogonality of sine and cosine functions, Dirichlet Conditions (Statement only). Expansion of periodic functions in a series of sine and cosine functions and determination of Fourier coefficients. Complex representation of Fourier series. Expansion of functions with arbitrary period. Expansion of non-periodic functions over an interval. Even and odd functions and their Fourier expansions. Application. Summing of Infinite Series. Term-by-Term differentiation and integration of Fourier Series. Parseval Identity. **(10 Lectures)**

Suggested References:

1. Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber, F.E. Harris, 2013, 7th Edn., Elsevier.
2. An introduction to ordinary differential equations, E.A. Coddington, 2009, PHI learning
3. Differential Equations, George F. Simmons, 2007, McGraw Hill.
4. Mathematical Tools for Physics, James Nearing, 2010, Dover Publications.
5. Mathematical methods for Scientists and Engineers, D.A. McQuarrie, 2003, Viva Book.
6. Advanced Engineering Mathematics, D.G. Zill and W.S. Wright, 5 Ed., 2012, Jones and Bartlett Learning
7. Mathematical Physics, Goswami, 1st edition, Cengage Learning
8. Engineering Mathematics, S.Pal and S.C. Bhunia, 2015, Oxford University Press
9. Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India.
10. Essential Mathematical Methods, K.F.Riley & M.P.Hobson, 2011, Cambridge Univ. Press
11. Fourier Analysis by M.R. Spiegel, 2004, Tata McGraw-Hill.
12. Mathematics for Physicists, Susan M. Lea, 2004, Thomson Brooks/Cole.
13. Differential Equations, George F. Simmons, 2006, Tata McGraw-Hill.
14. Partial Differential Equations for Scientists & Engineers, S.J. Farlow, 1993, Dover Pub.
15. Engineering Mathematics, S.Pal and S.C. Bhunia, 2015, Oxford University Press
16. Mathematical methods for Scientists & Engineers, D.A. McQuarrie, 2003, Viva Books
17. History of science and technology in ancient India: the beginnings, Debiprasad Chattopadhyaya, 1986, Firma KLM Pvt. Ltd.
18. A Concise History of Science in India, D.M. Bose, S.N. Sen, B.V. Subbarayappa, 1967, Orient Blackswan, Hyderabad.

PAPER: MECHANICS
PAPER CODE: MJPH02
MARKS: 100; CREDIT: 4
LECTURES: 60 HRS.

Fundamentals of Dynamics: Dynamics of a system of particles; Principle of conservation of momentum; Elastic and inelastic collisions between particles; Centre of Mass frame and Laboratory frame. **(6 Lectures)**

Rotational Dynamics: Angular momentum of a system of particles, Torque; Moment of Inertia, Calculation of moment of inertia for different geometrical objects; Kinetic energy of rotation; Motion involving both translation and rotation. **(10 Lectures)**

Motion of a particle under a central force field: Two-body problem and its reduction to one-body problem and its solution; Conservation of angular momentum and energy; Energy equation and energy diagram; Kepler's Laws; Runge-Lenz vector; Satellite in circular orbit and applications; Geosynchronous orbits; Weightlessness; Basic idea of global positioning system (GPS). **(10 Lectures)**

Non-inertial Systems: Non-inertial frames and fictitious forces; Uniformly rotating frame; Laws of Physics in rotating coordinate systems; Centrifugal force, Coriolis force and its applications; Components of Velocity and Acceleration in Cylindrical and Spherical Coordinate Systems. **(8 Lectures)**

Fluid Dynamics: Kinematics of Moving Fluids, Density and pressure in a fluid; An element of fluid and its velocity; Continuity equation and mass conservation; Stream-line motion, laminar flow; Bernoulli's equation; Poiseuille's equation for flow of a liquid through a pipe; Navier-Stokes equation, qualitative description of turbulence, Reynolds number. **(12 Lectures)**

Special Theory of Relativity: Michelson-Morley Experiment; Postulates of Special Theory of Relativity; Galilean Transformations; Lorentz Transformations; Time-dilation, Length contraction and twin paradox; Relativistic transformation of velocity; Relativistic addition of velocities; Variation of mass with velocity; Massless Particles; Mass-energy Equivalence; Relativistic Doppler effect; Relativistic kinematics, Collision and decay for a two-body system; Transformation of Energy and Momentum; Space-time diagrams. **(14 Lectures)**

Suggested References:

1. An introduction to mechanics, D. Kleppner, R. J. Kolenkow, 1973, McGraw-Hill.
2. Mechanics, Berkeley Physics, vol.1, C. Kittel, W. Knight, et.al. 2007, Tata McGraw-Hill.
3. Physics, Resnick, Halliday and Walker 8/e. 2008, Wiley.
4. Analytical Mechanics, G.R. Fowles and G.L. Cassiday. 2005, Cengage Learning.
5. Introduction to Special Relativity, R. Resnick, 2005, John Wiley and Sons.
6. University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole.
7. Mechanics, D.S. Mathur, S. Chand and Company Limited, 2000
8. Theoretical Mechanics, M.R. Spiegel, 2006, Tata McGraw Hill.

PAPER: ELECTRICITY & MAGNETISM
PAPER CODE: MJPH03
MARKS: 100; CREDIT: 4
LECTURES: 60 HRS.

Electrostatics: Gauss's law of electricity and its application to charge distribution with spherical, cylindrical and planer symmetry. Electrostatic potential of a localized charge distribution. Multipole expansion of electric potential. Laplace and Poisson equations and their applications**.** Method of image Charge and its application to plane infinite sheet and sphere. Electric field in dielectric media and boundary conditions. Displacement vector **D**. Relations between **E, P** and **D.** **(12 Lectures)**

Magnetostatics: Gauss law of Magnetism. Ampere's law and its application to solenoid and toroid, Magnetic vector potential. Multipole expansion of magnetic vector potential. Magnetic field in material media, Magnetization vector **M.** Magnetic intensity **H.** Boundary conditions. Magnetic susceptibility and permeability. Relations between **B, H, M, B-H** Curve and hysteresis. **(12 Lectures)**

Electromagnetism: Faraday's law, Displacement current and generalized Ampere's law. Maxwell's equations. Lorentz force. Motion of a charged particle in constant magnetic field. Scalar and Vector Potentials. Gauge Transformations. Wave Equation. Poynting Vector and Poynting Theorem. Electromagnetic field energy density. (**10 Lectures)**

Electrical Circuits: Kirchhoff's laws for AC circuits. Complex Reactance and Impedance. Series and parallel LCR Circuits - (1) resonance, (2) power dissipation and (3) quality factor, and (4) band width. **(6 Lectures)**

Network Theorems: Ideal Constant-voltage and Constant-current Sources. Thevenin theorem, Norton theorem, Superposition theorem, Reciprocity theorem, Maximum Power Transfer theorem. **(4 Lectures)**

Ballistic Galvanometer: Torque on a current Loop. Ballistic Galvanometer: Current and Charge Sensitivity. Electromagnetic damping. Logarithmic damping. CDR. **(4 Lectures)**

EM Wave Propagation: EM wave equation and its solution. Transverse nature of plane EM waves. Polarization of EM waves--linear, circular and elliptical polarized waves. Stokes parameters. Propagation of EM waves in different media: free space, dielectrics. Refractive index and dielectric constant. Boundary conditions at a plane interface between two linear media. Reflection and transmission at normal and oblique incidence in linear media. Fresnel's equations. Brewster's angle. Reflection & Transmission coefficients. Total internal reflection. Propagation of EM Waves through conducting media: Reflection at the interface of dielectric and conductor. Relaxation time. Skin depth. **(12 Lectures)**

Suggested References:

1. Foundations of Electricity & Magnetism, B. Ghosh, Books & Allied (P) Ltd., 5th Edn.
2. Electricity And Magnetism, A.B. Gupta, Books & Allied (P) Ltd.
3. Electricity, Magnetism & Electromagnetic Theory, S. Mahajan and Choudhury, 2012, Tata McGraw Hill
4. Electricity and Magnetism, Edward M. Purcell, 1986 McGraw-Hill Education
5. Introduction to Electrodynamics, D.J. Griffiths, Pearson Education India
6. Classical Electrodynamics, J.D. Jackson, John Wiley & Sons
7. Electrodynamics, F. Melia, The University of Chicago Press
8. Classical Theory of Fields, L.D. Landau, E.M. Lifshitz, Butterworth-Heinemann

PAPER: LABORATORY - I
PAPER CODE: MJPH04
MARKS: 100; CREDIT: 4
LECTURES: 120 HRS.

List of Practical:

Group - A

1. To determine the Moment of Inertia of a Flywheel.
2. To determine Coefficient of Viscosity of water by Capillary Flow Method (Poiseuille's method).
3. To determine the Young's Modulus of a metallic rod using cantilever method.
4. To determine the Modulus of Rigidity of a Wire by static method.
5. To determine the Modulus of Rigidity of a Wire by dynamical method.
6. To determine the elastic constants of a wire by Searle's method.
7. To determine g and velocity for a freely falling body using Digital Timing Technique
8. To determine the value of g using Bar Pendulum.
9. To determine the value of g using Kater's Pendulum.

Group - B

1. To study the characteristics of a series RC Circuit.
2. To determine an unknown Low Resistance using Potentiometer.
3. To determine an unknown Low Resistance using Carey Foster's Bridge.
4. To verify the Thevenin and Norton theorems.
5. To verify the Superposition and Maximum power transfer theorems.
6. To study response curve of a Series LCR circuit and determine its (a) Resonant frequency, (b) Impedance at resonance, (c) Quality factor Q, and (d) Band width.
7. To study the response curve of a parallel LCR circuit and determine its (a) Anti-resonant frequency and (b) Quality factor Q.
8. To measure the charge and current sensitivity and CDR of Ballistic Galvanometer
9. To determine a high resistance by leakage method using Ballistic Galvanometer.
10. To measure the field strength B and its variation in a solenoid (determine dB/dx)

Each student has to perform two experiments, one from each group, during semester examination.

PAPER: WAVES AND OPTICS
PAPER CODE: MJPH05
MARKS: 100; CREDIT: 4
LECTURES: 60 HRS.

Superposition of Collinear Harmonic oscillations: Linearity and Superposition Principle. Superposition of two collinear oscillations having (1) equal frequencies and (2) different frequencies (Beats). Superposition of N collinear Harmonic Oscillations with (1) equal phase differences and (2) equal frequency differences. **(3 Lectures)**

Superposition of two perpendicular Harmonic Oscillations: Graphical and Analytical Methods. Lissajous Figures with equal an unequal frequency and their uses. **(2 Lectures)**

Wave Motion: Plane and Spherical Waves. Longitudinal and Transverse Waves. Plane Progressive (Travelling) Waves. Wave Equation. Particle and Wave Velocities. Differential Equation. Pressure of a Longitudinal Wave. Energy Transport. Intensity of Wave. Water Waves: Rippled, Velocity of Transverse Vibrations of Stretched Strings. **(6 Lectures)**

Superposition of Harmonic Waves: Standing (Stationary) Waves in a String: Fixed and Free Ends. Analytical Treatment. Phase and Group Velocities. Changes with respect to Position and Time. Energy of Vibrating String. Transfer of Energy. Normal Modes of Stretched Strings. Plucked and Struck Strings. Melde's Experiment. Superposition of N Harmonic Waves. **(6 Lectures)**

Wave Optics: Electromagnetic nature of light. Definition and properties of wave front. Huygens Principle. Temporal and Spatial Coherence. **(2 Lectures)**

Interference: Division of amplitude and wavefront. Young's double slit experiment. Lloyd's Mirror and Fresnel's Biprism. Phase change on reflection: Stokes' treatment. Interference in Thin Films: parallel and wedge-shaped films. Fringes of equal inclination (Haidinger Fringes); Fringes of equal thickness (Fizeau Fringes). Newton's Rings: Measurement of wavelength and refractive index. **(9 Lectures)**

Interferometer: Michelson Interferometer- (1) Theory, (2) Determination of Wavelength, (3) Wavelength Difference, (4) Refractive Index, and (5) Visibility of Fringes. Fabry-Perot interferometer. **(4 Lectures)**

Diffraction: Kirchhoff's Integral Theorem, Fresnel-Kirchhoff's Integral formula. (Qualitative discussion only), Fraunhofer diffraction: Single slit. Circular aperture, Resolving Power of a telescope, Double slit. Multiple slits. Diffraction grating. Resolving power of grating. Fresnel Diffraction: Fresnel's Assumptions. Fresnel's Half-Period Zones for Plane Wave. Explanation of Rectilinear Propagation of Light. Theory of a Zone Plate: Multiple Foci of a Zone Plate. Fresnel's Integral, Fresnel diffraction pattern of a straight edge, a slit and a wire. **(12 Lectures)**

Polarization: Transverse nature of electromagnetic waves, Brewster's law, Plane polarized light – production and analysis, Polarization by Double Refraction, circular and elliptical polarizations. Nicol Prism, Production & detection of Plane, Circularly and Elliptically Polarized Light, Quarter-Wave and Half-Wave Plates. Babinet Compensator and its uses. **(10 Lectures)**

Indian contribution to the subject:
Concept of light in ancient India; Prakash; Hints in Rigveda; Kanada's Vaisheshika Sutras; Nature of light; Surya Siddhanta by Aryabhata; Bhaskaracharya's descript of refraction through a prism; Shiddhanta Shiromoni. **(6 Lectures)**

Suggested References:
1. Waves: Berkeley Physics Course, vol. 3, Francis Crawford, 2007, Tata McGraw-Hill.
2. Fundamentals of Optics, F.A. Jenkins and H.E. White, 1981, McGraw-Hill
3. Principles of Optics, Max Born and Emil Wolf, 7th Edn., 1999, Pergamon Press.
4. Optics, Ajoy Ghatak, 2008, Tata McGraw Hill
5. The Physics of Vibrations and Waves, H. J. Pain, 2013, John Wiley and Sons.
6. The Physics of Waves and Oscillations, N.K. Bajaj, 1998, Tata McGraw Hill.
7. Fundamental of Optics, A. Kumar, H.R. Gulati and D.R. Khanna, 2011, R. Chand Publications.

PAPER: CLASSICAL MECHANICS
PAPER CODE: MJPH06
MARKS: 100; CREDIT: 4
LECTURES: 60 HRS.

Lagrangian Dynamics: Review of Newtonian Mechanics; Generalized coordinates and velocities, Generalized force; D'Alembert's principle; Lagrangian and Euler-Lagrange equations of motion; Lagrangian formalism and its applications in different systems such as Simple Harmonic Oscillators, falling body in uniform gravity, coupled oscillators; Hamilton's principle, Derivation of Derivation of Euler-Lagrange equations of motion from Hamilton's principle; Shortest distance between two points, Brachistochrone problem; Symmetry and conservation laws; Noether's theorem; Canonical momenta and Hamiltonian; Hamilton's canonical equations of motion; Relativistic Lagrangian and its applications for some systems. **(15 Lectures)**

Canonical Transformations: Canonical transformations, examples of canonical transformations; Lagrange and Poisson bracket and their applications, invariance of Poisson bracket; Infinitesimal canonical transformation, generators for infinitesimal symmetry transformation; Integral invariance of Poincare, conservation theorems and angular momentum relation in Poisson bracket; Liouville theorem. **(15 Lectures)**

Hamilton-Jacobi Equation: Hamilton-Jacobi equation and characteristics functions, physical significance of this function, application of Hamilton-Jacobi equation, action and angle variables, importance of action angle variable, semi-classical approach to quantum mechanics from classical mechanics. **(12 Lectures)**

Rigid Bodies: Independent coordinates, orthogonal transformations and rotations (finite and infinitesimal), Euler theorem, Euler angle, inertia tensor and principal axes system, Euler equations, heavy symmetrical top. **(8 Lectures)**

Theory of Small Oscillations: Minima of potential energy and points of stable equilibrium, expansion of the potential energy around a minimum; small amplitude oscillations about the minimum, normal modes of oscillations; example of N identical masses connected in a linear fashion to (N-1) identical springs; eigen modes and eigen frequencies; normal coordinates. **(10 Lectures)**

Suggested References:

1. Classical Mechanics – H. Goldstein, Addison Wesley
2. Mechanics – L.D. Landau and E.M. Lifshitz, Pearson New International Edition
3. Classical Mechanics – N.C. Rana and P.S. Joag, Tata McGraw-Hill
4. Classical Dynamics – S.T. Thornton and J.B. Marion, Thomson Brooks Cole Publishing
5. Classical Mechanics – T.W.B. Kibble and F.H. Bershire, Imperial College Press
6. Theoretical Classical Mechanics – M.R. Spiegel (Schaum's Outline Series), Tata McGraw Hill, New Delhi

PAPER: THERMAL PHYSICS
PAPER CODE: MJPH07
MARKS: 100; CREDIT: 4
LECTURES: 60 HRS.

Ideal Gases: Principles underlying the kinetic theory of gases and the notion of random motion. The Maxwell-Boltzmann distribution law describing the spread of velocities in an ideal gas and its confirmation through experimentation. Understanding temperature through the analysis of molecular speeds at a microscopic level. Doppler broadening of Spectral Lines and Sterns Experiment. The Mean, RMS, and Most Probable Speeds. The degrees of Freedom. Law of equipartition of energy (statement only). Analysis of specific Heat of Gases. **(8 Lectures)**

Collision and transport: The concept of mean Free Path and collision Probability. The estimation of Mean Free Path from (a) Clausius treatment and (b) Maxwell's treatment. Thermal Conductivity and Diffusion. Brownian motion and its significance. **(5 Lectures)**

Real Gases: Departures from the Ideal gas equation and the Virial equation. Investigations by Andrews on CO_2 gas. Determination of critical constants and the transition between liquid and gaseous Phases. Distinctions between vapour and gas. Exploration of Boyle temperature. Utilization of the Van der Waals equation of state for real gases and the significance of critical constants. Understanding the Triple Point and its implications. Comparison with experimental data through p-V diagrams. Analysis of Joule's experiment and the concept of free adiabatic expansion in an ideal gas. Examination of the Joule-Thomson Porous Plug experiment and its relevance in real gas behaviour. Investigating the Joule-Thomson effect for Van der Waals gases, including the determination of the Temperature of inversion and Joule-Thomson cooling. **(10 Lectures)**

Radiation: Exploring Blackbody Radiation and its dependence on Temperature. Kirchhoff's Law of radiation and its implications. The Stefan Boltzmann Law - quantification of the total energy of radiation. Rayleigh-Jeans' Law and its description of energy distribution within blackbody radiation. Wien's Displacement Law and its Significance. Addressing the shortcomings of Rayleigh-Jeans' Law, notably the Ultraviolet Catastrophe. Introducing Planck's Quantum Postulates and their impact. Validating Planck's Law of Blackbody Radiation through experimental evidence. Deduction of Rayleigh-Jeans' Law, Stefan-Boltzmann Law, and Wien's Displacement Law from Planck's Law. **(5 Lectures)**

An Introduction to Thermodynamics: Understanding the Zeroth and First Laws and the Concept of Thermodynamic Equilibrium. Exploring the Zeroth Law's implications for Temperature and its role in defining equilibrium states. Investigating Work and Heat Energy in thermodynamic processes. Delving into the First Law of Thermodynamics and its implications for energy conservation. Introduction to State Functions and their Significance. Examining the Differential Form of the First Law and its applications. Understanding Internal Energy and its role in thermodynamic systems. Exploring the General Relationship between Specific Heat at Constant Pressure (C_p) and Specific Heat at Constant Volume (C_v). Analyzing Work Done during Isothermal and Adiabatic Processes. **(6 Lectures)**

Second Law of Thermodynamics: Reversible and Irreversible processes. Conversion of work into heat and vice versa. Analysis of Heat Engines and their operation. Carnot cycle, Carnot engine, and its efficiency. Studying refrigerators and their efficiency. The Kelvin-Planck and Clausius Statements and their

Equivalence. Understanding Carnot Theorem. Introduction to the thermodynamic scale of temperature and its relationship to the perfect gas scale. **(8 Lectures)**

Entropy: State function and concept of entropy. Change of entropy between two states. Clausius Theorem and Clausius Inequality. Generalized form of First and Second Laws of Thermodynamics in terms of Entropy. The entropy of an ideal Gas, Van der Waal's gas, and gas mixtures. Considering Entropy changes within systems and their surroundings. Entropy Changes in Reversible and Irreversible Processes. Principle of Increase of Entropy. Temperature-Entropy Diagrams for different engines. Third law of thermodynamics and unattainability of zero temperature. **(6 Lectures)**

Thermodynamic Potentials: Understanding extensive and intensive thermodynamic variables. Exploring the definitions, properties, and applications of Thermodynamic Potentials. Understanding magnetic work and cooling through adiabatic demagnetization. First and Second-Order phase transitions, Illustrated with Examples. **(5 Lectures)**

Maxwell's Thermodynamic Relations: Exploring the Derivations of Maxwell's Relations. Applications of Maxwell's Relations in Various Scenarios: Clausius-Clapeyron Equation, Determination of C_p-C_v values, Utilization in TdS Equations, Calculation of Joule-Kelvin Coefficient for Ideal and Van der Waals Gases. **(7 Lectures)**

Suggested References:

1. Heat and Thermodynamics: Mark W. Zeemansky and Richard Dittman, Special Indian Edition (8th edition), McGraw-Hill Education.
2. A Treatise of Heat, Meghnad Saha and B. N. Srivastava, 1958, Indian Press.
3. Thermal Physics, S. C. Garg, R. M. Bansal and C. K. Ghosh, 2nd Edition, 1993, Tata McGraw-Hill.
4. Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2010, Springer.
5. Thermodynamics, Kinetic Theory and Statistical Thermodynamics, F. W. Sears and G. L. Salinger, 3rd edition, 1998, Narosa.
6. Concepts of Thermal Physics, Stephen J. Blundell and Katherine M. Blundell, 2nd edition, 2009. Oxford University Press.
7. An Introduction to Thermal Physics, Daniel V. Schroeder, 1999 Pearson Education.
8. Fundamentals of statistical and thermal physics: Frederick Reif.
9. Thermodynamics and an introduction to thermostatistics, Herbert B. Callen, 2nd edition, Wiley, 1985.
10. Thermal Physics, A. B. Gupta and H. P. Roy, 3rd edition, Books and Allied Ltd., 2010.

PAPER: QUANTUM MECHANICS - I
PAPER CODE: MJPH08
MARKS: 100; CREDIT: 4
LECTURES: 60 HRS.

Introduction: Black body radiation; Planck's quantum; Photo-electric effect and Compton scattering; Atomic spectra & the Bohr model of the Hydrogen atom; The Stern-Gerlach Experiment – Angular momentum and spin; Young's double slit thought experiment; de Broglie wave-length and matter waves; Davisson-Germer experiment. **(8 Lectures)**

Basic postulates of QM & General Discussions: Schrödinger wave equation, Interpretation of Wave Function – Probability, probability current densities and continuity equation; Conditions for Physical Acceptability of Wave Functions – Normalization, continuity, etc. ; Linearity and Superposition Principles; Time-evolution of a quantum state for a time-independent Hamiltonian & Unitarity; Stationery states – Eigenvalues and Eigenfunctions; Role of boundary conditions; Operators, Expectation value & observable; Position-momentum uncertainty principle. **(10 Lectures)**

Free Particle: Wave Function of a Free Particle; Box-normalization; Application of superposition principles to the spread of Gaussian wave-packet for a free particle in one dimension; wave packets, Fourier transforms and momentum space wavefunction. **(5 Lectures)**

QM of a particle in presence of a potential: General discussion of bound states in an arbitrary potential; application to one-dimensional problem – square & rigid well potentials; delta-function potential; Tunnelling in one dimension - across a step potential and across a rectangular potential barrier; Particle in a three dimensional box; Technological applications -- Principles of Scanning Tunnelling Microscope, quantum well & quantum dots etc. **(12 Lectures)**

Simple Harmonic Oscillator (SHO): Schrödinger equation, Energy levels and energy eigenfunctions using Fröbenius method; Hermite polynomials; Ground state, zero point energy & uncertainty principle; Parity of wave-functions; Higher dimensional isotropic, anisotropic and coupled harmonic oscillators, degeneracy of levels; complex plot of wave-functions & shapes of probability densities for a few low lying states; Applications of SHO. **(8 Lectures)**

Quantum theory of hydrogen-like atoms: Hydrogen atom – Reduction of two-body problem to one-body problem; Time-independent Schrodinger equation in spherical polar coordinates; separation of radial & angular variables; effective potential & solutions of radial equation; Orbital angular momentum operator, spherical harmonics & quantum numbers; Energy eigenvalues; s, p, d shells & degeneracy; Parity of wave-functions; shapes of the probability densities for a few low lying states; discussions on hydrogen-like atoms – alkali atoms, positronium, muonium etc. **(12 Lectures)**

QM of identical particles: Many-particle systems – Identical & non-identical particles; Symmetric and antisymmetric wave functions; Single-particle states & Slater determinant; Example – N non-interacting bosonic (fermionic) oscillators; Connection with statistics and its implications. **(5 Lectures)**

Suggested References:

1. Quantum Mechanics – D.J. Griffiths, Pearson Education India.
2. Modern Quantum Mechanics, J.J. Sakurai, Pearson Education India.

3. Non-Relativistic Theory: Course of Theoretical Physics - Vol. 3, L D Landau and E M Lifshitz, Elsevier India.
4. Quantum Mechanics - L.I. Schiff, Tata-McGraw Hill Education Private Limited.
5. Principles of Quantum Mechanics – R Shankar, Springer.
6. A textbook of Quantum mechanics – Mathews and Venkatesan (Tata-McGrawHill Education Pvt. Ltd.)
7. Quantum Mechanics – B.H. Bransden & C J Joachain, Pearson Education India.
8. Quantum Mechanics 1, 2 – C. Cohen-Tannoudji, B Diu and F Laloe, Wiley VCH.
9. Feynman Lectures of Physics -Vol. III, R.P. Feynman, Pearson Education India.

PAPER: ANALOG ELECTRONICS (THEORY)
PAPER CODE: MJPH09T
MARKS: 75; CREDIT: 3
LECTURES: 45 HRS.

Semiconductor Diodes: P and N type semiconductors. Energy Level Diagram. Conductivity and Mobility, Concept of Drift velocity. PN Junction Fabrication (Simple Idea). Barrier Formation in PN Junction Diode. Static and Dynamic Resistance. Current Flow Mechanism in Forward and Reverse Biased Diode. Drift Velocity. Derivation for Barrier Potential, Barrier Width and Current for Step Junction. Current Flow Mechanism in Forward and Reverse Biased Diode. **(8 Lectures)**

Two-terminal Devices and their Applications: (1) Rectifier Diode: Half-wave Rectifiers. Centre-tapped and Bridge Full-wave Rectifiers, Calculation of Ripple Factor and Rectification Efficiency, C-filter (2) Zener Diode and Voltage Regulation. **(4 Lectures)**

Bipolar Junction transistors: n-p-n and p-n-p Transistors. Characteristics of CB, CE and CC Configurations. Current gains α and β Relations between α and β. Load Line analysis of Transistors. DC Load line and Q-point. Physical Mechanism of Current Flow. Active, Cut-off and Saturation Regions. **(6 Lectures)**

Amplifiers: Transistor Biasing and Stabilization Circuits. Fixed Bias and Voltage Divider Bias. Transistor as 2-port Network. h-parameter Equivalent Circuit. Analysis of a single-stage CE amplifier using Hybrid Model. Input and Output Impedance. Current, Voltage and Power Gains. Classification of Class A, B & C Amplifiers. **(10 Lectures)**

Feedback in Amplifier: Effect of Positive and Negative Feedback on Input Impedance, Output Impedance, Gain, Stability. Barkhausen's Criterion for self-sustained oscillations, different type of oscillator **(6 Lectures)**

Operational Amplifiers (Black Box approach): Characteristics of an Ideal and Practical Op-Amp. (IC 741) Open-loop and Closed-loop Gain. Frequency Response. CMRR. Slew Rate and concept of Virtual ground. **(5 Lectures)**

Applications of Op-Amps: Inverting and non-inverting amplifiers, Adder, Subtractor, Differentiator, Integrator, Log amplifier, Zero crossing detector, Wein bridge oscillator. **(6 Lectures)**

Suggested References:

1. Integrated Electronics, J. Millman and C.C. Halkias, 1991, Tata Mc-Graw Hill.
2. Electronics: Fundamentals and Applications, J.D. Ryder, 2004, Prentice Hall.
3. Solid State Electronic Devices, B. G. Streetman & S. K. Banerjee, 6th Edn.,2009, PHI Learning
4. Electronic Devices & circuits, S. Salivahanan & N. S. Kumar, 3rd Ed., 2012, Tata Mc-Graw Hill
5. OP-Amps and Linear Integrated Circuit, R. A. Gayakwad, 4th edition, 2000, Prentice Hall
6. Semiconductor Devices: Physics and Technology, S.M. Sze, 2nd Ed., 2002, Wiley India
7. Electronic Devices, 7/e Thomas L. Floyd, 2008, Pearson India

PAPER: ANALOG ELECTRONICS (LABORATORY)
PAPER CODE: MJPH09P
MARKS: 25; CREDIT: 1
LECTURES: 30 HRS.

List of Practical:

1. To study V-I characteristics of PN junction diode, and Light emitting diode.
2. To study the V-I characteristics of a Zener diode and its use as voltage regulator.
3. To study the characteristics of a Bipolar Junction Transistor in CE configuration.
4. To design a CE transistor amplifier of a given gain (mid-gain) using voltage divider bias.
5. To design a Wien bridge oscillator for given frequency using an op-amp.
6. To design a phase shift oscillator of given specifications using BJT.
7. To design an inverting amplifier using Op-amp (741, 351) for dc voltage of given gain
8. To design inverting amplifier using Op-amp (741, 351) and study its frequency response
9. To design non-inverting amplifier using Op-amp (741, 351) & study its frequency response
10. To study the zero-crossing detector and comparator
11. To add two dc voltages using Op-amp in inverting and non-inverting mode
12. To investigate the use of an op-amp as an Integrator.
13. To investigate the use of an op-amp as a Differentiator.

PAPER: LABORATORY - II
PAPER CODE: MJPH10
MARKS: 100; CREDIT: 4
LECTURES: 120 HRS.

List of Practical:

Group – A

1. To determine the frequency of an electric tuning fork by Melde's experiment and verify λ^2 –T law.
2. To investigate the motion of coupled oscillators.
3. To determine wavelength of sodium light using Fresnel Biprism.
4. To determine wavelength of sodium light using Newton's Rings.
5. To determine wavelength of Na source/ laser source using single slit diffraction.
6. To determine wavelength of Na source/ laser source using double slit diffraction.
7. To determine wavelength of (1) Na source and (2) spectral lines of Hg source using plane diffraction grating.
8. To determine dispersive power and resolving power of a plane diffraction grating.
9. To determine the thickness of a thin paper by measuring the width of the interference fringes produced by a wedge-shaped Film.

Group – B

1. To determine Mechanical Equivalent of Heat (J) by Callender and Barne's constant flow method.
2. To determine the Coefficient of Thermal Conductivity of Cu by Searle's Apparatus.
3. To determine the Coefficient of Thermal Conductivity of a bad conductor by Lee and Charlton's disc method.
4. To determine the Temperature Coefficient of Resistance by Platinum Resistance Thermometer.
5. To study the variation of Thermo-Emf of a Thermocouple with difference of Temperature of its Two Junctions.
6. To calibrate a thermocouple to measure temperature in a specified Range using
   (a) Null Method, (b) Direct measurement using Op-Amp difference amplifier and to determine Neutral Temperature.

Each student has to perform two experiments, one from each group, during semester examination.

PAPER: QUANTUM MECHANICS - II
PAPER CODE: MJPH11
MARKS: 100; CREDIT: 4
LECTURES: 60 HRS.

Fundamental Concepts: Postulates of Quantum Mechanics; Hilbert space; Hermitian & Unitary operators; Dirac notation of state vectors; Matrix representation of operators; Orthonormality, Completeness and Closure Relations of eigenkets; Discrete and Continuous basis; Change of basis; Coordinate and momentum representation of state vectors and operators; Eigenkets of position and momentum operators; Box-normalization; Observable and the Uncertainty Relation; An example – solutions of a SHO using annihilation-creation operators & Dirac notation of state vectors; SHO coherent & squeezed state.
(10 Lectures)

Angular Momentum: Orbital angular momentum; infinitesimal and finite rotations; generators of rotation, their representations and algebra; Euler Rotation; O(3) group; Conservation of L^2 in a spherically symmetric potential; Runge-Lenz vector and Coulomb potential; Introduction to spins – operators and eigenstates; SU(2) group; coupling of two angular momenta, L-S & J-J coupling; Clebsch-Gordon coefficients; Applications – fine structure & hyperfine corrections, atomic & molecular spectra, etc.
(10 Lectures)

Approximation Methods: Classical limit of Schrödinger equation and Hamilton-Jacobi equation; WKB approximation - application to potential barrier (α decay), SHO problems; Variational method - application to hydrogen and helium atoms. **(6 Lectures)**

Time-Independent perturbation theory: Introduction; Non-degenerate and degenerate cases; Anharmonic oscillators with cubic and quartic terms; Stark & Zeeman effects, spin-orbit coupling and alkali atoms; singlet and triplet states of helium atom. **(8 Lectures)**

Time-Dependent Hamiltonian & Perturbation Theory: Time evolution of quantum Systems; energy-time uncertainty relation; Exactly solved Time-dependent two-state problem; Ehrenfest Theorem; Example – time-evolution of SHO; Time-dependent perturbation theory; Schrödinger, Heisenberg and interaction Pictures; Dyson series; Transition rates; Adiabatic approximation & Berry phase; Sudden approximation – examples ; Constant and Harmonic Perturbation; Applications to interactions with the classical radiation field; Fermi's golden rule, electric dipole approximation, absorption cross-section, spontaneous and stimulated emission of radiation. **(12 Lectures)**

Scattering Theory: The general formalism (Lab and CM frames, cross sections); Integral equation of scattering; Green's function; Born approximation; Condition for validity of Born approximation; Scattering from Yukawa and Coulomb potential; Spherical potential; Partial wave analysis and phase-shifts; Optical theorem; Scattering by a rigid sphere; Effective range and scattering length (S-wave only); Eikonal approximation; Cross-sections for scattering of identical particles. **(14 Lectures)**

Suggested References: All the books referred for course of Quantum Mechanics-I (Code: MJPH08)

PAPER: SOLID STATE PHYSICS - I
PAPER CODE: MJPH12
MARKS: 100; CREDIT: 4
LECTIRES: 60 HRS.

Crystal Structure of Solids: Crystalline State, Basic Definitions, Elements of Symmetry, Bravais Lattices and Crystal System, Crystal Directions and Planes, Miller Indices, Inter-Planer Spacing, Simple Crystal Structures (SC, BCC, FCC, HCP), Examples: Sodium Chloride, Cesium Chloride, Diamond, Zinc Blende), Amorphous Solids, Interatomic Forces, Types of Bonding. **(10 Lectures)**

Imperfection in crystal: Defects in Crystals, Point defects, Color centre, Line Defects, Dislocations, Schottky defects and Frenkel defects in Ionic Crystals. **(5 Lectures)**

X-ray Diffraction in Crystals: Generation and Absorption of X-rays, Characteristic and Continuous Spectrum, X-ray Diffraction, Bragg's Law, Reciprocal Lattice, Brillouin Zones, Scattering from an Atom and a Crystal - Atomic and Structure Factors, Laue equation, Experimental Techniques - Rotating Crystal method, Laue method, Powder method (idea only), Neutron and Electron Diffractions (idea only). **(10 Lectures)**

Lattice Dynamics: Lattice Vibrations and Phonons, Linear Monoatomic and Diatomic Chains, Acoustical and Optical Phonons, Qualitative Description of the Phonon Spectrum in Solids, Specific Heat of Solids - Dulong and Petit's Law, Einstein and Debye theory. **(8 Lectures)**

Semiconductors: Introduction to Energy Band and Classification of Solids (Conductor, Semiconductor and Insulator), Effective Mass, Carrier Concentrations and Conductivity of Semiconductor, Electron and Hole Mobility, Direct and Indirect Band Gap Semiconductors, Photoconduction in Semiconductors, Measurement of Resistivity (Four Probe Method), Hall Effect and Determination of Hall Coefficient. **(10 Lectures)**

Magnetic Properties of Solids: Magnetic permeability, Magnetization, Magnetic susceptibility, Bohr magneton, Electron spin and magnetic moment, Origin of magnetism (orbital angular momentum, spin angular momentum), Magnetic moment of a current loop, Larmor frequency, Different magnetic materials, Diamagnetism-Langevin theory, Paramagnetism – Classical Theory (Curie Law). **(5 Lectures)**

Dielectric and Ferroelectric Properties of Solids: Review of basic idea (Gausses theorem, Dielectrics and Gauss theorem, Electric flux density and polarization, Dipole moment and polarization), Microscopic concept of Polarization (Electronic polarization, Ionic polarization, Orientational polarization); Langevin's theory of polarization in polar dielectrics, Local electric field in solids, Clausius-Mosotti Equation, Relation between dielectric constant and refractive index, Polarization in ionic crystals, Properties of dielectrics in alternating field, Anomalous dielectric dispersion – Complex dielectric constant and dielectric loss.
Ferroelectricity, Curie's Law, Ferroelectric domains, PE hysteresis loop, Classification of ferroelectric materials, Piezoelectricity. Applications. **(12 Lectures)**

Suggested References:

1. Introduction to Solid State Physics, Charles Kittel, 8^{th} Edition, 2004, Wiley India Pvt. Ltd.
2. Solid State Physics, N.W. Ashcroft and N.D. Mermin, 1976, Cengage Learning
3. Solid-state Physics, H. Ibach and H. Luth, 2009, Springer

4. Elements of Solid State Physics, J.P. Srivastava, 4th Edition, 2015, Prentice-Hall of India
5. Introduction to Solids, Leonid V. Azaroff, 2004, Tata Mc-Graw Hill
6. Solid State Physics, Rita John, 2014, McGraw Hill
7. Elementary Solid State Physics, 1/e M. Ali Omar, 1999, Pearson India
8. Solid State Physics, M.A. Wahab, 2011, Narosa Publications
9. The Physics of Solids, Richard John Turton, Oxford University Press.

PAPER: DIGITAL ELECTRONICS (THEORY)
PAPER CODE: MJPH13T
MARKS: 75; CREDIT: 3
LECTURE: 45 HRS.

Digital Circuits: Difference between Analog and Digital Circuits. Binary Numbers. Decimal to Binary and Binary to Decimal Conversion. BCD, Octal and Hexadecimal numbers. AND, OR and NOT Gates (realization using Diodes and Transistor). NAND and NOR Gates as Universal Gates. XOR and XNOR Gates and application as Parity Checkers. **(6 Lectures)**

Boolean algebra: De Morgan's Theorems. Boolean Laws. Simplification of Logic Circuit using Boolean Algebra. Fundamental Products. Idea of Minterms and Maxterms. Conversion of a Truth table into Equivalent Logic Circuit by (1) Sum of Products Method and (2) Karnaugh Map. **(6 Lectures)**

Data processing circuits: Basic idea of Multiplexers, De-multiplexers, Decoders, Encoders. **(4 Lectures)**

Arithmetic Circuits: Binary Addition. Binary Subtraction using 2's Complement. Half and Full Adders. Half & Full Subtractors, 4-bit binary Adder/Subtractor. **(5 Lectures)**

Sequential Circuits: SR, D, and JK Flip-Flops. Clocked (Level and Edge Triggered) Flip-Flops. Preset and Clear operations. Race-around conditions in JK Flip-Flop. M/S JK-Flop. **(6 Lectures)**

Timers: IC 555: block diagram and applications: Astable multivibrator and Monostable multivibrator. **(3 Lectures)**

Shift registers: Serial-in-Serial-out, Serial-in-Parallel-out, Parallel-in-Serial-out and Parallel-in-Parallel-out Shift Registers (only up to 4 bits). **(2 Lectures)**

Counters (4 bits): Ring Counter. Asynchronous counters, Decade Counter. Synchronous Counter. **(4 Lectures)**

Intel 8085 Microprocessor Architecture: Main features of 8085. Block diagram. Components. Pin-out diagram. Buses. Registers. ALU. Memory. Stack memory. Timing & Control circuitry. Timing states. Instruction cycle, Timing diagram of MOV and MVI. Introduction to Assembly Language and ALP. **(9 Lectures)**

Suggested References:

1. Digital Principles and Applications, A.P. Malvino, D.P.Leach and Saha, 7th Ed., 2011, Tata McGraw Hill.
2. Fundamentals of Digital Circuits, Anand Kumar, 2nd Edn, 2009, PHI Learning Pvt. Ltd.
3. Digital Circuits and systems, Venugopal, 2011, Tata McGraw Hill.
4. Digital Electronics G K Kharate ,2010, Oxford University Press
5. Digital Systems: Principles & Applications, R.J.Tocci, N.S.Widmer, 2001, PHI Learning
6. Logic circuit design, Shimon P. Vingron, 2012, Springer.
7. Digital Electronics, Subrata Ghoshal, 2012, Cengage Learning.
8. Microprocessor Architecture Programming & applications with 8085, 2002, R.S. Goankar, Prentice Hall.

PAPER: DIGITAL ELECTRONICS (LABORATORY)
PAPER CODE: MJPH13P
MARKS: 25; CREDIT: 1
LECTURE: 30 HRS.

List of Practical:

1. To design a switch (NOT gate) using a transistor.
2. To verify and design AND, OR, NOT and XOR gates using NAND gates.
3. To design a combinational logic system for a specified Truth Table.
4. To design Half Adder, Full Adder and 4-bit binary Adder.
5. To design Half Subtractor, Full Subtractor, Adder-Subtractor using Full Adder I.C.
6. To build Flip-Flop (RS, Clocked RS, D-type and JK) circuits using NAND gates.
7. To build JK Master-slave flip-flop using Flip-Flop ICs
8. To build a 4-bit Counter using D-type/JK Flip-Flop ICs and study timing diagram.
9. To design an astable multivibrator of given specifications using 555 Timer.
10. To design a monostable multivibrator of given specifications using 555 Timer.
11. Write the following programs using 8085 Microprocessor
    (a) Addition and subtraction of numbers using direct addressing mode
    (b) Addition and subtraction of numbers using indirect addressing mode
    (c) Multiplication by repeated addition.
    (d) Division by repeated subtraction.
    (e) Use of CALL and RETURN Instruction.

PAPER: STATISTICAL MECHANICS
PAPER CODE: MJPH14
MARKS: 100; CREDIT: 4
LECTURES: 60 HRS.

Introduction: What does Statistical Mechanics involve? Define microstates and macrostates. Statistical postulate. Phase space for thermodynamic systems, phase space density. Ergodic hypothesis. Concept of ensemble - Microcanonical ensemble, Canonical ensemble, and Grand-Canonical ensemble. Macroscopic quantity: Ensemble average over microstates. Liouville's theorem and its consequences. **(4 Lectures)**

Microcanonical Ensemble: Independent macroscopic variables. Establish connection between statistics and thermodynamics (through Boltzmann Law). Counting of microstates for thermodynamical systems: (1) a system of ideal gas and (2) a system of simple harmonic oscillators. Fundamental phase space volume corresponding to a microstate. Obtain the equation of states and other macroscopic quantities and compare them with the existing ones. Discuss Gibbs paradox and resolve it. Shortcomings of microcanonical approach. **(5 Lectures)**

Canonical Ensemble: Independent macroscopic variables. Canonical phase space density and the expression for canonical Partition function. Discuss free energy, average energy, entropy through microscopic view. Determine partition function for some thermodynamic systems like ideal gas, harmonic oscillators etc. and calculate equation of states and various relevant macroscopic quantities. General expression for density of states from canonical Partition function and its application to the systems of classical gas and harmonic oscillators. Law of Equipartition of energy, its applications to specific heat and the limitations. Statistics of a paramagnetic system. Thermodynamic functions of two energy level systems. Negative temperature. Obtain the dependence of energy fluctuation on number of particles of a thermodynamic system and discuss its implications. **(8 Lectures)**

Grand-Canonical Ensemble: Independent macroscopic quantities. Grand Canonical phase space density and the Grand-Canonical partition function, and Grand-Canonical potential. Determination of Grand-Canonical partition function for some thermodynamic systems like ideal gas, harmonic oscillator, relativistic gas etc. Entropy and other macroscopic quantities through microscopic view. Determination of statistical fluctuations of energy and particle number at thermodynamic limit: Comparison of three ensembles. **(5 Lectures)**

Formulation of Quantum Statistics: Define density operator, Quantum ensemble average in terms of density operator. Density operator in different ensembles. Statistics of an electron in a magnetic field using density operator. **(4 Lectures)**

Symmetrization and anti-symmetrization: Exchange degenarcy problem for multiparticle quantum system. Resolution of exchange degenarcy problem: symmetrization and anti-symmetrization. Bosons, Fermions and MB particles. Examples of symmetrization and anti-symmetrization with 2,3 and N (large) number of particles. Normalization for N particle symmetric and anti-symmetric wavefunction (Slater determinant). **(3 Lectures)**

Ideal Quantum systems: Grand-canonical ensemble in quantum statistical mechanics. Microstate w.r.t occupation number (Fock space). Advantage of grand-canonical ensemble. Grand-Canonical partition function for Bose-Einstein, Fermi and MB particles. Derivation of Bose-Einstein, Fermi and MB distribution laws. Entropy and other macroscopic quantities through grand-canonical partition function. **(4 Lectures)**

Ideal Bose gas: Bose-Einstein Statistics or B-E distribution law. One particle density of states. Thermodynamic quantities: Average energy, Pressure, Specific heat, Entropy etc. of an Ideal Bose Gas. Bose-Einstein condensation. Liquid He (qualitative description). Radiation as photon gas. Derivation of Planck's law from B-E statistics. Lattice oscillations in solid: Einstein and Debye model. **(7 Lectures)**

Ideal Fermi gas: Fermi-Dirac Distribution Law. One particle density of states. Thermodynamic quantities: Average energy, Pressure, Specific heat, Entropy etc. of an ideal Fermi Gas. Degenerate Fermi Gas. Fermi Energy. Electron gas in a Metal. Specific Heat of Metals. Relativistic Fermi Gas. White Dwarf Stars. Chandrasekhar Mass Limit. **(10 Lectures)**

Imperfect Gas: Cluster expansion for classical gas. Calculation of partition function for low densities. Equation of state. Virial coefficients. Van der Waals equation. **(4 Lectures)**

Indian Contribution to the Subject:
Meghnad Saha: Biography, Saha's ionization formula, Saha's views on national problems (Atomic energy, river physics : flood and dam) and social concerns, Satyendra Nath Bose: Biography, Bose statistics, Bosons, Bose-Einstein condensation, Bose's views on Planck's law and the hypothesis of light quanta. **(6 Lectures)**

Suggested References:

1. Statistical Mechanics, R.K. Pathria, Paul D. Beale, 3rd edition, 2011, Academic Press
2. Statistical Mechanics – Kerson Huang, Second Edition, 2008, Wiley student edition.
3. Statistical Physics, L.D. Landau and E.M. Lifshitz, 3rd edition, Elsevier.
4. Statistical Mechanics, E.S.R. Gopal, John Wiley & Sons, 1976.
5. Statistical Mechanics, B.K. Agarwal and Melvin Eisner, 4th edition, New Age International Publishers, 2023.
6. Elementary Statistical Physics, Charles Kittle, Dover Publications, 2012.
7. Statistical Physics of Particles, Mehran Kardar, Cambridge University Press, 2007.
8. Introduction to Modern Statistical Mechanics, David Chandler, Oxford University Press, 1987.
9. Statistical Mechanics, F. Mandl, 2nd edition, Wiley Indian Pvt. Ltd., 2014.
10. Equilibrium Statistical Physics, M. Plischke and B. Bergersen, 3rd edition, World Scientific, 2006.

PAPER: NUCLEAR & PARTICLE PHYSICS
PAPER CODE: MJPH15
MARKS: 100; CREDIT: 4
LECTURE: 60 HRS.

Development of Nuclear and Particle Physics: Discoveries of electron, nucleus, proton, neutron, electron neutrino, positron, muon, W and Z bosons, quarks, Higgs boson. **(3 Lectures)**

Accelerators and Detectors: van de Graff accelerator, Pelletron, LINAC, Cyclotron, Synchrotron, Synchrotron radiation, Passage of particles through matter – gaseous, scintillation, nuclear emulsion and solid state detectors with examples of particle detection; outline of complex detectors in Nuclear and Particle Physics – Clover detector, INGA, NAND, CMS, Kamiokande, etc. **(5 Lectures)**

Relativistic Kinematics: Reference frames, Lorentz Transformation, Natural units, Energy-momentum in two-body decay, neutrino hypothesis in β decay of neutron; kinematics of three body decay, maximum and minimum energy; minimum energy required for interactions. **(4 Lectures)**

Probability & Statistics: – Basics of probability and statistics to understand results on differential distributions **(2 Lectures)**

General Properties of Nuclei: Constituents of nucleus and their intrinsic properties, Mass, radii, charge density, matter density, binding energy, and its variation with mass number, main features of binding energy versus mass number curve, mass parabola, N/A plot, angular momentum, parity, magnetic moment, electric moments, nuclear excited states. (4 **Lectures)**

Nuclear Models: Liquid drop model, semi empirical mass formula and significance of its various terms, condition of nuclear stability, two nucleon separation energies, Fermi gas model (degenerate fermion gas, nuclear symmetry potential in Fermi gas), evidence for nuclear shell structure, nuclear magic numbers, basic assumption of shell model, concept of mean field, residual interaction, concept of nuclear force. **(6 Lectures)**

Radioactivity decay: (a) Alpha decay: basics of α-decay processes, theory of α-emission, Gamow factor, Geiger Nuttall law, Fine structure of α-decay, angular momentum and parity in alpha decay, spectroscopy. (b) β-decay: energy kinematics for β-decay, positron emission, electron capture, neutrino hypothesis, Fermi theory, Kurie plot, angular momentum and parity selection rules, allowed and forbidden transitions, Fermi and Gamow-Teller Transitions (c) Gamma decay: Gamma rays emission & kinematics. **(6 Lectures)**

Nuclear Reactions: Types of Reactions, Conservation Laws, kinematics of reactions, Q-value, reaction rate, cross section, Concept of compound and direct Reaction, Resonance reaction, Coulomb scattering (Rutherford scattering). **(4 Lectures)**

Fundamental interactions and the Standard Model: Introduction to Electromagnetic, Weak, Strong and Gravitational interactions – mediators, strength and range; introduction to the Standard Model and its particle content; classification of elementary particles, quark model of hadrons, classification of hadrons, concept of colour; symmetry and conservation laws, Baryon and Lepton numbers; doublets of weak interaction; quark confinement, elementary ideas about discrete space-time symmetries in particle physics, CP and CPT invariance, Phenomenological aspects of CP violation in kaons, beta decay;(2-pion and 3-pion decays, CP violation in K_L and K_S systems, Fitch and Cronin experiment) (**14 Lectures)**

Neutrino Physics: Sources of neutrinos, probes for Astrophysics; detection of neutrinos, neutrino experiments – Homestake, Super-Kamiokande, SNO, Ice Cube; introduction to solar neutrino problem, and neutrino oscillation; Majorana neutrino and neutrinoless double beta decay (qualitative discussion) (6 **Lectures)**

Indian Contribution to the Subject:
Rishi Kanada: Paramanu-bad, Sangkhyo-darshan: Tanmatro, Homi J. Bhabha – biography, electron – positron scattering, Bhabha-Heitler theory of cosmic ray showers, role in the theoretical understanding of mesons and muons; Ennakal Chandy George Sudarshan – biography, originator of the V-A theory of Weak interactions alongside A. Marshak, advocate for the existence of tachyons. **(6 Lectures)**

Suggested References:

1. Nuclear Physics – R.R. Roy and B.P. Nigam (New Age International)
2. Introductory Nuclear Physics – Kenneth S. Krane (Wiley)
3. Atomic and Nuclear Physics (Vol.-2) – S.N. Ghosal (S. Chand group)
4. Introduction to Nuclear Physics – H.A. Enge (Addison Wesley)
5. Nuclear Physics – I. Kaplan (Narosa Publications)
6. Introductory Nuclear Theory – L.R.B Elton (Sir Isaac Pitman & sons)
7. Elementary Nuclear Theory – H.A. Bathe and P. Morrison (Dover Publications)
8. Nuclear Physics – E. Fermi (University of Chicago press)
9. Nuclei and Particles – E. Segre (W.A. Benjamin)
10. Introduction to Elementary Particles - D.J. Griffiths
11. Introduction to High Energy Physics - D.H. Perkins

PAPER: LABORATORY - III
PAPER CODE: MJPH16
MARKS: 100; CREDIT: 4
LECTURES: 120 HRS.

List of Practical:

1. To study photo-electric effect.
2. To determine the Planck's constant using LEDs of different colors.
3. To determine the value of e/m using Thomson method.
4. To determine the charge of an electron using Millikan oil drop apparatus.
5. To measure the susceptibility of paramagnetic solution (Quincke`s Tube Method).
6. To determine the Hall coefficient of a semiconductor sample.
7. To measure the resistivity of a semiconductor (Ge) with temperature to determine its band gap (four-probe method).
8. To draw the B-H curve for iron using solenoid & determine energy loss from hysteresis curve.
9. To determine the wavelength and velocity of ultrasonic waves in a liquid by studying the diffraction through ultrasonic grating.
10. To verify the Stefan`s law of radiation and to determine Stefan's constant.
11. To determine the specific rotation of sugar solution using polarimeter.
12. To study the polarization of light by reflection and determine the polarizing angle for air-glass interface.

(New practical will be added in future)

Each student has to perform two experiments during semester examination.

PAPER: MATHEMATICAL METHODS - II
PAPER CODE: MJPH17
MARKS: 100; CREDIT: 4
LECTURES: 60 HRS.

Complex Analysis: Brief Revision of Complex Numbers and their Graphical Representation. Euler's formula, De Moivre's theorem, Roots of Complex Numbers. Functions of Complex Variables. Analyticity and Cauchy-Riemann Conditions. Examples of analytic functions. Singular functions: poles and branch points, order of singularity, branch cuts. Integration of a function of a complex variable. Cauchy's Inequality. Cauchy's Integral formula. Simply and multiply connected region. Laurent and Taylor's expansion. Residues and Residue Theorem. Application in solving Definite Integrals. **(22 Lectures)**

Fourier Transforms: Fourier Integral theorem. Fourier Transform. Examples. Fourier transform of trigonometric, Gaussian, finite wave train & other functions. Representation of Dirac delta function as a Fourier Integral. Fourier transform of derivatives, Inverse Fourier transform, Convolution theorem. Properties of Fourier transforms (translation, change of scale, complex conjugation, etc.). Three dimensional Fourier transforms with examples. Application of Fourier Transforms to differential equations: One dimensional Wave and Diffusion/Heat Flow Equations. **(9 Lectures)**

Laplace Transforms: Laplace Transform (LT) of Elementary functions. Properties of LTs: Change of Scale Theorem, Shifting Theorem. LTs of 1st and 2nd order Derivatives and Integrals of Functions, Derivatives and Integrals of LTs. LT of Unit Step function, Dirac Delta function, Periodic Functions. Convolution Theorem. Inverse LT. Application of Laplace Transforms to 2nd order Differential Equations: Damped Harmonic Oscillator, Simple Electrical Circuits, Coupled differential equations of 1st order. Solution of heat flow along infinite bar using Laplace transform. **(9 Lectures)**

Frobenius Method and Special Functions: Singular Points of Second Order Linear Differential Equations and their importance. Frobenius method and its applications to differential equations. Legendre, Bessel, Hermite and Laguerre Differential Equations. Properties of Legendre Polynomials: Rodrigues Formula, Generating Function, Orthogonality. Simple recurrence relations. Expansion of function in a series of Legendre Polynomials. Bessel Functions of the First Kind: Generating Function, simple recurrence relations. Zeros of Bessel Functions (Jo(x) and J1(x)) and Orthogonality. **(20 Lectures)**

Suggested References:

1. Mathematical Methods for Physics and Engineers, K.F Riley, M.P. Hobson and S. J. Bence, 3rd ed., 2006, Cambridge University Press
2. Mathematics for Physicists, P. Dennery and A.Krzywicki, 1967, Dover Publications
3. Complex Variables, A.S.Fokas & M.J.Ablowitz, 8th Ed., 2011, Cambridge Univ. Press
4. Complex Variables, A.K. Kapoor, 2014, Cambridge Univ. Press
5. Complex Variables and Applications, J.W. Brown & R.V. Churchill, 7th Ed. 2003, Tata McGraw-Hill
6. First course in complex analysis with applications, D.G. Zill and P.D. Shanahan, 1940, Jones & Bartlett

PAPER: CLASSICAL ELECTRODYNAMICS
PAPER CODE: MJPH18
MARKS: 100; CREDIT: 4
LECTURES: 60 HRS.

Maxwell's equations: Revision of Maxwell's equations. Electromagnetic (EM) waves. Poynting theorem. Maxwell's Stress tensor. Momentum Density and Angular Momentum Density. Gauge transformations. Coulomb and Lorentz gauges. Helmholtz theorem. **(8 Lectures)**

Relativistic Electrodynamics: Review of Special Theory of relativity, Special Relativity and Maxwell's equations. Invariance of Maxwell's equations under Lorentz transformation (LT), LT as rotation of Minkowski space. Concepts of invariant interval. Light cone. Event and world line. Minkowski diagrams. Four-vectors and tensors: Discussions on Four velocity. Four acceleration. Four momentum. Four wave vector. Four force. Four potentials. Four current density in the relativistic framework. Simple applications of four vectors in relativistic particle mechanics. Doppler effect and aberration of light. LT of EM fields. Field strength tensor and its dual. Invariant quantities in EM fields. Covariant formulation of Maxwell's equations in tensor notation **(16 Lectures)**

Radiation: Inhomogeneous wave equations and their solutions by Green's function method. Retarded potentials. Radiation from localized sources and multipole expansion in the radiation zone. Dipole and quadrapole radiation. Radiation from oscillating electric and magnetic dipole. Basic principles of antenna. Antenna radiation patterns. Lienard-Wiechart potentials, Fields due to a moving point charge – uniform and accelerated motion. Radiation at low velocity. Larmour formula and its relativistic generalization. Radiation when velocity and acceleration are parallel. Bremsstrahlung radiation when velocity and acceleration are perpendicular. Cyclotron and Synchrotron radiation. Angular distribution of radiated power in each case. Cerenkov radiation (qualitative treatment only). Radiation reaction. Abraham-Lorentz formula. Thomson scattering. Rayleigh scattering **(18 Lectures)**

Charged Particle Dynamics in Electromagnetic Fields: Debye shilding. Plasma oscillation. plasma parametrs. Motion of charged particle in uniform static magnetic field. static electric field and crossed electric and magnetic fields. Particle drifts. Grad-B drift and curvature drift of charged particles in nonuniform static magnetic fields. adiabatic invariance of magnetic moment of a charged particle and magnetic mirroring. Sokolov-Ternov effect (qualitative discussion) **(12 Lectures)**

Indian Contribution to the Subject:
Jagadish Chandra Bose: biography, experiments on refraction, diffraction and polarization, radio wave detector, contribution to biology. **(6 Lectures)**

Suggested References:

1. Classical Electrodynamics – J.D. Jackson, John Wiley & Sons
2. Electrodynamics – F. Melia, The University of Chicago Press
3. Classical Electricity and Magnetism – W.K.H. Panofsky, M. Phillips, Addison-Wesley
4. Classical Theory of Fields – L.D. Landau, E.M. Lifshitz, Butterworth-Heinemann
5. Introduction to Electrodynamics – D.J. Griffiths, Pearson Education India
6. Electrodynamics and Classical Theory of Fields and Particles – A.O. Barut, Dover Publications

PAPER: ATOMIC AND MOLECULAR PHYSICS
PAPER CODE: MJPH19
MARKS: 100; CREDIT: 4
LECTURES: 60 HRS.

One Electron Atoms: Review of Non-relativistic theory and the Dirac theory of the hydrogen atom, Expansion of the Dirac Hamiltonian in powers of v/c and fine structure, Lamb shift, Hyperfine structure and Isotope shifts, alkali spectra and elementary ideas of quantum defects, Rydberg and Exotic atoms. **(6 Lectures)**

Two-Electron Atoms: Para and Ortho states, role of spin in two-electron atoms and Pauli's Exclusion Principle, Perturbation and Variational approximations for the two-electron atoms. Doubly excited states of two-electron atoms, Autoionization, Auger effect. **(6 Lectures)**

Many-Electron Atoms: Central field approximation, periodic system of elements, Thomas -Fermi model, Hartree-Fock method and the self-consistent field, correction to the central field approximation - L-S and J-J coupling, origin of X-ray spectra. **(8 Lectures)**

Interaction of Atoms with Radiation: Selection rules, Line intensities and lifetime of excited states, Line shapes and widths, Pressure and Doppler broadening, Photoelectric effect, atoms in external static fields: Zeeman, Paschen-Bach and Stark effects. **(6 Lectures)**

Molecular Structure: General nature of molecular structure, Rotational, Vibrational and electronic motion, Born-Oppenheimer separation of electronic and nuclear wave functions, LCAO method, Heitler-London method for H_2 molecule, recoil effect in emission and absorption, Mössbauer effect. **(6 Lectures)**

Molecular Spectra: Rotational energy levels of diatomic molecules, vibrational, rotational sprctra of molecules, anharmonic oscillator models for diatomic molecules, pre-dissociation and Dissociation, Rayleigh Law, Raman scattering, electronic spectra of diatomic molecules, Deslandre's table, Fortrat diagram, Franck-Condon principle, Fluorescence, Phosphorescence, Photoluminescence, electronic spin and Hund's coupling cases, Effect of nuclear spin on diatomic molecules, inversion spectrum of Ammonia. **(12 Lectures)**

Laser: Population Inversion, Spatial and Temporal coherence, Ammonia Maser and He-Ne Laser, Tunable lasers, Laser cooling of atoms. **(5 Lectures)**

Magnetic Resonance Spectroscopy: Principle of magnetic resonance, Electron spin resonance and Nuclear magnetic resonance, Chemical shifts. **(5 Lectures)**

Indian Contribution to the Subject: Chandrashekhar Venkata Raman - biography, molecular diffraction of light, Raman effect, fascinating colours of butterflies. **(6 Lectures)**

Suggested References:

1. Physics of Atoms and Molecules – B H Bransden and C J Joachain, Pearson India
2. Fundamentals of Modern Physics – Robert Eisberg, John-Wiley
3. Introduction to Molecular Spectroscopy – Gordon Barrow McGraw Hill
4. Molecular Spectra and Molecular Structure: Spectra of Diatomic Molecules – Gerhard Herzberg (R.E. Krieger Publishing Company)
5. Chemical Applications of Group Theory – Frank Albert Cotton (John Willey & Sons)
6. Fundamentals of Molecular Spectroscopy – C N Banwell and Elaine M McCash (McGrawHill, Indian edition)

PAPER: NANOSCIENCE
PAPER CODE: MJPH20-1
MARKS: 100; CREDIT: 4
LECTURE: 60 HRS.

Physics at the Nanoscale: Nanostructures (0D, 1D, 2D and 3D), Band structure and density of states of material at nanoscale, electron states in direct and indirect gap semiconductors nanocrystals, size effects in nano systems, quantum confinement and its consequences, quantum wells, quantum wires, quantum dots and artificial atoms, confinement in disordered and amorphous systems. (10 lectures)

Essential Approaches and Forces at Nanoscale
Bonding Forces and Energies- Types of bonding- Ionic- Covalent- Metallic - van der Waals-π- π-stacking - Hydrogen bonding. Aggregation of Nanoparticles - Homogeneous aggregation, Heterogeneous aggregation, Coalescence and Rippening; Sedimentation - Dispersion and transformation. Homogeneous Nucleation, Hydrophobic Interactions- Steric Forces. (10 Lectures)

Growth of Nanostructures: Synthesis of metal, semiconductor, carbon and bio nanomaterials; Grains and grain boundaries, distribution of grain sizes, pores, strains. Thin film preparation methods (thermal evaporation, sputtering, pulsed laser deposition and molecular beam epitaxy), Gas phase synthesis of nanopowder, chemical and colloidal methods, mechanical milling, dispersion in solid-doped glasses and sol gel method; Green synthesis, Functionalization of nanoparticles. (10 lectures)

Characterization Basics: Powder XRD, absorption spectroscopy, scanning electron microscopy, scanning probe microscopy, transmission electron microscopy, Raman spectroscopy, photoluminescence.
(5 lectures)

Dielectric Properties: Coulomb interaction in nanostructures. Concept of dielectric constant for nanostructures and charging of nanostructure. Quasi-particles and excitons: Excitons in direct and indirect band gap semiconductor nanocrystals. Quantitative treatment of quasiparticles and excitons. Charging effects. (10 lectures)

Optical Properties: Optical properties and radiative processes: General formulation absorption, emission and luminescence; Optical properties of heterostructures and nanostructures. Carrier transport in nanostructures: Coulomb blockade effect, scattering and tunnelling of 1D particle; applications of tunnelling, single electron transistors. Defects and impurities: Deep level and surface defects.
(10 lectures)

Applications of Nanomaterials: Ceramic capacitors and magnetic recording, nanophosphors and photonic devices (LED, solar cells), quantum dot heterostructure lasers, optical switching and optical data storage, CNT based transistors, magnetic data storage, graphene/graphene oxide, energy devices.
(5 lectures)

Suggested Readings

1) Carbon Nanotubes, S. Reich, C. Thomsen & J. Maultzsch, (Wiley-VCH, 2004)
2) Characterization of Nanophase Materials, Z. L. Wang (Ed.) (Wiley-VCH, 2000)
3) Introduction to Nanotechnology, C. P. Poole Jr. & F. J. Owens (Wiley-Interscience, 2003)
4) Nanomaterials and Nanochemistry, C. Brechignac, P. Houdy and M. Lahmani (Springer, 2006)
5) Nanostructure, V. A. Shchukin, N. N. Ledentsov and D. Bimberg (Springer, 2004)
6) Nanostructured Materials and Nano technology, H. S. Nalwa (Ed.) (Academic Press, 2002)
7) Nanostructures-Theory & Modelling, C. Delerue and M. Lannoo (Springer, 2004) 35
8) Semiconductor Nanocrystal Quantum Dots, A. L. Rogach (Ed.) (Springer Wien NY, 2008)
9) Surface Science: An Introduction by K. Oura, M. Katayama, A. V. Zotov, V. G. Lifshits, A. A. Saranin (Springer 2003) &
10) Elements of X-Ray Diffraction by B.D. Cullity S.R. Stock, Third Edition (Pearson Education Limited, 2014)

PAPER: NUCLEAR SCIENCE - THEORY AND APPLICATIONS
PAPER CODE: MJPH20-2
MARKS: 100; CREDIT: 4
LECTURE: 60 HRS.

Nuclear Properties: Nuclear Radius, Mass and Abundances of Nuclides, Nuclear Binding Energy, Nuclear Angular Momentum and Parity, Nuclear Electromagnetic Moments and Excited States. **(5 Lectures)**

Force Between Nucleons: Deuteron Problem, Nucleon-Nucleon Scattering, Proton-Proton and Neutron-Neutron Interactions, Properties of Nuclear Force, The Exchange Force Model. **(5 Lectures)**

Nuclear Models and Structure: Shell Model, Even-Z, Even-N Nuclei and Collective Structure, More Realistic Nuclear Models, Collective Model of nucleus: deformable liquid drop and nuclear fission, shell effects on liquid drop energy, collective vibrations and rotations, pattern of excited states; Gamma Spectroscopy. **(12 Lectures)**

Nuclear Reactions: Types of Reactions and Conservation Laws, Energetics of Nuclear Reactions, Isospin, Reaction Cross Sections, Experimental Techniques, Coulomb Scattering, Nuclear Scattering, Scattering and Reaction Cross Sections, Optical Model, Compound-Nucleus Reactions, Direct Reactions, Resonance Reactions, Heavy-ion Reactions, Nuclear Fusion, Nuclear Fission. **(10 Lectures)**

Neutron Physics: Neutron Sources, Absorption and Moderation of Neutrons, Neutron-induced Reactions and Cross Sections, Neutron Capture, Interference and Diffraction with Neutrons. **(5 Lectures)**

Nuclear Tools: Gas-Filled Detectors, Scintillator Detectors, Semiconductor Detectors, Counting Statistics, Energy Measurements, Coincidence Measurements and Time Resolution, Measurement of Nuclear Lifetimes, Electrostatic Accelerator, Cyclotron, Synchrotron, Linear Accelerator. **(12 Lectures)**

Applications of Nuclear Science: Radioactive dating,Trace Element Analysis, Mass spectrometry with accelerators, Alpha-decay applications, Biomedical Application, Diagonistic Nuclear Medicine, Therapeutic Nuclear Medicine, Power production and nuclear waste; Dosimeter and Radiation Safety. **(5 Lectures)**

India's Contribution in Nuclear Science and Technology: Developmental journey since 1945; nuclear energy revolution - contribution from Homi Bhabha, Raja Ramanna, Srinivasan and others; Development of Nuclear power plants in India; APSARA – India's first nuclear research reactor; Atomic Energy Programme in India; Smiling Buddha – India's first nuclear weapon test **(6 Lectures)**

Suggested References:

1. Introductory Nuclear Physics – Kenneth S. Krane, John Wiley & Sons
2. Basic Ideas and Concepts in Nuclear Physics – K. Heyde, Overseas Press
3. Nuclear Structure from a Simple Perspective – Richard F. Casten, Oxford University Press
4. Nuclear Models – W. Greiner and J.A. Maruhn, Springer
5. Introduction to Nuclear Reactions – G.R. Satchler, Springer
6. Nuclear Physics: Theory and Experiment – R.R. Roy, B.P. Nigam, New Age International Publishers
7. Nuclear Power in India: A Comparative Analysis – David Hart; Publisher: Routledge; 1st edition (2021)

PAPER: PHYSICS OF DEVICES AND INSTRUMENTS (THEORY)
PAPER CODE: MJPH20-3T
MARKS: 75; CREDIT: 3
LECTURE: 45 HRS.

Devices: Characteristic and small signal equivalent circuits of UJT and JFET. Metal-semiconductor Junction. Metal oxide semiconductor (MOS) device. Ideal MOS and Flat Band voltage. SiO2-Si based MOS. MOSFET– their frequency limits. Enhancement and Depletion Mode MOSFETS, CMOS.
(10 Lectures)

Power supply and Filters: Block Diagram of a Power Supply, Qualitative idea of C and L Filters. Line and load regulation, Regulation using discrete components – Series regulations, Shunt regulation, Short circuit protection, IC Regulators. **(7 Lectures)**

Filters: Active and Passive Filters, Low Pass, High Pass, Band Pass and band Reject Filters.
(3 Lectures)

Processing of Devices: Basic process flow for IC fabrication, Electronic grade silicon. Crystal plane and orientation. Defects in the lattice. Oxide layer. Oxidation Technique for Si. Metallization technique. Positive and Negative Masks. Optical lithography. Electron lithography. Feature size control and wet anisotropic etching. Lift off Technique. Diffusion and implantation. **(10 Lectures)**

Digital Data Communication Standards: Serial Communications: RS232, Handshaking, Implementation of RS232 on PC. Universal Serial Bus (USB): USB standards, Types and elements of USB transfers. Devices (Basic idea of UART). Parallel Communications: General Purpose Interface Bus (GPIB), GPIB signals and lines, Handshaking and interface management, Implementation of a GPIB on a PC. Basic idea of sending data through a COM port. **(5 Lectures)**

Introduction to communication systems: Block diagram of electronic communication system, Need for modulation. Amplitude modulation. Modulation Index. Analysis of Amplitude Modulated wave. Sideband frequencies in AM wave. CE Amplitude Modulator. Demodulation of AM wave using Diode Detector. Basic idea of Frequency modulation. **(10 Lectures)**

Suggested References:

1. Physics of Semiconductor Devices, S.M. Sze & K.K. Ng, 3rd Ed.2008, John Wiley & Sons.
2. Electronic devices and integrated circuits, A.K. Singh, 2011, PHI Learning Pvt. Ltd.
3. Op-Amps & Linear Integrated Circuits, R.A.Gayakwad, 4 Ed. 2000,PHI Learning Pvt. Ltd
4. Electronic Devices and Circuits, A. Mottershead, 1998, PHI Learning Pvt. Ltd.
5. Electronic Communication systems, G. Kennedy, 1999, Tata McGraw Hill.
6. Introduction to Measurements & Instrumentation, A.K. Ghosh, 3rd Ed., 2009, PHI Learning Pvt. Ltd.
7. Semiconductor Physics and Devices, D.A. Neamen, 2011, 4th Edition, McGraw Hill
8. PC based instrumentation; Concepts & Practice, N.Mathivanan, 2007, Prentice-Hall of India

PAPER: PHYSICS OF DEVICES AND INSTRUMENTS (LABORATORY)
PAPER CODE: MJPH20-3P
MARKS: 25; CREDIT: 1
LECTURE: 30 HRS.

List of Practical:

1. To design a power supply using bridge rectifier and study effect of C-filter.
2. To design a series regulator circuit using Zener diode and transistors.
3. To design the active Low pass and High pass filters of given specification.
4. To design the active filter (wide band pass and band reject) of given specification.
5. To study the output and transfer characteristics of a JFET.
6. To design a common source JFET Amplifier and study its frequency response.
7. To study the output characteristics of a MOSFET.
8. To design an Amplitude Modulator using Transistor.
9. To design an envelope detector.
10. To design PWM, PPM, PAM and Pulse code modulation using Ics.
11. To write a program to glow an LED via USB port of PC.
12. To write a program to sense the input voltage at a pin of USB port and subsequently glow the LED connected with another pin of USB port.

Reference Books:

1. Basic Electronics: A text lab manual, P.B. Zbar, A.P. Malvino, M.A.Miller,1994, Mc-Graw Hill
2. Integrated Electronics, J. Millman and C.C. Halkias, 1991, Tata Mc-Graw Hill.
3. Electronics : Fundamentals and Applications, J.D. Ryder, 2004, Prentice Hall.
4. OP-Amps and Linear Integrated Circuit, R. A. Gayakwad, 4th edn., 2000, Prentice Hall.
5. PC based instrumentation; Concepts & Practice, N.Mathivanan, 2007, Prentice-Hall of India

PAPER: STATISTICAL METHODS IN PHYSICS
PAPER CODE: MJPH20-4
MARKS: 100; CREDIT: 4
LECTURES: 60 HRS.

Introduction to Probability and Statistics: Event, Observation and Measurement, Outcome spaces and events, Assignment of Probabilities to Events, Axioms of probability, Conditional Probability, Independence, and Bayes' Theorem, Random Events and Variables **(5 Lectures)**

Probability Distributions and their Properties: Discrete and Continuous Distributions, Expected values: mean, variance, skewness, kurtosis, Moment generating function, Some important distributions (Uniform Distribution, Binomial Distribution, Poisson Distribution, Normal Distribution, Log-normal distribution, Exponential Distribution, Chi-square Distribution, Gamma Distribution, Student's t Distribution), Pseudo random numbers, Generating different probability distributions using random numbers. **(10 Lectures)**

Measurement Uncertainties: Definition of measurement and its uncertainties, statistical and systematic uncertainty, error propagation, Averaging correlated/uncorrelated measurements, biased measurements, Resampling methods – Jackknife & Bootstrap **(5 Lectures)**

Statistical Inference: Concepts of statistical inference, Maximum Likelihood method for parameter inference, Method of moments, Method of Least Squares, Linear Regression, confidence intervals, Hypothesis testing techniques - Significance level and P-values; Model selection and Goodness of Fit tests (Chi-square test, Likelihood ratio test, Kolmogorov-Smirnov test, Student's t test, F test); Bayesian statistical inference **(10 Lectures)**

Multivariate Analysis: Concepts of Multivariate Analysis, Multivariate distances, Multivariate Normal distribution, Multivariate probability densities, Multiple Linear Regression, Multivariate Analysis of Variance (MANOVA) **(10 Lectures)**

Clustering, Classification and Data Mining: Concepts of clustering and classification, Agglomerative hierarchical clustering, k-means clustering, Principal Component Analysis (PCA), Singular Value Decomposition (SVD), Linear Discriminant Analysis (LDA), Quadratic Discriminant Analysis (QDA), Classification trees, Nearest-neighbour classifiers, Artificial neural networks, Support Vector Machines (SVM), Random Forest **(20 Lectures)**

Suggested References:

1. Probability, Random variables, & Random processes, H.P. Hsu, Schaum's outline series, McGraw-Hill Education, 2014
2. Theory of probability and random process, L.B. Koralov, Y.G. Sinai, Springer, 2012
3. Mathematical Statistics: A Unified Introduction, G.R. Terrell, Springer, 1999
4. Statistical challenges in Astronomy, E. D. Feigelson, G.J. Babu, Springer, 2003

PAPER: QUANTUM MECHANICS - III
PAPER CODE: MJPH20-5
MARKS: 100; CREDIT: 4
LECTURES: 60 HRS.

Bell's Theorem and Its Consequences: Measurement and the Interpretation of States; State preparation, determination, collapse of wave-function etc.; Correlation in spin singlet state & EPR paradox; Einstein's locality principle and hidden variables; the Bell inequality; Experimental tests of non-locality. **(5 Lectures)**

Geometric phase and Pancharatnam's work: Brief review of adiabatic processes in classical mechanics; the adiabatic theorem in quantum mechanics; geometric phase and Pancharatnam's idea; evolution of energy eigenstates; Berry phase and Berry curvature; applications to two-level systems; implications for Aharonov Bohm effect. **(6 Lectures)**

Quantum entanglement & quantum information theory: Qubit; spin- ½ & Bloch sphere; density operator; pure vs. mixed ensemble; Schmidt decomposition; experiments & loopholes; usage of entanglement: dense coding, quantum teleportation etc.; Classical information theory; Shannon entropy; quantum information-types and channels; von Neumann entropy and its properties; no-cloning theorem. **(12 Lectures)**

Relativistic Quantum Mechanics: Inadequacy of Klein-Gordon equation; Dirac equation; Algebra of Dirac matrices; Plane wave solutions; Prediction of antiparticles; Spin of electron and Pauli spin matrices; Pauli equation; Magnetic moment of the electron; Relativistic Hydrogen atom and its Non-relativistic limit; Covariant form of Dirac Equation; Parity, charge conjugation, time reversal operation; Dirac equation in lower dimensions & their applications in condensed matter systems. **(14 Lectures)**

Second quantization: Introduction & motivation – shortcomings of Dirac equation; Concept of a field**;** Schrödinger field, equivalent many-body system, eigen states; Klein-Gordon field as a collection of harmonic oscillators, normal ordering, causality, Klein-Gordon propagator; quantization of free complex scalar field; quantization of free vector and spinor fields; Description of interacting real scalar ϕ^4 field theory – time-ordering, Wick's theorem, scattering etc. **(23 Lectures)**

Suggested References:

1 Modern Quantum Mechanics (Revised Edition), J. J. Sakurai, Pearson Education, India.
2 Quantum Computation and Quantum Information, M. A. Nielsen and I. L. Chuang, Cambridge University Press 2000.
3 Lecture Notes on Quantum Entanglement, J. Preskill, http://www.theory.caltech.edu/ preskill/ph229/
4 Relativistic Quantum Fields, James D. Bjorken, Sidney D. Drell, Dover Publications.
5 Quantum Field Theory, C. Itzykson and J. B. Zuber, Dover Publications.
6 Lecture Notes by D. Tong: www.damtp.cam.ac.uk/user/tong/qft.html
7 A First Book of Quantum Field Theory(Second Edition), Amitabha Lahiri and Palash B. Pal, Narosa Publishing House.
8 A textbook of Quantum mechanics – Mathews and Venkatesan (Tata-McGrawHill Education Pvt. Ltd.)

PAPER: SOLID STATE PHYSICS - II
PAPER CODE: MJPH21
MARKS:100; CREDITS: 4
LECTURES: 60 HRS.

Electronic Properties of Metals: Statistics of free electron gas, heat capacity of electron gas, electron scattering and source of resistance, variation of resistivity with temperature, thermal conduction, Wiedemann-Franz Law, motion of electrons in static electric and magnetic fields, Hall effect, magnetoresistance, thermionic emission, Schottky effect. **(10 Lectures)**

Thermal Properties of Solids: Specific heat capacity of solids, Debye approximation and its experimental verification, Born cut-off procedure, Gruneissen relation, anharmonicity, thermal expansion, thermal conductivity of solids & lattice, Umklapp process. **(10 Lectures)**

Band Theory of Solids: Periodic potential and Bloch's theorem, Kronig-Penny model, weak potential approximation, density of states in different dimensions, energy gaps, Fermi surface and Brillouin zones. Origin of energy bands and band gaps, effective mass, tight-binding approximation and calculation of simple band-structures. Motion of electrons in lattices, wave packets of Bloch electrons, semi-classical equations of motion, motion in static electric and magnetic fields, theory of holes, cyclotron resonance. **(15 Lectures)**

Magnetism: Van Vleck paramagnetism, Pauli spin paramagnetic susceptibility, Quantum mechanical treatment of paramagnetism, Curie's law, Weiss theory of ferromagnetism, ferromagnetic domains, B-H curve, Hysteresis and energy loss, Hund's rule, Rare Earth, Iron group ions, quenching of orbital angular momentum, Heisenberg's exchange interaction, antiferromagnetism, ferrimagnetism. **(15 Lectures)**

Superconductivity: Introduction to superconductors, Meissner effect, Type-I and II superconductors, London' equation and penetration depth, thermodynamics of superconducting state, Cooper pair, BCS theory (qualitative), flux quantization, superconductor under ac field, Josephson effect, high T_c superconductors. **(10 Lectures)**

Suggested References:

1. Kittel, C., Introduction to Solid State physics 7th Edition (Wiley, Eastern Ltd., 1996)
2. Neil W. Ashcroft and N. David Mermin, Solid State Physics, Brooks / Cole, a part of Cengage Learning (1976).
3. J. M. Ziman, Principles of the theory of solids (2nd edition), Cambridge University Press.
4. Ibach, H. & Luth, H., Solid State Physics, (Springer-Verlag)
5. Dekker, A. J., Solid State Physics (Macmillan India Ltd., 2003)
6. Patterson, J. D., Introduction to the Theory of Solid State Physics, (Addison-Wesley)
7. Hall, H.E. and Hook J.R., Solid State Physics, 2nd Edition, (Wiley, 1991)
8. Azaroff, L.V., Introduction to Solids, (Tata McGraw Hill, 1977)
9. Pillai, S.O., Solid State Physics (New Age International Publishers, 2018)
10. Kumar, A., Introduction to Solid State Physics (PHI Learning, 2010).
11. Otfried Madelung, Introduction to Solid State Theory, Springer (edition 1978).

PAPER: LABORATORY - IV
PAPER CODE: MJPH22
MARKS: 100; CREDIT: 4
LECTURES: 120 HRS.

List of Practical:

1. To determine the Lande g-factor by using an electron spin resonance spectrometer.
2. To determine magnetoresistance.
3. To study the temperature dependence of Hall coefficient.
4. To study the temperature dependence of dielectric constant of a ferroelectric crystal.
5. To study the characteristics of a PN junction and to determine the reverse saturation current, material constant, temperature co-efficient of junction voltage.
6. To study Zeeman effect with external magnetic field - determination of hyperfine splitting.
7. To determine the excitation potential of an atomic sample (Franck – Hertz experiment).
8. To determine the dielectric constant of liquid.
9. To determine the mass absorption coefficient of aluminum using GM counter.
10. To determine the unknown energy of γ-ray using SCA.
11. To study Faraday effect.
12. To determine the numerical aperture and attenuation constant of Optical Fibre
13. To determine the dissociation energy and the force constant of iodine molecules.
14. To determine the (i) average wavelength and (ii) separation of D1 and D2 lines of sodium by using Michelson interferometer.
15. To study the electro-optic rotation using Pockels effect set up.
16. To determine charge-mass ratio (e/m) by Zeeman effect (Fabry Perot Etalon)

Each student has to perform two experiments, one from each group, during semester examination.

PAPER: ADVANCED ELECTRONICS
PAPER CODE: MJPH23-1
MARKS: 100; CREDIT: 4
LECTURES: 60 HRS.

Physics of Semiconductor devices: Carrier concentrations in semiconductors; Band structure of p-n junction; Basic semiconductor equations; p-n diode current voltage characteristics; Dynamic diffusion capacitances; Ebers-Moll equation. **8 Lectures**

Semiconductor devices: (From the point of view of band structure, variation of electrical field across the junction etc.) homo and hetero junction devices, metal semiconductor junctions: Schottky barriers; rectifying contacts; ohmic contacts, miscellaneous semiconductor devices: Tunnel diode; Photodiode; Solar cell; LED; Laser diode, LDR, MOS-capacitors; capacitance voltage characteristics of MIS structure, C-V characteristics of various junctions. **12 Lectures**

Semiconductor Process Technology: Oxidation, Diffusion, Ion implantation, Silicon crystal growth from melt, GaAs crystal growth techniques, Deposition of dielectrics, Sputtering, Lithography and Etching, Next-Generation lithographic methods, Wet chemical etching, Dry etching, Twin-Tub CMOS process. **10 Lectures**

Microwave diodes: Gunn and IMPATT diodes – introduction, RWH mechanism for Gunn action, modes of bulk device and modes of Gunn diode, derivation of criterion for Gunn oscillation; IMPATT diode – introduction, source of DNR; Read diode - avalanche zone analysis of Read diode, drift zone analysis-power-frequency limitation. **12 Lectures**

Basics of Radar: Pulsed radar–Range equation, implications of range equation, maximum and minimum range; Doppler radar – moving target indicator radar, CW radar, FM radar and FM altimeter, blind speed of radar. **5 Lectures**

Filter: Constant -K filters - High-pass and low-pass filters-Calculation of attenuation constant and phase shift constant-design of HPE and LPE – shortcomings of constant K filters. **5 Lectures**

Transmission line: Primary constants, Derivation of Telegrapher's equation, expressions for voltage and current on the line, input impedance of the line, sources of distortion and distortion-less propagation, fault location on the line. **8 Lectures**

Suggested References:

1. Network, lines and fields – J.D. Ryder
2. Telecommunications – W. Fraser
3. Advanced Electronics – T. Chattopadhyay
4. Semiconductor Devices – S.M. Sze
5. Phase Lock Loop – Gardner
6. Solid State Electronic Devices; Ben G. Streetman and Sanjay Banerjee; Pearson Education.
7. An Introduction to Semiconductor Devices; Author: Donald A. Neamen; McGraw Hill.

PAPER: BASICS OF MACHINE LEARNING (LABORATORY)
PAPER CODE: MJPH23-2
MARKS: 100; CREDIT: 4
LECTURES: 120 HRS.

Introduction to Machine Learning: Definition, scope, and applications of machine learning, supervised, unsupervised, and reinforcement learning, The components of a machine learning system: Data, model, and evaluation, Python and libraries for machine learning: NumPy, Pandas, scikit-learn **(20 Lectures)**

Data Processing: Handling missing data and data imputation**,** Feature scaling and normalization, Categorical encoding and feature engineering **(10 Lectures)**

Linear Regression: Implementing simple linear regression, logistic regression and multiple linear regression, Model evaluation and interpretation **(10 Lectures)**

Classification Algorithms: Implementing decision trees for classification, Random Forest algorithm in machine learning, Implementing support vector machines (SVM), Implementing K-means clustering, Implementing hierarchical clustering **(16 Lectures)**

Dimensionality Reduction: Implementing Principal Component Analysis (PCA), Singular Value Decomposition (SVD), Linear Discriminant Analysis (LDA) and Quadratic Discriminant Analysis (QDA), Visualizing high-dimensional data using dimensionality reduction techniques **(16 Lectures)**

Model Evaluation and Validation: Implementing cross-validation techniques, Confusion matrix, ROC curve, and precision-recall curve, Mean squared error, R-squared score, and residual plots **(16 Lectures)**

Introduction to Neural Networks: Implementing a simple artificial neural network from scratch, Building and training neural networks, Model optimization for neural networks, Basics of Physics-informed neural networks (PINNs) **(16 Lectures)**

Deep Learning: Implementing convolutional neural networks (CNNs) for image classification, Implementing recurrent neural networks (RNNs) for sequence data, Transfer learning with pre-trained deep learning models , Some applications of deep learning in Physics (e.g. Particle detection and classification, Galaxy classification, Gravitational wave detection, Dark matter mapping, Material discovery, Phase transition prediction, turbulence modelling, Quantum state estimation) **(16 Lectures)**

Suggested References:

1. Introduction to Machine Learning, Ethem Alpaydin, The MIT Press, Cambridge, Massachusetts London, England, 2015
2. Introduction to Machine Learning with Python: A Guide for Data Scientists, Andreas C. Muller and Sarah Guido, O'Reilly Media, Inc., 1005 Gravenstein Highway North, Sebastopol, CA 95472, 2016

PAPER: ADVANCED MATHEMATICAL METHODS
PAPER CODE: MJPH23-3
MARKS: 100; CREDIT: 4
LECTURE: 60 HRS.

Linear Vector Spaces: Vector Spaces and Subspaces. Linear Independence and Dependence of Vectors. Basis and Dimensions of a Vector Space. Change of Basis. Homomorphism and Isomorphism of Vector Spaces. Linear Transformations. Algebra of Linear Transformations. Non-singular Transformations. Representation of Linear Transformations by Matrices. **(10 Lectures)**

Matrices: Addition and Multiplication of Matrices. Null Matrices. Diagonal, Scalar and Unit Matrices. Upper-Triangular and Lower-Triangular Matrices. Transpose of a Matrix. Symmetric and Skew-Symmetric Matrices. Conjugate of a Matrix. Hermitian and Skew-Hermitian Matrices. Singular and Non-Singular Matrices. Orthogonal and Unitary Matrices. Trace of a Matrix. Inner Product. Eigenvalues and Eigenvectors. Cayley-Hamilton Theorem. Diagonalization of Matrices. Solutions of Coupled Linear Differential Equations. **(10 Lectures)**

Group Theory: Review of Sets, Mapping and Binary Operations, Relation, Types of Relations. Groups: Elementary properties of Groups, Uniqueness of Solution, Subgroup, Centre of a Group, Co-sets of a Subgroup, Cyclic Group, Permutation/Transformation. Homomorphism and Isomorphism of Group. Normal and Conjugate Subgroups, Completeness and Kernel. **(10 Lectures)**

Some special groups with operators: Representation of reducible and irreducible matrices. Continuous group. Lie Group. Definition of Generator. Basics of SO(2), SO(3), U(1), SU(2), SU(3) groups. **(5 Lectures)**

Cartesian Tensors: Transformations of Cartesian Coordinates, Relation between Direction Cosines. Tensors. Vector Algebra and Calculus using Cartesian Tensors: Scalar and Vector Products, Scalar and Vector Triple Products. Differentiation. Gradient, Divergence and Curl of Tensor Fields. Vector Identities. Tensorial Formulation of Analytical Solid Geometry: Equation of a Line. Angle Between Lines. Projection of a Line on another Line. Condition for Two Lines to be Coplanar. Foot of the Perpendicular from a Point on a Line. Rotation Tensor (No Derivation). Isotropic Tensors. Moment of Inertia Tensor. Stress and Strain Tensors: Symmetric Nature. Elasticity Tensor. Generalized Hooke's Law. **(15 Lectures)**

General Tensors: Transformation of Co-ordinates. Einstein's Summation Convention, Minkowski Space. Contravariant & Covariant Vectors. Contravariant, Covariant and Mixed Tensors. Kronecker Delta and Permutation Tensors. Alternating Tensors. Algebra of Tensors. Sum, Difference & Product of Two Tensors. Contraction. Quotient Law of Tensors. Symmetric and anti-symmetric Tensors. Metric Tensor. **(10 Lectures)**

Suggested References:

1. Mathematical Methods for Physicists, G. B. Arfken, H. J. Weber and F. E. Harries (Elsevier Academic Press, New York, 1970).
2. Mathematical Method of Physics, J. Mathews and R. L. Walker (Pearson Education Limited, 1971)
3. Mathematical Methods in the Physical Sciences, Mary L. Boas (John Wiley & Sons, USA, 2006)
4. Vector Analysis and an Introduction to Tensor Analysis (Schaum Series), Murrar R. Spiegel (McGraw-Hill, 1959)
5. Cartesian Tensor: An Introduction, G. Temple (Dover Publications INC. New York, 2004)
6. Mathematical Physics with Applications, Problems and Solutions, V. Balakrishan (Ane Books Pvt. Ltd. India, 2020)

PAPER: LASER PHYSICS
PAPER CODE: MJPH23-4
MARKS: 100; CREDIT: 4
LECTURE: 60 HRS.

Introduction: Einstein coefficients, Light amplification, Threshold condition, Line broadening mechanism, Ammonia beam maser, MASER operation. **(6 Lectures)**

Coherent states: Minimum uncertainty wave-function, temporal development of minimum uncertainty wave-function, coherent state of the radiation field, properties of coherent states. **(4 Lectures)**

Semiclassical Theory of Laser: Electromagnetic field equations, expansion in normal modes of cavity, Lamb's self-consistency equations, Density matrix equations, Polarization of the medium, Single mode operation. **(6 Lectures)**

Gas Laser Theory: Polarization of Doppler broadened medium, Rate equations and solutions, Hole burning, Lamb dip, two-mode operation. **(6 Lectures)**

Multimode Operation: Polarization of the media, free-running operation, locking of beat frequencies between N-modes, Two-mode operation. **(6 Lectures)**

Quantum theory of laser: Quantization of the radiation field, Photon number states, Field equation of motion, Laser photon statistics, Laser line width. **(6 Lectures)**

Properties of laser beams and types of lasers: Coherence properties of laser light, Spatial and temporal coherence, Directionality; different types of lasers - Ruby Laser, Helium-Neon Laser, Carbon di-oxide Laser, Solid state Laser, Semiconductor diode Laser, Quantum well lasers, Free electron Lasers, and Dye Lasers. **(12 Lectures)**

Applications of lasers in Science and Industry:
(a) Spatial frequency filtering, Holography, Three-dimensional hologram, Reconstruction.
(b) Laser induced fusion, laser energy requirements, energy confinement, Isotope separation.
(c) Harmonic generation, Stimulated Raman emission, self-focusing.
(d) Lasers in industries: Material processing, tracking, LIDAR, medical application
(8 Lectures)

Indian Contribution to the Subject:
Early developments of laser in India; Photothermal spectroscopy; laser induced plasma; E.C.G. Sudarshan's work on coherence; Dr. R. Srinivasan's contribution in laser-based eye surgery. **(6 Lectures)**

Suggested References:
1. The quantum Theory of Light – R. Loudon (Oxford Science publication)
2. Lasers: Theory and Applications – K. Thyagrajan and A.K. Ghatak (Plenum Press)
3. Laser Physics – M. Sargent III, M.O. Scully and W.E. Lamb Jr. (Addition Wesley)
4. Introduction to Laser Physics – K. Shimoda (Springer)
5. Laser Fundamentals – William T. Silfvast, Cambridge University Press.

PAPER: PARTICLE PHYSICS
PAPER CODE: MJPH23-5
MARKS: 100; CREDIT: 4
LECTURES: 60 HRS.

Symmetries: Discrete Symmetries – Parity (P), Charge-Conjugation (C), Time-Reversal, CP-symmetry, CPT-Theorem; Lie-groups, Lie-algebra, Lorentz group; SU(2), SU(3) and SU(N) groups. **(5 Lectures)**

Quark Model: Baryon and meson multiplets; Baryon and meson masses, Gell-Mann-Okubo mass formula; Heavy quark multiplets; concept of colour (4 **Lectures)**

Bound states: Positronium, Quarkonium, Charmonium, Bottomonium, Light Quark Mesons; Baryons – wave functions, Magnetic Moments **(3 Lectures)**

Fermionic wave functions: Dirac equation and its solutions, properties of Dirac spinors – spin, helicity, Lorentz Transformation, charge conjugation and parity operators; properties of gamma matrices; bilinear covariants and their properties under transformations. **(9 Lectures)**

Electromagnetic interactions: scattering amplitudes, trace theorems; electron-muon and Compton scattering, differential and total cross-sections **(6 Lectures)**

Weak Interaction: Different weak decays of quarks, leptons and hadrons; quark mixing – Cabibbo angle, CKM matrix, comparison of decay rates; charged current interaction, decay of muon and charged pion, neutron; neutral current interaction; lepton universality and number of neutrino types from experimental data. **(7 Lectures)**

Quantum Chromodynamics: electron-proton scattering; structure of baryons **(4 Lectures)**

Gauge Theory: Gauge invariance - Abelian, non-Abelian, higher order diagrams and evolution of gauge couplings (concept only). **(4 Lectures)**

Standard Model (SM): Spontaneous symmetry breaking, Higgs mechanism, SM of Electroweak interaction, Spontaneous Breaking of SU(2)×U(1) symmetry; determination of W, Z and Higgs masses, Fermion mass generation and mixing; CP violation and the necessity of the third generation. **(8 Lectures)**

Indian Contribution to Particle Physics: Bhabha (electron-positron) scattering, Bhabha-Heitler theory of cosmic ray showers, Bibha Chowdhury and D.M. Bose's experiments involving cosmic rays leading to the first identification of pi-mesons, E.C.G. Sudharshan's pioneering work on V-A theory describing weak interactions, Sudarshan's prediction of tachyons **(6 lectures)**

Beyond the Standard Model: Shortcomings of the SM, idea of Grand Unified Theory, Supersymmetry (SUSY) – basic ideas, particle content of SUSY, R-Parity, implications of R-Parity conservation and non-conservation, Dark Matter; other BSM ideas. **(4 Lectures)**

Suggested References:

1 Introduction to Elementary Particles - D.J. Griffiths, Wiley-VCH.
2 Quarks and Leptons – F. Halzen and A.D. Martin, Wiley-VCH
3 Introduction to High Energy Physics – D.H. Perkins, Cambridge University Press
4 Particle Physics – B.R. Martin and G. Shaw, John Wiley and Sons
5 An Introductory Course of Particle Physics – P.B. Pal, CRC Press
6 Modern Elementary Particle Physics – G. Kane, Addison-Wesley
7 The Review of Particle Physics, Particle Data Group, http://pdg.lbl.gov

PAPER: INTRODUCTION TO NONLINEAR DYNAMICS
PAPER CODE: MJPH23-6
MARKS: 100; CREDIT: 4
LECTURES: 60 HRS.

Introduction and overview: Brief history of dynamical systems; Importance of being nonlinear; Mechanical systems as Dynamical Systems; Idea of phase space and concept of dissipative & non-dissipative systems by using phase-space volume; Method of quadrature, constant of motion & exact solution; Examples: Simple Harmonic oscillators (SHO), simple pendulum, Duffing oscillator; Effect of damping & driving force; One dimensional mapping and discrete dynamical systems. **(10 Lectures)**

Phase Portrait & Stability Analysis: One and two dimensional flows; Phase portraits on plane; Equilibrium points and linear stability analysis; Classification of equilibrium points; Illustrative Examples: SHO, simple pendulum, Duffing oscillator, Population models, Rate equations for chemical reactions, game theory etc.; Limit cycles; Van der Poll oscillator, Poincaré-Bendixon's theorem; Higher dimensional systems; Poincaré section; Hamiltonian Systems; Nonlinear stability analysis; Lyapunov function; Computing and visualizing trajectories on the computer using software packages. (1**8 Lectures)**

Bifurcation: Introduction; Saddle-node, transcritical, pitchfork and Hopf bifurcations; Imperfect bifurcations and catastrophes; Examples: Hysteresis in the driven pendulum; Landau theory of Phase transitions; Josephson junction; synchronous flashing of fireflies, Love affairs, Epidemic models etc. **(12 Lectures)**

Chaos: Introduction; Sensitivity to the initial condition; Chaos in Logistic map; Chaos in continuous dynamical systems; Detecting chaos from Time series, Poincaré map, Power spectrum, autocorrelation function, Lyapunov exponent etc. Different types of attractors; Different routes to chaos; Example: Lorenz system, Damped driven pendulum etc.; Chaos based cryptography. **(15 Lectures)**

Fractals: Introduction; Self similarity and fractal geometry: Fractals in nature – trees, coastlines, earthquakes etc.; Cantor set; Need for fractal dimension to describe self-similar structure; Deterministic fractal vs. self-similar fractal structure; Fractals in dynamics – Serpinski gasket and Diffusion-limited aggregation. **(5 Lectures)**

Suggested References:

1. Nonlinear Dynamics and Chaos with applications to Physics, Biology, Chemistry and Engineering, Steven H Strogatz, Indian Edition by Sarat Book House, Kolkata.
2. Differential Equations, Dynamical Systems and Introduction to Chaos, M W. Hirsch, S. Smale and R L. Devaney, Third Edition, Academic Press.
3. Nonlinear Dynamics: Integrability, Chaos and Patterns, M. Lakshmanan and S. Rajasekar, Springer.
4. Understanding Nonlinear Dynamics, Daniel Kaplan and Leon Glass, Springer.
5. Chaos and integrability in nonlinear dynamics: An introduction, M. Tabor, John Wile & Sons.

PAPER: TOOLS AND TECHNIQUES FOR NUCLEAR PHYSICS EXPERIMENTS
PAPER CODE: MJPH23-7
MARKS: 100; CREDIT: 4
LECTURES: 60 HRS.

Radiation Detectors: General Properties of Radioactive Sources and Radiation Detectors, Counting Statistics and Error Calculation; Energy Resolution, Detection Efficiency, Dead Time; Gas Detector: Ionization, Charge Migration and Collection, Avalanche, Multiplication, Quenching; Ionization Chambers, Proportional Counters, Multi-wire proportional counters (MWPC), Geiger-Muller Counters; Solid State Detectors: Surface-Barrier Detectors, Silicon Strip Detectors, High Purity Ge (HPGe) Gamma-ray Detectors, Multi-Detector Arrays; Scintillation Counters: Organic and Inorganic Scintillators, Photomultiplier Tubes(PMT), Radiation Spectroscopy with Scintillators; Slow and Fast Neutron Detection Methods. Background Radiation and Detector Shielding. **(18 Lectures)**

Nuclear Electronics: Fast and slow signals**,** Pulse Shaping – Preamplifiers, CR-RC shaping - Pulse height discriminators, Shapers, Triggering, Leading Edge, CFT; Single channel analyzer (SCA) – ADC, TDC, Multi-channel analyzer (MCA); Computer-controlled electronics, Digital signals, Common Control Signals (Z, C, I), NIM/CAMAC data acquisition system; Dataway operations, Multi-Crate systems, Coincidence Technique. **(10 Lectures)**

Accelerator and Ancillary Devices : Ion-sources, Electric and Magnetic Lenses, Quadrupole Magnets, Vacuum Techniques, Vacuum Pumps, Beam Optics – Electrostatic accelerators; Cockroft-Walton high-voltage generator, Van de Graff Accelerator, Tandem, Pelletron, Cyclotron Accelerators, Synchrocyclotron, phase stability, AVF cyclotron, Synchrotrons, Linear Accelerators, Colliding Beam Accelerators; Accelerator and Ancillary Facilities, Recoil Mass Spectrometer, Accelerator Mass Spectrometer (AMS); Target preparation. **(10 Lectures)**

Experimental Methods: Particle Identification: ΔE-E method; Bethe-Bloch Formula, Energy loss, dE/dX, Bragg peak, Time of Flight (TOF) and n-γ discrimination, Multiplicity, Charged Particle Detection, Neutron Spectroscopy and γ-ray Spectroscopy, Angular Distribution and Correlation; Pulse Height Selection and Coincidence Technique, Energy Spectrum Measurement, Fast-Slow Circuits, Pulse Shape Discriminations (PSD), Electronic Logic for Experiments, One-body Scattering, Two-body Scattering, Polarization Measurement, Doppler shift and Doppler Broadening, Life-time Measurements: Delay Coincidence, Pulsed Beam (Slope and Centroid Shift), Recoil Distance Method (RDM) and Doppler shift Attenuation Method (DSAM); Measurement of Magnetic and Quadrupole Moments (g-factor, Hyperfine Interaction) of Excited Nuclear States; Radioactive Ion-beam (RIB) and its production technique **(16 Lectures)**

Nuclear Physics Experiments by Indian scientists in early days: Meghnad Saha's contribution in popularising nuclear science in India – experiments with cyclotron; Contribution of S.N. Ghoshal to Nuclear science – experimental verification of Bohr's theory of Compound Nucleus – a significant step towards understanding nuclear fusion-fission dynamics **(6 Lectures)**

Suggested Reference:

1. Radiation Detection and Measurement – G.F. Knoll, John Wiley & Sons
2. Techniques for Nuclear & Particle Physics Experiments – W.R. Leo, Springer & Verlag
3. Physics & Engineering of Radiation Detection – S.N. Ahmed, Academic Press
4. Nuclear Physics, Principles and Applications – J.S. Lilly, John Wiley & Sons
5. Nuclear Physics – S.N. Ghoshal, S. Chand & Co

PAPER: ASTRONOMY AND ASTROPHYSICS
PAPER CODE: MJPH23-8
MARKS: 100; CREDIT: 4
LECTURES: 60 HRS.

Golden period of Hindu Science: Aryabhata and the heliocentric hypothesis, Varahamihira, Brahmagupta, Sridhara and Bhaskara, Surya siddhanta, Jain science, Kerala school of mathematics, Sawai Jai Singh and late Hindu astronomy, Indian calendars and eras. (10 Lectures)

Astronomical Scales: Astronomical Distance, Mass and Time Scales, Brightness, Radiant Flux and Luminosity, Measurement of Astronomical Quantities, Astronomical Distances, Determination of Distance by Parallax Method, Apparent and Absolute magnitude scale, Distance Modulus, Bolometric luminosity, Distance Measurement using Cepheid Variables. (4 Lectures)

Basic concepts of positional Astronomy: Celestial Sphere, Geometry of a Sphere, Celestial coordinate systems, Ecliptic coordinate systems, Galactic coordinate systems, Conversion of coordinates, Equatorial System, Ecliptic, Equinoxes, Solstice, Zenith, Nadir, Meridian, Diurnal Motion of the Stars, Solar day, Sidereal day, Sidereal month, Synodic month. (5 Lectures)

Basic Parameters of Stars: Determination of Temperature and Radius of a star, Determination of Masses from Binary orbits, Stellar motions, Stellar spectral classification and their Temperature dependence, Blackbody approximation, Hertzsprung-Russell Diagram, Luminosity classification. (6 Lectures)

Astronomical techniques: Basic Optical Definitions for Astronomy, Magnification, Light Gathering Power, Resolving Power, Diffraction Limit, Atmospheric Windows, Rayleigh Criterion, Optical Telescopes, Types of Reflecting Telescopes, Telescope Mountings, Space Telescopes, Radio Telescopes, Detectors and their use with Telescopes, Types of Detectors, detection Limits with Telescopes, Photometry, Spectroscopy, CCDs, Deep surveys. (8 Lectures)

Stellar Evolution: Star formation, Virial theorem, Gravitational energy, Hydrostatic equilibrium, Thermonuclear reactions in stars, *pp* chains and the CNO cycle, Energy transport inside stars (Radiation and Convection), End stages of low mass, internediate mass and high mass stars, Formation of White dwarf, Neutron star, and Black hole (qualitative discussions). (10 Lectures)

The Solar system: Solar Parameters, Solar Photosphere, Solar Atmosphere, Chromosphere, Corona, Solar wind, Solar Activity, Solar cycle, Sunspots, Formation of the Solar System, The Nebular Model, Tidal Forces and Planetary Rings, Inner planets, Jovian planets, Dwarf planets, Asteroids, Comets, Meteoroids, Kuiper-belt objects, Oort cloud. (6 Lectures)

Our Galaxy: Basic structure and properties of the Milky Way, Bulge, Disk, Stellar Halo, Interstellar medium, Gas and Dust in the Galaxy, Nature of Rotation of the Milky Way, Differential Rotation of the Galaxy and Oort Constant, Rotation Curve of the Galaxy and the Dark Matter, Nature of the Spiral Arms, Stars and Star Clusters of the Milky Way, Galactic Centre. (6 Lectures)

Indian Contribution to Modern Astrophysics: Subrahmanyan Chandrasekhar: biography, Birth and death of a star, White dwarf, Neutron star, Black hole; C. V. Vishveshwara: biography, understanding of black holes and gravitational waves; Amal Kumar Raychaudhuri: biography and his research in General Theory of Relativity and Cosmology; S. Dutta Majumder and P. C. Vaidya – their works on General Theory of Relativity. Jayant V. Narlikar: biography and his works. (5 Lectures)

Suggested References:

1. Modern Astrophysics, B.W. Carroll & D.A. Ostlie, Addison-Wesley Publishing Co.
2. Introductory Astronomy and Astrophysics, M. Zeilik and S.A. Gregory, 4^{th} Edition, Saunders College Publishing.
3. Astrophysics – Stars and Galaxies : K.D. Abhyankar, Universities Press, 2001
4. Astrophysics – A. Raychaudhuri, Cambridge University Press
5. An Introduction to the Study of Stellar Structure – S. Chandrasekhar, Dover Publications, 2003
6. An introduction to Astrophysics - Baidyanath Basu, Second printing, Prentice Hall of India Private limited, New Delhi,2001.
7. Fundamental Astronomy - H. Karttunen, P. Kroger, H. Oja, M. Poutanen, K. J.Donner, Springer, 2007.
8. Introduction to Astronomy and Cosmology - Ian Morison, John Wiley & Sons, 2013.

MINOR COURSES IN PHYSICS

[Discipline-Specific Minor Courses]

PAPER: MECHANICS (THEORY)
PAPER CODE: MNPH01T
MARKS: 75; CREDIT: 3
LECTURES: 45 HRS.

Number System in Ancient India: Methods of Indian numerals, Bakshali manuscript and invention of the zero, concept of large and small numbers and scales, Aryabhata and his decimal number system (*dashamik sthanmaan*), concept of Pi, Shulva-sutra, Baudhayana, Brahmagupta and growth of geometry, Vedic Mathematics. **(6 Lectures)**

Ordinary Differential Equations: 1st order homogeneous differential equations. 2nd order homogeneous differential equations with constant coefficients. **(5 Lectures)**

Laws of Motion: Frames of reference. Newton's Laws of motion. Dynamics of a system of particles. Centre of Mass. **(5 Lectures)**

Momentum and Energy: Conservation of momentum. Work and energy. Conservation of energy. Motion of rockets. **(5 Lectures)**

Rotational Motion: Angular velocity and angular momentum. Torque. Conservation of angular momentum. **(5 Lectures)**

Gravitation: Newton's Law of Gravitation. Motion of a particle in a central force field (motion is in a plane, angular momentum is conserved, areal velocity is constant). Kepler's Laws (statement only). Satellite in circular orbit and applications. Geosynchronous orbits. **(7 Lectures)**

Elasticity: Hooke's law, Stress-strain diagram. Elastic moduli, Relation between elastic constants. Poisson's Ratio, Expression for Poisson's ratio in terms of elastic constants. Work done in stretching and work done in twisting a wire, Twisting couple on a cylinder. Determination of Rigidity modulus by static torsion. Determination of elastic constants by Searle's method. **(6 Lectures)**

Oscillations: Simple harmonic motion. Differential equation of SHM and its solutions. Kinetic and Potential Energy, Total Energy and their time averages. Damped oscillations. **(6 Lectures)**

Suggested References:

1. An introduction to mechanics, D. Kleppner, R.J. Kolenkow, 1973, McGraw-Hill.
2. Classical Mechanics, Dr. J.C. Upadhyaya, Himalaya Publishing House
3. Introduction to Classical Mechanics, R. G. Takwale and P. S. Puranik, McGraw-Hill.
4. Physics – Resnick, Halliday & Walker 9/e, 2010, Wiley
5. Mechanics, D.S. Mathur, S. Chand and Company Limited, 2000

PAPER: MECHANICS (LABORATORY)
PAPER CODE: MNPH01P
MARKS: 25; Credit: 1
LECTURES: 30 HRS.

List of Practical:

1. To measure the length (or diameter) using Vernier callipers, screw gauge and travelling microscope.
2. To determine the Moment of Inertia of a flywheel.
3. To determine the Young's Modulus by method of flexure.
4. To determine the Modulus of Rigidity of a wire by Maxwell's needle.
5. To determine the elastic constants of a wire by Searle's method.
6. To determine the value of g by Bar Pendulum.
7. To determine the value of g by Kater's Pendulum.
8. To study the Motion of a Spring and calculate (a) Spring Constant, (b) g.
9. To determine the rigidity modulus of a material taken in the form of wire by statical method.
10. To determine the rigidity modulus of a material taken in the form of wire by dynamical method.

Suggested References:

1. Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.
2. An Advanced Course in Practical Physics, D. Chattopahyay, P. C. Rakshit and B. Saha, New Central Book Agency (P) Ltd.
3. A Textbook of Advanced Practical Physics, Samir Kumar Ghosh, New Central Book Agency (P) Ltd.
4. A Text Book of Practical Physics, Indu Prakash and Ramakrishna, 11th Edition, 2011, Kitab Mahal, New Delhi.

PAPER: ELECTRICITY AND MAGNETISM (THEORY)
PAPER CODE: MNPH02T
MARKS: 75; CREDIT: 3
LECTURE: 45 HRS.

Vector Analysis: Review of vector algebra (Scalar and Vector product). Gradient, Divergence, Curl and their significance. Vector Integration: Line, surface and volume integrals of Vector fields. Gauss-divergence theorem and Stoke's theorem of vectors (statement only). **(7 Lectures)**

Electrostatics: Electrostatic Field. Electric flux. Gauss's theorem of electrostatics. Applications of Gauss theorem- Electric field due to point charge, infinite line of charge, uniformly charged spherical shell and solid sphere, plane charged sheet, charged conductor. Electric potential as line integral of electric field. Potential due to a point charge, Electric dipole, Uniformly charged spherical shell and solid sphere. Calculation of electric field from potential. Capacitance of an isolated spherical conductor. Parallel plate, spherical and cylindrical condenser. Energy per unit volume in electrostatic field. Dielectric medium, Polarisation, Displacement vector. Gauss's theorem in dielectrics. Parallel plate. capacitor completely filled with dielectric. **(20 Lectures)**

Magnetostatics: Biot-Savart's law and its applications- straight conductor, circular coil, solenoid carrying current. Divergence and curl of magnetic field. Magnetic vector potential. Ampere's circuital law. Magnetic properties of materials: Magnetic intensity, magnetic induction, permeability, magnetic susceptibility. Brief introduction of dia-, para-and ferro-magnetic materials. **(8 Lectures)**

Electromagnetic Induction: Faraday's laws of electromagnetic induction, Lenz's law, self and mutual inductance, L of single coil, M of two coils. Energy stored in magnetic field. **(3 Lectures)**

Maxwell`s equations and Electromagnetic wave propagation: Equation of continuity of current, Displacement current, Maxwell's equations, Poynting vector, energy density in electromagnetic field, electromagnetic wave propagation through vacuum and isotropic dielectric medium, transverse nature of EM waves, polarization. **(7 Lectures)**

Suggested References:
1. Electricity and Magnetism, Edward M. Purcell, 1986, McGraw-Hill Education
2. Electricity & Magnetism, J. H. Fewkes and J. Yarwood. Vol. I, 1991, Oxford Univ. Press
3. Electricity and Magnetism, D C Tayal, 1988, Himalaya Publishing House.
4. University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole.
5. D. J. Griffiths, Introduction to Electrodynamics, 3rd Edition, 1998, Benjamin Cummings.

PAPER: ELECTRICITY AND MAGNETISM (LABORATORY)
PAPER CODE: MNPH02P
MARKS: 25; CREDIT: 1
LECTURE: 30 HRS.

List of Practical:

1. To use a Multimeter for measuring
   (a) Resistances, (b) AC and DC Voltages, (c) DC Current, and (d) checking electrical fuses.
2. Use of Ballistic Galvanometer:
   (i) To measure the charge and current sensitivity
   (ii) To measure CDR
   (iii) To determne a high resistance by Leakage Method,
   (iv) To determine Self Inductance of a Coil by Rayleigh's Method.
3. To compare capacitances using De'Sauty's bridge.
4. To measure the field strength B and its variation in a Solenoid (Determine dB/dx)
5. To study the Characteristics of a Series RC Circuit.
6. To study a series LCR circuit and determine its
   (a) Resonant frequency, (b) Quality factor Q
7. To study a parallel LCR circuit and determine its
   (a) Anti-resonant frequency, (b) Quality factor Q
8. To determine a Low Resistance by Carey Foster's Bridge.
9. To verify the Thevenin and Norton theorems
10. To verify the Superposition, and Maximum Power Transfer Theorems

Suggested References:

1. Advanced Practical Physics for students, B. L. Flint & H. T. Worsnop, 1971, Asia Publishing House.
2. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers
3. A Text Book of Practical Physics, I. Prakash & Ramakrishna, 11th Edition 2011, Kitab Mahal
4. Engineering Practical Physics, S. Panigrahi & B. Mallick, 2015, Cengage Learning

PAPER: THERMAL PHYSICS (THEORY)
PAPER CODE: MNPH03T
MARKS: 75; CREDIT: 3
LECTURES: 45 HRS.

Kinetic Theory of Gases: Derivation of Maxwell's law of distribution of velocities and its experimental verification, Mean free path, Transport Phenomena: Viscosity, Conduction and Diffusion, Law of equipartition of energy (no derivation) and its applications to specific heat of gases; mono-atomic and diatomic gases. **(12 Lectures)**

Laws of Thermodynamics: Thermodynamic Description of system: Zeroth Law of thermodynamics and temperature. First law and internal energy, conversion of heat into work, Various Thermodynamical Processes, Applications of First Law: General Relation between C_P and C_V, Work Done during Isothermal and Adiabatic Processes, Compressibility and Expansion Coefficient, Reversible and irreversible processes, Second law and Entropy, Carnot's cycle & theorem, Entropy changes in reversible & irreversible processes, Entropy-temperature diagrams, Third law of thermodynamics, Unattainability of absolute zero. **(15 Lectures)**

Thermodynamic Potentials: Enthalpy, Gibbs and Helmholtz functions, Maxwell's relations and applications. **(6 Lectures)**

Theory of Radiation: Blackbody radiation, Spectral distribution, Concept of Energy Density, Derivation of Planck's law, Deduction of Wien's distribution law, Rayleigh-Jeans Law, Stefan Boltzmann Law from Planck's law. **(6 Lectures)**

Indian Contribution to the Subject:
Meghnad Saha: Biography, Saha's ionization formula, Saha's views on national problems (Atomic energy, river physics : flood and dam) and social concerns. **(6 Lectures)**

Suggested References:

1. Heat and Thermodynamics: Mark W. Zeemansky and Richard Dittman, Special Indian Edition (8th edition), McGraw-Hill Education.
2. A Treatise of Heat, Meghnad Saha and B. N. Srivastava, 1958, Indian Press.
3. Thermal Physics, S. C. Garg, R. M. Bansal and C. K. Ghosh, 2nd Edition, 1993, Tata McGraw-Hill.
4. Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2010, Springer.
5. Thermodynamics, Kinetic Theory and Statistical Thermodynamics, F. W. Sears and G. L. Salinger, 3rd edition, 1998, Narosa.
6. Concepts of Thermal Physics, Stephen J. Blundell and Katherine M. Blundell, 2nd edition, 2009. Oxford University Press.
7. An Introduction to Thermal Physics, Daniel V. Schroeder, 1999 Pearson Education.
8. Fundamentals of statistical and thermal physics: Frederick Reif.
9. Thermodynamics and an introduction to thermostatistics, Herbert B. Callen, 2nd edition, Wiley, 1985.
10. Thermal Physics, A. B. Gupta and H. P. Roy, 3rd edition, Books and Allied Ltd., 2010.

PAPER: THERMAL PHYSICS (LABORATORY)
PAPER CODE: MNPH03P
MARKS: 25; CREDIT: 1
LECTURES: 30 HRS.

List of Practical:

1. To determine Mechanical Equivalent of Heat (J) by Callender and Barne's constant flow method.
2. To verify Stefan's law.
3. To determine the coefficient of thermal conductivity of Cu by Searle's Apparatus.
4. To determine the coefficient of thermal conductivity of a bad conductor by Lee and Charlton's disc method.
5. To determine the temperature co-efficient of resistance by Platinum resistance thermometer.
6. To study the variation of thermo-emf across two junctions of a thermocouple with temperature.

Suggested References:

1. Advanced Practical Physics for students, B. L. Flint & H. T. Worsnop, 1971, Asia Publishing House.
2. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers
3. A Text Book of Practical Physics, Indu Prakash and Ramakrishna, 11th Edition, 2011, Kitab Mahal, New Delhi.
4. A Laboratory Manual of Physics for Undergraduate Classes, D.P. Khandelwal, 1985, Vani Publication.

PAPER: WAVES AND OPTICS (THEORY)
PAPER CODE: MNPH04T
MARKS: 75; CREDITS: 3
LECTURES: 45 HRS.

Superposition of Two Collinear Harmonic Oscillations: Linearity & Superposition Principle. (1) oscillations having equal frequencies and (2) oscillations having different frequencies (beats). **(2 Lectures)**

Superposition of Two Perpendicular Harmonic Oscillations: Graphical and Analytical methods. Lissajous figures with equal and unequal frequencies and their uses. **(3 Lectures)**

W**ave Motion - General:** Transverse waves on a String. Travelling and Standing waves on a string. Normal modes of a string. Group Velocity, Phase velocity. Plane Waves, Spherical waves, Cylindrical waves, Wave intensity. **(5 Lectures)**

Fermat's principle: Fermat's principle, Laws of reflection and refraction from Fermat's principle. Thin lenses: Combination of lenses, Chromatic aberration in lens, achromatic of combination of lenses, spherical aberration in a lens and its remedy, eye pieces, types of telescopes. **(6 Lectures)**

Sound: Simple harmonic motion - force vibration and resonance – Fourier's Theorem – Application to saw tooth wave and square wave - intensity and loudness of sound – decibels - intensity levels - musical notes - musical scale. Acoustics of buildings: Reverberation and time of reverberation - Absorption coefficient - Sabine's formula - measurement of reverberation time - acoustic aspects of hall and auditoria. **(6 Lectures)**

Wave optics: Electromagnetic nature of light. Definition and properties of wave front. Huygen's Principle. **(3 Lectures)**

Interference: Interference: Division of amplitude and division of wavefront. Young's Double Slit experiment. Lloyd's Mirror and Fresnel's Biprism. Phase change on reflection: Stokes' treatment. Interference in Thin Films: parallel and wedge-shaped films. Fringes of equal inclination (Haidinger Fringes); Fringes of equal thickness (Fizeau Fringes). Newton's Rings: measurement of wavelength and refractive index. **(7 Lectures)**

Diffraction: Fraunhofer diffraction- Single slit; Double Slit. Multiple slits and Diffraction grating. Fresnel Diffraction: Half-period zones. Zone plate. Fresnel Diffraction pattern of a straight edge, a slit and a wire using half-period zone analysis. **(7 Lectures)**

Indian Contribution to the Subject:
Concept of light in ancient India; Prakash; Hints in Rigveda; Kanada's Vaisheshika Sutras; Nature of light; Surya Siddhanta by Aryabhata; Bhaskaracharya's descript of refraction through a prism; Shiddhanta Shiromoni. **(6 Lectures)**

Suggested References:

1. Fundamentals of Optics, F.A Jenkins and H.E White, 1976, McGraw-Hill
2. Principles of Optics, B.K. Mathur, 1995, Gopal Printing
3. Fundamentals of Optics, H.R. Gulati and D.R. Khanna, 1991, R. Chand Publications
4. University Physics. F.W. Sears, M.W. Zemansky and H.D. Young. 13/e, 1986, Addison-Wesley

PAPER: WAVES AND OPTICS (LABORATORY)
PAPER CODE: MNPH04P
MARKS: 25; CREDIT: 1
LECTURE: 30 HRS.

List of Practical:

1. To determine the frequency of an electric tuning fork by Melde's experiment and verify λ^2 –T law.
2. To study Lissajous Figures.
3. Familiarization with: Schuster`s focusing; determination of angle of prism.
4. To determine refractive index of the Material of a prism using sodium source.
5. To determine the dispersive power and Cauchy constants of the material of a prism using mercury source.
6. To determine wavelength of sodium light using Fresnel Biprism.
7. To determine wavelength of sodium light using Newton's Rings.
8. To determine wavelength of (i) Na source and (ii) spectral lines of Hg source using plane diffraction grating.
9. To determine dispersive power and resolving power of a plane diffraction grating.
10. To determine the wavelength of Laser light using Diffraction with Single Slit.
11. To determine wavelength of (i) Sodium and (ii) spectral lines of the Mercury light using plane diffraction Grating.

Suggested References:

1. Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.
2. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers
3. A Text Book of Practical Physics, Indu Prakash and Ramakrishna, 11th Edition, 2011, Kitab Mahal, New Delhi.

SKILL ENHANCEMENT COURSES in PHYSICS

PAPER: BASIC COMPUTER PROGRAMMING
PAPER CODE: SECPH01
MARKS: 75; CREDIT: 3
LECTURES: 90 HRS.

Introduction and Overview: Computer architecture and organization, memory and Input/output devices.

Basics of Scientific Computing: Binary and decimal arithmetic, Floating point numbers, algorithms, Sequence, Selection and Repetition, single and double precision arithmetic, underflow & overflow emphasize the importance of making equations in terms of dimensionless variables, Iterative methods.

Errors and error analysis: Truncation and round off errors, Absolute and relative errors, Floating point computations.

Review of C Programming fundamentals: Introduction to Programming, constants, variables and data types, operators and Expressions, I/O statements, scanf and printf, c in and c out, Manipulators for data formatting, Control statements, decision making and looping statements (*If-statement, If-else Statement, Nested if Structure, Else-if Statement, Ternary Operator, Goto Statement, Switch Statement)* Unconditional and Conditional Looping. While Loop. Do-While Loop. FOR Loop. Break and Continue Statements. Nested Loops, Arrays (*1D & 2D*) and strings, user defined functions, Structures and Unions, Idea of classes and objects, Sum and average of a list of numbers, largest of a given list of numbers and its location in the list, sorting of numbers in ascending descending order, Binary search, Series summation.

Bisection and Newton Raphson Methods: Solution of Algebraic and Transcendental equations, Solutions of linear and quadratic equations.

Interpolation Methods: Newton Gregory Forward and Backward difference formula, Evaluation of trigonometric functions e.g. $\sin\theta$, $\cos\theta$, $\tan\theta$, etc., Error estimation of linear interpolation.

Numerical differentiation and Integration: Forward and Backward difference formula, Trapezoidal and Simpson rules, Given Position with equidistant time data to calculate velocity and acceleration and vice versa.

Solution of Ordinary Differential Equations (ODE): First order Differential equation Euler, modified Euler and Runge-Kutta (RK) second and fourth order methods, First order differential equation like Radioactive decay, Current in RC, LC circuits with DC source, Newton's law of cooling, Classical equations of motion, Solutions of the coupled differential equations, The differential equation describing the motion of a pendulum (using RK 4 order method).

Random number generation: Monte Carlo method, area of circle, area of ellipse, area of square, volume of sphere, value of pi (π). Find the area of *B-H* Hysteresis loop.

Suggested References:

1. Introduction to Numerical Analysis, S.S. Sastry, 5^{th} Edn., 2012, PHI Learning Pvt. Ltd.
2. Schaum's Outline of Programming with C++. J. Hubbard, 2000, McGraw-Hil Pub.
3. Numerical Recipes in C: The Art of Scientific Computing, W.H. Pressetal, 3^{rd} Edition, 2007, Cambridge University Press.
4. A first course in Numerical Methods, U.M. Ascher & C. Greif, 2012, PHI Learning.

5. Elementary Numerical Analysis, K.E. Atkinson, 3rd Edn., 2007, Wiley India Edition.
6. Numerical Methods for Scientists & Engineers, R.W. Hamming, 1973, Courier Dover Pub.
7. An Introduction to computational Physics, T. Pang, 2nd Edn., 2006, Cambridge Univ. Press
8. Computational Physics, Darren Walker, 1st Edn., 2015, Scientific International Pvt. Ltd

ANY ONE OF THE FOLLOWING THREE SKILL ENHANCEMENT COURSES WILL BE OFFERED BY THE DEPARTMENT IN SEMESTER II AS SECPH02

PAPER: BASIC INSTRUMENTATION SKILLS
PAPER CODE: SECPH02
MARKS: 75; CREDIT: 3
LECTURES: 45 HRS.

This course is to get exposure with various aspects of instruments and their usage.

History of Measurement Systems in India: Units of length - cubit, yard, krosh, jojon; Units of weight - ratti, tola, ser, maund; Units of volume - chhataank, pav, seer; Units of time – Nimesha, Kala, Muhurta, pal, danda; Sundials - Samrat Yantra, Rama Yantra, Nadi Valaya Yantra. **(6 Lectures)**

Basic of Measurement: Instruments accuracy, precision, sensitivity, resolution range etc. Errors in measurements and loading effects. Multimeter: Principles of measurement of dc voltage and dc current, ac voltage, ac current and resistance. Specifications of a multimeter and their significance. **(6 Lectures)**

Electronic Voltmeter: Advantage over conventional multimeter for voltage measurement with respect to input impedance and sensitivity. Principles of voltage, measurement (block diagram only). Specifications of an electronic Voltmeter/ Multimeter and their significance. AC millivoltmeter: Type of AC millivoltmeters: Amplifier- rectifier, and rectifier- amplifier. Block diagram ac millivoltmeter**,** specifications and their significance. **(6 Lectures)**

Cathode Ray Oscilloscope: Block diagram of basic CRO. Construction of CRT, Electron gun, electrostatic focusing and acceleration (Explanation only– no mathematical treatment), brief discussion on screen phosphor, visual persistence & chemical composition. Time base operation, synchronization. Front panel controls. Specifications of a CRO and their significance. Use of CRO for the measurement of voltage, frequency, time period. Special features of dual trace, introduction to digital oscilloscope, probes. Digital storage Oscilloscope: working principle. **(10 Lectures)**

Signal Generators and Analysis Instruments: Block diagram, explanation and specifications of low frequency signal generators. pulse generator, and function generator. Brief idea for testing, specifications. Distortion factor meter, wave analysis. **(5 Lectures)**

Impedance Bridges & Q-Meters: Block diagram of bridge. working principles of basic (balancing type) RLC bridge. Specifications of RLC bridge. Block diagram & working principles of a Q- Meter. Digital LCR bridges. **(4 Lectures)**

Digital Instruments: Principle and working of digital meters. Comparison of analog & digital instruments. Characteristics of a digital meter. Working principles of digital voltmeter. **(3 Lectures)**

Digital Multimeter: Block diagram and working of a digital multimeter. Working principle of time interval, frequency and period measurement using universal counter/frequency counter, time- base stability, accuracy and resolution. **(5 Lectures)**

Suggested References:

1. A text book in Electrical Technology - B L Theraja - S Chand and Co.
2. Performance and Design of AC machines - M G Say ELBS Edition.
3. Digital Circuits and systems, Venugopal, 2011, Tata McGraw Hill.
4. Digital Electronics, Subrata Ghoshal, 2012, Cengage Learning.
5. Electronic Devices and Circuits, S. Salivahanan & N. S.Kumar, 3rd Ed., 2012, Tata Mc-Graw Hill
6. Electronic circuits: Handbook of Design and Applications, U. Tietze, Ch. Schenk, 2008, Springer
7. Electronic Devices, 7/e Thomas L. Floyd, 2008, Pearson India

PAPER: RENEWABLE ENERGY AND ENERGY HARVESTING
PAPER CODE: SECPH02
MARKS: 75; CREDIT: 3
LECTURES: 45 HRS.

The aim of this course is to provide exposure of theoretical knowledge.

Fossil fuels and Alternate Sources of energy: Fossil fuels and nuclear energy, their limitation, need of renewable energy, non-conventional energy sources. An overview of developments in Offshore Wind Energy, Tidal Energy, Wave energy systems, Ocean Thermal Energy Conversion, solar energy, biomass, biochemical conversion, biogas generation, geothermal energy tidal energy, Hydroelectricity. **(10 Lectures)**

Solar energy: Solar energy, its importance, storage of solar energy, solar pond, non-convective solar pond, applications of solar pond and solar energy, solar water heater, flat plate collector, solar distillation, solar cooker, solar green houses, solar cell, absorption air conditioning. Need and characteristics of photovoltaic (PV) systems, PV models and equivalent circuits, and sun tracking systems. **(10 Lectures)**

Wind Energy harvesting: Fundamentals of Wind energy, Wind Turbines and different electrical machines in wind turbines, Power electronic interfaces, and grid interconnection topologies. **(4 Lectures)**

Ocean Energy: Ocean Energy Potential against Wind and Solar, Wave Characteristics and Statistics, Wave Energy Devices, Tide characteristics and Statistics, Tide Energy Technologies, Ocean Thermal Energy, Osmotic Power, Ocean Bio-mass. **(4 Lectures)**

Geothermal Energy: Geothermal Resources, Geothermal Technologies. **(2 Lectures)**

Hydro Energy: Hydropower resources, hydropower technologies, environmental impact of hydro power sources. **(2 Lectures)**

Piezoelectric Energy harvesting: Introduction, Physics and characteristics of piezoelectric effect, materials and mathematical description of piezoelectricity, Piezoelectric parameters and modelling piezoelectric generators, Piezoelectric energy harvesting applications, Human power **(7 Lectures)**

Electromagnetic Energy Harvesting: Linear generators, physics mathematical models, recent applications, Carbon captured technologies, cell, batteries, power consumption, Environmental issues and Renewable sources of energy, sustainability. **(6 Lectures)**

Suggested References:

1. Non-conventional energy sources - G.D Rai - Khanna Publishers, New Delhi
2. Solar energy - M P Agarwal - S Chand and Co. Ltd.
3. Solar energy - Suhas P Sukhative, Tata McGraw - Hill Publishing Company Ltd.
4. Godfrey Boyle, “Renewable Energy, Power for a sustainable future”, 2004, Oxford University Press, in association with The Open University.
5. Dr. P Jayakumar, Solar Energy: Resource Assessment Handbook, 2009

PAPER: RADIATION SAFETY
PAPER CODE: SECPH02
MARKS: 75; CREDIT: 3
LECTURES: 45 HRS.

The aim of this course is to create awareness regarding radiation hazards and safety.

Basics of Atomic and Nuclear Physics: Basic concept of atomic structure; X rays characteristic and production; concept of bremsstrahlung and auger electron, The composition of nucleus and its properties, mass number, isotopes of element, spin, binding energy, stable and unstable isotopes, law of radioactive decay, Mean life and half-life, basic concept of alpha, beta and gamma decay, concept of cross section and kinematics of nuclear reactions, types of nuclear reaction, Fusion, fission. **(8 Lectures)**

Interaction of Radiation with matter: Types of Radiation: Alpha, Beta, Gamma and Neutron and their sources, sealed and unsealed sources, **Interaction of Photons -** Photo-electric effect, Compton Scattering, Pair Production, Linear and Mass Attenuation Coefficients, **Interaction of Charged Particles:** Heavy charged particles - Beth-Bloch Formula, Scaling laws, Mass Stopping Power, Range, Straggling, Channelling and Cherenkov radiation. Beta Particles- Collision and Radiation loss (Bremsstrahlung), **Interaction of Neutrons**- Collision, slowing down and Moderation. **(10 Lectures)**

Radiation detection and monitoring devices: Basic idea of different units of activity, KERMA, exposure, absorbed dose, equivalent dose, effective dose, collective equivalent dose, Annual Limit of Intake (ALI) and derived Air Concentration (DAC). Basic concept and working principle of gas detectors (Ionization Chambers, Proportional Counter, Multi-Wire Proportional Counters (MWPC) and Gieger Muller Counter), Scintillation Detectors (Inorganic and Organic Scintillators), Solid States Detectors and Neutron Detectors, Thermoluminescent Dosimetry. **(10 Lectures)**

Radiation safety management: Biological effects of ionizing radiation, Operational limits and basics of radiation hazards evaluation and control: radiation protection standards, International Commission on Radiological Protection (ICRP) principles, justification, optimization, limitation, introduction of safety and risk management of radiation. Nuclear waste and disposal management. Brief idea about Accelerator driven Sub-critical system (ADS) for waste management **(10 Lectures)**

Application of nuclear techniques: Application in medical science (e.g., MRI, PET, Projection Imaging Gamma Camera, radiation therapy), Archaeology, Art, Crime detection, Mining and oil. Industrial Uses: Tracing, Gauging, Material Modification, Sterilization, Food preservation. (**7 Lectures**)

Suggested References:

1. W.E. Burcham and M. Jobes – Nuclear and Particle Physics – Longman (1995)
2. G.F.Knoll, Radiation detection and measurements
3. Thermoluninescense Dosimetry, Mcknlay, A.F., Bristol, Adam Hilger (Medical Physics Handbook 5)
4. W.J. Meredith and J.B. Massey, "Fundamental Physics of Radiology". John Wright and Sons, UK, 1989.
5. J.R. Greening, "Fundamentals of Radiation Dosimetry", Medical Physics Hand Book Series, No.6, Adam Hilger Ltd., Bristol 1981.
6. Practical Applications of Radioactivity and Nuclear Radiations, G.C. Lowental and P.L. Airey, Cambridge University Press, U.K., 2001
7. Martin and S.A. Harbisor, An Introduction to Radiation Protection, John Willey & Sons, Inc. New York, 1981.
8. W.R. Hendee, "Medical Radiation Physics", Year Book – Medical Publishers Inc. London, 1981

PAPER: COMPUTATIONAL METHODS IN PHYSICS
PAPER CODE: SECPH03
MARKS: 75; CREDIT: 3
LECTURES: 90 HRS.

Complex Solutions: Finding the solutions of coupled algebraic equations and generation of fractals by using Newton Raphson method.

Matrix Manipulation: Addition and multiplication of matrices, Numerical solution of simultaneous linear equations: Gauss-Seidel, Gaussian elimination, eigenvalues and eigenvectors.

Curve Fitting: Polynomial fitting of experimental data through matrix inversion method.

Interpolation: Interpolation of a set of data with equal and unequal spacing.

Fast Fourier Transform: Fourier Transform, Fast Fourier Transform (FFT), FFT of some real functions, FFT in higher dimensions, Fourier Transform of real data, spectral applications.

Monte Carlo Simulation: Random number generation and quality, Monte Carlo Integration – simple examples, metropolis algorithm and its application - Ising spin system, simple problem in statistical mechanics.

Numerical integration: Numerical integration of different types of integrals (for example integration with limits zero to infinity, integrals of the type $\int_0^\infty x^{-p} f(x)dx,\ 0 < p < 1$, where $f(x)$ is an analytic function.

Ordinary Differential Equation: Runge-Kutta and other multi-step methods for first order and higher order ordinary differential equations with give initial conditions, stiff differential equation, applications to dynamical systems, example: Lorenz equations, stochastic differential equation, Delay differential equations, solution of simple systems.

Boundary-value problem: Shooting method, relaxation method, Examples: Stationary Schrödinger equation of harmonic and anharmonic oscillators in one-dimension, spheroidal harmonics.

Partial Differential Equations: Introduction, initial-value problem, example: wave-equation in one dimension.

Suggested References:

1. Computational Mathematics, B.P. Demidovich, I.A. Maron and G. Yankovski (Translator), Central Books Limited

MULTIDISCIPLINARY COURSES
in PHYSICS

PAPER: INTRODUCTION TO ASTRONOMY AND ASTROPHYSICS
PAPER CODE: MDPH01
MARKS: 75; CREDIT: 3
LECTURES: 45 HRS.

Course Outcome: Upon completion of this course, students will be able to understand the origin and evolution of the Universe. The course will give a comprehensive introduction to the measurement of basic astronomical parameters such as astronomical scales, luminosity and relevant astronomical quantities. It will provide an overview on key developments in observational astrophysics. Students will have an idea of the instruments used for astronomical observations, the formation of planetary systems and their evolution with time; the physical properties of the Sun and the other components of the solar system; stellar and interstellar components of our Milky Way galaxy. Students will have an understanding of the origin and evolution of galaxies, presence of dark matter and large scale structures of the Universe.

Unit I: **Golden period of Hindu Science**
Aryabhata and the heliocentric hypothesis, Varahamihira, Brahmagupta, Sridhara and Bhaskara, Surya siddhanta, Jain science, Kerala school of mathematics, Sawai Jai Singh and late Hindu astronomy, Indian calendars and eras. **(10 Lectures)**

Unit II: Introduction
The Copernican Revolution, Astronomical distances, Parallax, Our place in the universe, Phases of the Moon, Eclipses of the Sun & Moon. **(2 Lectures)**

Unit III: The Sun and the solar system
The Sun: properties of the photosphere, chromosphere and corona, Sunspots, Solar system's objects: Theory of formation of the solar system (introductory idea only); Inner planets, Jovian planets, Dwarf planets, Asteroid belt, Meteors and Meteorites, Comets, Kuiper belt objects and the Oort cloud, Exoplanets. **(6 Lectures)**

Unit IV: Positional Astronomy
Celestial sphere, Cardinal points and the circles on the celestial sphere, Concept of time: universal time, solar time, mean solar time, local sidereal time and Julian day. Introduction to constellations, ecliptic and diurnal motion of stars, Seasons, Calendar, Julian date and heliocentric correction. **(6 Lectures)**

Unit V: Astronomical Techniques
Introduction to telescopes – telescope size and light gathering power, resolving power (qualitative discussion only), Different types of optical telescopes (reflecting and refracting), Space telescopes, hands on sessions using open source software (Stellarium). **(6 Lectures)**

Unit VI: Stars and Galaxies
Birth of a star, Stellar evolution, End state of stars: Supernova, White dwarf, Neutron star and Black hole, The Milky Way, Properties of the galactic centre, Morphological classification of galaxies: Spiral, Elliptical and Lenticular galaxies, Hubble's tuning fork diagram, Active galaxies. **(5 Lectures)**

Unit VII: Large Scale Structure and Cosmology

Clusters, Superclusters, Cosmic web, Distance ladder in cosmology, Cepheid variables, Cosmic expansion of the universe and Hubble's law, Concept of the Hot Big Bang, Introductory concepts of dark matter and dark energy, Cosmic Microwave Background (CMB). **(5 Lectures)**

Unit VIII: Indian Contribution to Modern Astrophysics

Subrahmanyan Chandrasekhar: biography, Birth and death of a star, Black hole, Neutron star, and White dwarf. C. V. Vishveshwara: biography, understanding of black holes and gravitational waves.
Amal Kumar Raychaudhuri: biography and his research in general relativity and Cosmology. P. C. Vaidya and his work in the general theory of relativity Jayant V. Narlikar: biography, Cosmology, Inter University Centre for Astronomy and Astrophysics (IUCAA) **(5 Lectures)**

(Different sessions for the students will be arranged to observe the sun, moon, constellations, etc.)

Suggested References:

1. Astrophysics: Stars and Galaxies - K.D. Abhyankar, Tata McGraw Hill Publication, 1992.
2. Astrophysics of the Solar System - K.D. Abhyankar, Universities Press. India Pvt. Ltd. Hyderabad, 1999.
3. An Introduction to Astrophysics - Baidyanath Basu, Tanuka Chattopadhyay, Sudhindra Nath Biswas, PHI Learning Pvt. Ltd., 2010.
4. Astrophysics for Physicists - Arnab Rai Choudhuri, Cambridge University Press, 2010.
5. Introduction to Astronomy and Cosmology - Ian Morison, John Wiley \& Sons, 2013.
6. Fundamental Astronomy - H. Karttunen, P. Kroger, H. Oja, M. Poutanen, K. J. Donner, Springer, 2007.

PAPER: PHYSICS IN EVERYDAY LIFE
PAPER CODE: MDPH02
MARKS: 75; CREDIT: 3
LECTURES: 45 HRS.

Introduction to basic concepts in Physics:
Importance of Physics in everyday life, Measurements and units, Newton's Laws of Motion, Work, Energy, Power, Conservation Laws, Projectile motion, Coriolis force, Friction, Heat, temperature, specific heat capacity, Laws of thermodynamics, conductivity and insulation, Electric current, Ohm's Law, resistors, capacitors, and circuits, Electrical power and energy consumption, Basics of magnetism, magnetic fields, electromagnetism, Periodic motion, Simple harmonic motion, resonance, harmonics, standing waves, Random motion, Brownian motion, diffusion and its relevance to gases, liquids, and biological processes, Waves and optics, reflection, refraction, dispersion, scattering, interference, diffraction, and polarization.
[12 Lectures]

Physics of everyday home appliances and modern technologies:
Electric bulbs and fans, electrical circuits, heating elements, motors, Air conditioners and Refrigerators, thermodynamics in refrigeration cycles, heat pumps, and compressors, Microwave ovens, heating by microwaves, Vacuum cleaners, motors and suction, Television and Cameras, image formation, LCD/LED technology, image sensors, Mobile phones, capacitive touchscreens, battery technology, signal transmission, Wi-Fi, Principles of engines and efficiency, physics of fuel combustion, thermodynamic efficiency, electric motors in appliances and vehicles, Memory devices and digital technologies, Solid-state drives, hard disks, and flash memory, polarised sunglasses, cameras, optical fibers, Principles of LASER and its applications in in laser surgery, barcode scanners, laser printers, Medical Physics, Endoscopy, light transmission through fiber optics, image formation, Ultrasonography, sound waves, ultrasound imaging principles, X-rays, CT Scans, and MRI. **[15 Lectures]**

Physics of natural phenomena:
Blue colour of sky, red colours of sky during sunrise and sunset, Rainbow formation, Mirage formation, Lightning and thunder, Tornadoes and Hurricanes, Tides, Aurora Borealis, Phases of the Moon, Solar and lunar eclipses, Seasons, Simple methods for determining the sizes of Sun, Moon and Earth.
[8 Lectures]

Physics of the living world: Breathing, Heart pumping blood, Blood flow, Muscle contraction, Nerve signal transmission, DNA packaging, Perception of colour, Night vision, Bird flight and insect hovering, Fish swimming, Gecko climbing, Spider webs, Capillary action in plants, Thermal regulation and leaf designs in plants, Seed dispersal mechanics. **[10 Lectures]**

Reference Books:

1. How Things Work: The Physics of Everyday Life, Louise A. Bloomfield, John Willey & Sons
2. Storm in a Teacup: The Physics of Everyday Life, Helen Czerski, W. W. Norton & Company
3. The Physics of Life, Adrian Bejan, St. Martin's Press
4. Physics of the Human Body, Richard P. McCall, The Johns Hopkins University Press

PAPER: RADIATION SAFETY
PAPER CODE: MDPH03
MARKS: 75; CREDIT: 3
LECTURES: 45 HRS.

Introduction: Radioactivity, alpha decay, beta decay, gamma radiation, x-rays, internal conversion electrons, neutrons, fission fragments; source activity, radioactive decay law, inverse square law, time distance shielding **[10 hours]**

Dosimetry and radiation Protection: importance of dosimetry, radiation dose and rates, radiation exposure, flux/fluence rate, integrated flux/fluence, exposure and absorbed dose: mathematical definitions, Kerma, cema and terma, measuring exposure, cavity theories, Linear energy transfer (LET), internal dose; passive dosimetry, film dosimetry, Microdosimetry, units: The Roentgen, absorbed dose, relative biological effectiveness (RBE), equivalent dose, effective dose, typical doses from sources in the environment, high doses received in a short time, long-level dose, operational dose limits and calculations. **[18 hours]**

Biological effects of radiation: acute and chronic radiation exposure, effects of symptoms of exposure, exposure limits, radiation protection, exposure reduction, products containing radioactive sources, shielding requirements, radiation survey instruments, radiation emitting devices, sealed sources and device registration, detectors, accelerators and irradiators. **[12 hours]**

Risk communication, safety culture, radiation safety in the nuclear physics laboratory, emergency planning, mandatory regulatory requirements and AERB, radioactive waste management. **[5 hours]**

Problems and tutorials

Reference Books:

1. Introduction to Health Physics - H. Cember & T. Johnson (McGraw-Hill)
2. Physics for radiation protection: A Handbook – J. Martin (Wiley)
3. Data reduction and error analysis for physical sciences – P.R. Bevington & D.K. Robinson (McGraw-Hill)
4. Physics & Engineering of radiation detection – S.N. Ahmed (Elsevier)
5. Techniques for Nuclear and particle physics Experiments – Willian R. Leo (Springer)

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