Department of Physics

Dibrugarh University, Dibrugarh – 786004, Assam, India

SYLLABUS for FIVE YEAR INTEGRATED POST GRADUATE PROGRAMME (FYIPGP) in PHYSICS of DIBRUGARH UNIVERSITY as per NEP-2020 Guidelines

Approved by the Meeting of the Board of Studies in Physics held on July 2, 2024

Preamble

The National Education Policy (NEP 2020) is a groundbreaking initiative approved by the Union Cabinet of India on 29th July 2020. Its central aim is to overhaul the antiquated education system and achieve the ambitious aspirations of modern education in the 21st century. The NEP 2020 envisions a transformative shift towards holistic and multidisciplinary undergraduate education, which can produce versatile, reflective, and inventive individuals. With a commitment to realizing the objectives of the NEP 2020, Dibrugarh University, Dibrugarh, launched the implementation process in February 2022. The process began with the publication of a general program structure for the Four Year Undergraduate Programme (FYUGP) for all disciplines in accordance with the UGC's FYUGP Curriculum and Credit Framework on 27th January 2023. In keeping pace with the NEP 2020, the meeting of the Board of Studies (BoS) in Physics, convened on 9th February 2023 endorsed the partial program structure and syllabus, and the subsequent meeting held on 2nd July 2024 endorsed the full program structure and syllabus for the Five Year Postgraduate Programme (FYIPGP) in Physics, designed for Dibrugarh University. This syllabus intends to provide students with a comprehensive understanding of the discipline, enable them to hone critical thinking and problem-solving skills, and equip them to tackle the demands and prospects of the 21st century.

Introduction

The NEP-2020 presents a unique opportunity to revolutionize the higher education system in India by shifting the focus from teachers to students. This policy promotes Outcome-Based Education, where the desired graduate attributes serve as the foundation for designing programs, courses, and supplementary activities that enable students to achieve the desired learning outcomes. The curriculum framework for the FYIPGP in Physics aims to provide a strong foundation in the subject and equip students with valuable cognitive abilities and skills necessary for success in diverse professional careers in a developing and knowledge-based society. The framework adheres to globally competitive standards of knowledge and skills in Physics while emphasizing the development of scientific orientation, an enquiring spirit, problem-solving skills, and values that promote rational and critical thinking.

The FYIPGP in Physics offered by Dibrugarh University is a comprehensive and challenging curriculum that aims to provide students with a strong foundation in the discipline while exposing them to cutting-edge developments in the field. The program's structure is multidisciplinary, allowing students to explore the intersections between physics and other fields of study. This approach provides students with a broader perspective and helps them understand the interconnectedness of various areas of knowledge. The program also aims to promote students' personal and professional growth by motivating them to engage in co-curricular and extracurricular activities, which will help them develop essential skills like leadership, teamwork, and communication.

The program's syllabus is designed to promote critical thinking, develop problem-solving abilities, and encourage creativity. It includes laboratory work and practical exercises that give students the opportunity to apply theoretical concepts to real-world problems and enhance their scientific skills. The program also emphasizes the importance of ethics, social responsibility, and sustainable development, instilling in students a sense of responsibility towards society and the environment.

The FYIPGP program in Physics for Dibrugarh University is designed to prepare students for the challenges and opportunities of the 21st century. The program's multidisciplinary and holistic approach equips students with the skills and knowledge necessary for success in a rapidly changing world. Its commitment to social responsibility and sustainable development reflects its mission to produce not only accomplished physicists but also responsible and ethical global citizens.

The NEP 2020 promotes multidisciplinary education in the undergraduate program that integrates social sciences, arts and humanities with science, technology, engineering and mathematics. For holistic development of individuals, it requires to develop all capacities of human beings including intellectual, social, physical, emotional and moral behavior. Individuals should be acquainted with fields across the arts, humanities, languages, sciences and social sciences; professional, technical and vocational fields; soft skills, such as communication, discussion and debate etc. In order to develop such holistic and multidisciplinary education, the curriculum and credit framework for the FYUGP in Physics are designed accordingly. The FYIPGP in Physics consists of six different types of courses: (i) Core Courses, (ii) Minor Courses, (iii) Generic Elective Courses (GEC), (iv) Ability Enhancement Courses (AEC), (v) Value Added Courses (VAC) and (vi) Skill Enhancement Courses (SEC). As per NEP's recommendations, the FYIPGP in Physics also features multiple exit options:

1. A Certificate after completing 1 year of study.
2. A Diploma after completing 2 years of study.
3. A Bachelor's degree after completion of 3 years.
4. A 4-year Multidisciplinary Bachelor's degree.
5. A 5-year Integrated Post Graduate degree.

Aim and Objectives

The goals and objectives of FYIPGP should aim to:

1. Establish an environment in all educational institutions that consolidates the knowledge obtained at the secondary level and inspires students to develop a profound interest in Physics, acquire a broad and balanced understanding of physical concepts, principles, and theories of Physics.
2. Learn, design, and conduct experiments in laboratories to demonstrate the concepts, principles, and theories learned in the classroom.
3. Develop the ability to apply the knowledge gained in the classroom and laboratories to specific problems in theoretical and experimental Physics.
4. Expose students to the vast scope of Physics as a theoretical and experimental science with applications in solving most of the problems in nature, spanning from infrared to ultraviolet regimes.
5. Emphasize Physics as the most critical branch of science to pursue interdisciplinary and multidisciplinary higher education and research in interdisciplinary and multidisciplinary areas.
6. Emphasize the importance of Physics as the most critical discipline for sustaining existing industries and establishing new ones, creating job opportunities at all employment levels.

The proposed curriculum should enable students to acquire knowledge and skills necessary to solve problems progressively from novice problem solvers at entry level to expert problem solvers at graduation. Specifically, by the end of the first year, students should have the ability to solve well-defined problems, while at the end of the second year, they should be able to solve broadly defined problems. By the end of the third year, they should be able to solve complex problems that are ill-structured, requiring multidisciplinary skills to solve them. During the fourth year, students should gain experience in workplace problem solving in the form of internships, research experience to prepare for higher education, or entrepreneurship experience.

Graduate Attributes

Graduates in Physics are expected to possess a range of attributes that will enable them to succeed in their chosen careers. The NEP 2020 recognizes the importance of these attributes and aims to equip students with the necessary knowledge and skills to excel in their chosen careers. Some of such attributes connected to FYIPGP are:

1. **Disciplinary knowledge and skills:** Graduates in Physics should possess a strong foundation in the concepts and principles of Physics, as well as the ability to apply this knowledge to solve complex problems.
2. **Skilled communication**: Physics graduates should be able to effectively communicate their ideas and findings through oral, written, and visual means to a diverse audience, including scientists, policymakers, and the general public.
3. **Critical thinking and problem-solving capacity:** Physics graduates should be able to analyze and evaluate information, identify and define problems, develop and implement solutions, and make evidence-based decisions.
4. **Sense of inquiry:** Physics graduates should have a curiosity-driven and self-directed approach to learning, as well as the ability to ask insightful questions and explore new areas of knowledge.
5. **Team player/worker:** Physics graduates should be able to collaborate effectively with others, including peers, colleagues, and interdisciplinary teams, to achieve common goals.
6. **Project management skills:** Physics graduates should have the ability to plan, organize, and manage projects, including research projects, from conception to completion.
7. **Digital and ICT efficiency:** Physics graduates should be proficient in the use of digital tools and information and communication technologies (ICT), including programming languages, simulation software, and data analysis tools.
8. **Ethical awareness/reasoning:** Physics graduates should have a strong ethical awareness and the ability to apply ethical reasoning in decision-making, including consideration of social, cultural, and environmental impacts.
9. **National and international perspective:** Physics graduates should be aware of the global and national issues related to science and technology, as well as their roles and responsibilities as global citizens.
10. **Computational and problem-solving skills:** Physics graduates should have strong computational skills and the ability to use computational tools and techniques for problem-solving and data analysis.

Programme Learning Outcomes

PO1: Disciplinary knowledge: Students will **develop** an adequate foundation of theoretical concepts and experimental techniques in physics.

PO2: Problem solving capacity: Students will be able to **apply** the knowledge of physics to **solve** problems using mathematical tools, experimental methods and computational techniques in relevant areas.

PO3: Communication and presentation skills: Students will be able to communicate effectively about their understanding, ideas and findings to **explain** natural phenomena.

PO4: Analytical and critical thinking: Students will be able to **evaluate** the validity of information and evidence as well as to **assess** different methodologies & tools. They will be able to critically **analyze** the existing knowledge and diverse situations.

PO5: Digital and ICT efficiency: Students will be able to **use** modern ICT tools in a variety of learning environments for knowledge gain, and work situations to broaden the capability and improve efficiency.

PO6: Teamwork and leadership: Students will be able to **develop** teamwork and leadership abilities to work effectively in a co-operative and coordinated manner within diverse teams and peer groups.

PO7: Research and inquiry: The students will **develop** the skills of observation and inquiries, and the ability to identify and articulate problems/issues.

PO8: Multidisciplinary learning: Students will be able to **analyze** a problem through a multidisciplinary approach.

PO9: Ethics and Values: Students will **comply with** ethical conduct and adhere to professional standards in learning.

PO10: Employability and entrepreneurial skills: Students will **acquire** adequate skills and knowledge to become employable and/or entrepreneur.

Teaching-Learning Process

The NEP 2020 has brought about a revolutionary change in the education system in India. One of its major focuses is on outcome-based education, which involves a shift from teacher-centric to learner-centric pedagogies and from passive to active pedagogies. This change requires a significant shift in the way teaching and learning are approached. The NEP 2020 emphasizes that each and every course has to be designed with specific objectives and outcomes in mind. To achieve these goals, appropriate teaching-learning pedagogical tools have to be adopted.

The pedagogy for FYIPGP in Physics is based on the L+T+P model where L, T, and P stand for Lecture, Tutorial, and Practical respectively. This approach recognizes the importance of a well-rounded education that includes theoretical knowledge, practical experience, and personal development.

The teaching method for a theory course includes lectures that are aided with prescribed textbooks, e-learning resources, and self-study materials. The lectures are designed to provide a comprehensive understanding of the subject matter. The use of e-learning resources and self-study materials helps students to learn at their own pace and to reinforce their understanding of the material covered in the lectures.

In addition to lectures, tutorials are also an important part of the pedagogy for FYIPGP in Physics. Tutorials are interactive sessions where students can ask questions, clarify their doubts, and engage in discussions with their peers and teachers. Tutorials are designed to encourage active learning and to promote critical thinking.

To understand the link between theory and experiments, laboratory courses are designed which include practical classes. This approach recognizes that practical experience is essential for a comprehensive understanding of the subject matter. The laboratory courses are designed to provide hands-on experience to students and to help them develop the necessary skills for conducting experiments.

The pedagogy for FYIPGP in Physics recognizes the importance of a holistic approach to education. It is not just about acquiring knowledge, but also about developing the necessary skills and competencies to succeed in the real world. The outcome-based approach emphasizes the importance of developing critical thinking skills, problem-solving skills, communication skills, and teamwork skills.

In conclusion, the NEP 2020 has brought about a significant shift in the education system in India. The focus on outcome-based education and learner-centric pedagogies has led to a more holistic approach to education. The pedagogy for FYIGP in Physics is based on the L+T+P model and emphasizes the importance of lectures, tutorials, and practical classes. The use of appropriate teaching-learning pedagogical tools and assessment methods is an integral part of the approach. The outcome-based approach recognizes that education is not just about acquiring knowledge, but also about developing the necessary skills and competencies to succeed in the real world.

Assessment Methods

A. Assessment Method for a Theory-based Core Course: The assessment of a 4-credit theory-based Core course will be performed over a total of 100 marks which is distributed as: (i) 40 marks for internal assessment and (ii) 60 marks for an end semester examination.

Mode of Internal Assessment: The internal assessment shall be based on a continuous formative evaluation process over the entire semester. Evaluation of 40 marks shall be done as per the following scheme:

Activity	Marks
1st In-semester Examination	10
2nd In-semester Examination	10
Seminar/presentation, assignment, regularity, classroom activity etc. (at least two activities)	20

End Semester Examination:
Total Marks: **60**
Duration of examination: As per the University guidelines.
The question paper shall be set as per the University guidelines.

B. Assessment Method for a Practical/ Laboratory-based Core Course: The entire assessment of a 4-credit practical-based Core course will be performed over a total of 100 marks which is distributed as: (i) 40 marks for internal assessment and (ii) 60 marks for an end semester examination.

Mode of Internal Assessment: The internal assessment shall be based on a continuous formative evaluation process over the entire semester. Evaluation of 40 marks shall be done as per the following scheme:

Activity	Marks
Attendance	10
Maintenance of Laboratory Notebook	10
Viva-voce on performed experiments	20

End Semester Examination:
Total Marks: **60**
Duration of examination: As per the University guidelines.
One experiment to be performed.
Evaluation of 60 marks on the performed experiment shall be done as per the University guidelines.

C. Assessment Method for a Theory-based Discipline Specific Elective (DSE) Course: The assessment of a 4-credit theory-based DSE course will be performed over a total of 100 marks which is distributed as: (i) 40 marks for internal assessment and (ii) 60 marks for an end semester examination.

Mode of Internal Assessment: The internal assessment shall be based on a continuous formative evaluation process over the entire semester. Evaluation of 40 marks shall be done as per the following scheme:

Activity	Marks
1st In-semester Examination	10
2nd In-semester Examination	10
Seminar/presentation, assignment, regularity, classroom activity etc. (at least two activities)	20

End Semester Examination:
Total Marks: **60**
Duration of examination: As per the University guidelines.
The question paper shall be set as per the University guidelines.

D. Assessment Method for a Practical/ Laboratory-based Discipline Specific Elective (DSE) Course: The entire assessment of a 4-credit practical-based DSE course will be performed over a total of 100 marks which is distributed as: (i) 40 marks for internal assessment and (ii) 60 marks for an end semester examination.

Mode of Internal Assessment: The internal assessment shall be based on a continuous formative evaluation process over the entire semester. Evaluation of 40 marks shall be done as per the following scheme:

Activity	Marks
Attendance	10
Maintenance of Laboratory Notebook	10
Viva-voce on performed experiments	20

End Semester Examination:
Total Marks: **60**
Duration of examination: As per the University guidelines.
One experiment to be performed.
Evaluation of 60 marks on the performed experiment shall be done as per the University guidelines.

E. Assessment Method for a Theory-based Minor Course: The assessment of a 4-credit theory-based Minor course will be performed over a total of 100 marks which is distributed as: (i) 40 marks for internal assessment and (ii) 60 marks for an end semester examination.

Mode of Internal Assessment: The internal assessment shall be based on a continuous formative evaluation process over the entire semester. Evaluation of 40 marks shall be done as per the following scheme:

Activity	Marks
1st In-semester Examination	10
2nd In-semester Examination	10
Seminar/presentation, assignment, regularity, classroom activity etc. (at least two activities)	20

End Semester Examination:
Total Marks: **60**
Duration of examination: As per the University guidelines.

The question paper shall be set as per the University guidelines.

F. Assessment Method for a Practical/ Laboratory-based Minor Course:
The entire assessment of a 4-credit practical-based Minor course will be performed over a total of 100 marks which is distributed as: (i) 40 marks for internal assessment and (ii) 60 marks for a end semester examination.

Mode of Internal Assessment: The internal assessment shall be based on a continuous formative evaluation process over the entire semester. Evaluation of 40 marks shall be done as per the following scheme:

Activity	**Marks**
Attendance	10
Maintenance of Laboratory Notebook	10
Viva-voce on performed experiments	20

End Semester Examination:
Total Marks: **60**
Duration of examination: As per the University guidelines.
One experiment to be performed.
Evaluation of 60 marks on the performed experiment shall be done as per the University guidelines.

G. Assessment Method for a Skill Enhancement Course (SEC): The assessment of a 3-credit [1 (T) + 2 (P)] SE Course will be performed over a total of 100 marks which is distributed as: (i) 40 marks for internal assessment and (ii) 60 marks for an end semester examination.

Mode of Internal Assessment: The internal assessment shall be based on a continuous formative evaluation process over the entire semester. Evaluation of 40 marks shall be done as per the following scheme:

Activity	**Marks**
One In-semester Theory Examination	10
Attendance/Classroom and Laboratory activity/ Performance/Maintenance of Laboratory Notebook	20
Viva-voce	10

End Semester Examination:
Total Marks: **60**
Duration of theory examination: As per the University guidelines.
Duration of laboratory/ practical/ hand-on exercise examination: As per the University guidelines.
The total of 60 marks shall be distributed as:

Type of examination	**Marks**
Written examination for 1-credit theory	30
Practical/Hands-on examination for 2-credit practical	30

The question paper for 1-credit theory examination shall be set as per the University guidelines.
The evaluation of 30 marks in the 2-credit laboratory/ practical/ hand-on exercise examination shall

be done as per the University guidelines.

H. Assessment Method for a Generic Elective Course (GEC): The assessment of a 3-credit GE course will be performed over a total of 100 marks which is distributed as: (i) 40 marks for internal assessment and (ii) 60 marks for an end semester examination.

Mode of Internal Assessment: The internal assessment shall be based on a continuous formative evaluation process over the entire semester. Evaluation of 40 marks shall be done as per the following scheme:

Activity	**Marks**
1st In-semester Examination	10
2nd In-semester Examination	10
Seminar/presentation, assignment, regularity, classroom activity etc. (at least two activities)	20

End Semester Examination:
Total Marks: **60**
Duration of examination: As per the University guidelines.
The question paper shall be set as per the University guidelines.

General structure and distribution of number of Courses in the FYIPGP in Physics

Semester	Core (4)	Minor (4)	AEC (4)	GEC (3)	SEC (3)	VAC (2)	Intern./ CE/ Project (4)	Research	DSE (4)	Total Credit
I	1	1	1	1	1	1	×	×	×	20
II	1	1	1	1	1	1	×	×	×	20
III	2	1	×	1	1	1	×	×	×	20
IV	4	1	×	×	×	×	×	×	×	20
V	3	1	×	×	×	×	1	×	×	20
VI	4	1	×	×	×	×	×	×	×	20
VII	3	1	×	×	×	×	×	RM (4)	×	20
VIII	2	1	×	×	×	×	×	Diss. (8)	2 (In lieu of Diss.)	20
IX	3	×	×	×	×	×	×	Project/ Diss. (4)	1	20
X	2	×	×	×	×	×	×	Diss. (8)	1 + 2 (In lieu of Diss.)	20

PROGRAMME STRUCTURE

Year	Semester	Course	Title of the Course	Total Credits
Year 01	1st Semester	**C - 1**	Mechanics and Properties of Matter	4
		Minor 1	Mechanics (for disciplines other than Physics)	4
		AEC - 1	Modern Indian Language	4
		GEC - 1	Evolution of Science / Introduction to Communication Technology	3
		SEC - 1	Electrical circuits and Network Skills / Electrical Wiring and Maintenance	3
		VAC - 1	Value Added Course	2
			Total of Semester 1	**20**
	2nd Semester	**C - 2**	Waves and Optics	4
		Minor 2	Waves and Optics (for disciplines other than Physics)	4
		AEC - 2	English Language and Communication Skills	4
		GEC - 2	Materials Today / Digital and Space Technologies	3
		SEC - 2	Basic Instrumentation Skills	3
		VAC - 2	Value Added Course	2
			Total of Semester 2	**20**
	Grand Total (Semester 1 and 2)			**40**
Students on exit shall be awarded Undergraduate Certificate (in the field of study/ discipline) after securing the requisite 40 credits in Semesters 1 and 2 provided they secure 2 credits in work based vocational courses offered during summer term or internship/ apprenticeship in addition to 6 credits from skill based courses earned during 1st and 2nd Semester.				
		C - 3	Mathematical Physics I	4
		C - 4	Physics Lab I (Major)	4

Year 02	**3rd Semester**	**Minor 3**	Physics Lab I (Minor) (for disciplines other than Physics)	4
		GEC - 3	The Universe /Atmosphere of the Earth and Climate Change	3
		SEC - 3	Computational Physics Skills / Renewable Energy and Energy Harvesting	3
		VAC - 3	Value Added Course	2
			Total of Semester 3	**20**
	4th Semester	**C - 5**	Electricity and Magnetism	4
		C - 6	Thermal Physics	4
		C - 7	Elements of Modern Physics	4
		C - 8	Physics Lab II (Major)	4
		Minor 4	Electricity and Magnetism (for disciplines other than Physics)	4
			Total of Semester 4	**20**
	Grand Total (Semester 1 to 4)			**80**
Students on exit shall be awarded Undergraduate Diploma (in the field of study/ discipline) after securing the requisite 88 credits on completion of Semester 4 provided they secure additional 4 credit each in skill based vocational course offered during 1st year or 2nd year summer term.				
Year 03	**5th Semester**	**C - 9**	Mathematical Physics II	4
		C - 10	Quantum Mechanics I	4
		C - 11	Statistical Mechanics I	4
		Minor 5	Thermal Physics	4
		Internship/ Community Engagement	Internship (2) + Comm. Engmnt (2) **OR** Internship (4) / Comm. Engmnt. (4)	4
			Total of Semester 5	**20**
		C - 12	Electromagnetic Theory	4

	6th Semester	**C - 13**	Condensed Matter Physics I	4
		C - 14	Electronics I	4
		C - 15	Physics Lab III (Major)	4
		Minor - 6	Physics Lab II (Minor)	4
			Total of Semester 6	**20**
	Grand Total (Semester 1 to 6)			**120**
Students on exit shall be awarded Bachelor of (in the field of study/ discipline) Honours (3 years) after securing the requisite 120 credits on completion of Semester 6.				
Year 04	**7th Semester**	**C - 16**	Mathematical Physics III	4
		C - 17	Classical Mechanics	4
		C - 18	Quantum Mechanics II	4
		Minor - 7	Elements of Modern Physics	4
		Research	Research Methodology	4
			Total of Semester 7	**20**
	8th Semester	**C - 19**	Condensed Matter Physics II	4
		C - 20	Electronics II	4
		Minor 8	Condensed Matter Physics	4
		Research / DSE	Research Project / Dissertation (8) **OR** DSE - I (4) + DSE - II (4)	8
			Total of Semester 8	**20**
	Grand Total (Semester 1 to 8)			**160**
Students on exit shall be awarded Bachelor of (in the field of study/ discipline) Honours (4 years) / Honours with Research (4 years) after securing the requisite 160 credits on completion of Semester 8.				
		C - 21	Electrodynamics	4
		C - 22	Nuclear and Particle Physics	4

Year 05	**9th Semester**	**C - 23**	Atomic and Molecular Physics	4
		DSE	Any one course from Group III	4
		Research	Project	4
			Total of Semester 9	**20**
	10th Semester	**C - 24**	Statistical Mechanics II	4
		C - 25	Numerical Methods and Programming	4
		DSE	Any one course from Group IV	4
		Research / DSE	Dissertation (6+2) **OR** DSE -V (4) + DSE -VI (4)	8
			Total of Semester 10	**20**
	Grand Total (Semester 1 to 10)			**200**

Abbreviations used:

1. C = Major
2. GEC = Generic Elective Course / Multidisciplinary Course
3. AEC = Ability Enhancement Course
4. SEC = Skill Enhancement Course
5. VAC = Value Added Course
6. DSE = Discipline Specific Elective
7. LO = Learning Outcomes
8. L = Lectures
9. T = Theory Class
10. P = Practical Class
11. M = Marks
12. H = Hours

List of Major Core Courses:

Semester	Course Code	Course Title	Credit
I	PHY-C-1	Mechanics and Properties of Matter	4
II	PHY-C-2	Waves and Optics	4
III	PHY-C-3	Mathematical Physics I	4
	PHY-C-4	Physics Lab I (Major)	4
IV	PHY-C-5	Electricity and Magnetism	4
	PHY-C-6	Thermal Physics	4
	PHY-C-7	Elements of Modern Physics	4
	PHY-C-8	Physics Lab II (Major)	4
V	PHY-C-9	Mathematical Physics II	4
	PHY-C-10	Quantum Mechanics I	4
	PHY-C-11	Statistical Mechanics I	4
VI	PHY-C-12	Electromagnetic Theory	4
	PHY-C-13	Condensed Matter Physics I	4
	PHY-C-14	Electronics I	4
	PHY-C-15	Physics Lab III (Major)	4
VII	PHY-C-16	Mathematical Physics III	4
	PHY-C-17	Classical Mechanics	4
	PHY-C-18	Quantum Mechanics II	4
VIII	PHY-C-19	Condensed Matter Physics II	4
	PHY-C-20	Electronics II	4
IX	PHY-C-21	Electrodynamics	4
	PHY-C-22	Nuclear and Particle Physics	4
	PHY-C-23	Atomic and Molecular Physics	4

X	PHY-C-24	Statistical Mechanics II	4
	PHY-C-25	Numerical Methods and Programming	4

List of Discipline Specific Elective (DSE) Courses:

Semester	Course Code	Course Title	Credit
VIII	**Group I** (In lieu of Dissertation, any one to be chosen**)**		
	PHY-DSE-IA	Nuclear and Particle Physics	4
	PHY-DSE-IB	Plasma Physics	4
	PHY-DSE-IC	Physics of Devices and Instruments	4
	PHY-DSE-ID	Physics Lab IV (Major)	4
	Group II (In lieu of Dissertation, any one to be chosen**)**		
	PHY-DSE-IIA	Astronomy and Astrophysics	4
	PHY-DSE-IIB	Nanomaterials and Applications	4
	PHY-DSE-IIC	Physics of The Earth	4
	PHY-DSE-IID	Computational Physics Lab	4
	PHY-DSE-IIE	Physics Lab V (Major)	4
IX	**Group III** (Compulsory, any one to be chosen**)**		
	PHY-DSE-IIIA	Theory of Relativity	4
	PHY-DSE-IIIB	High Energy Physics I	4
	PHY-DSE-IIIC	Astrophysics and Cosmology I	4
	PHY-DSE-IIID	Condensed Matter Physics I	4
	PHY-DSE-IIIE	Communication Electronics	4
	PHY-DSE-IIIF	Space Physics	4
	Group IV (Compulsory, any one to be chosen**)**		
	PHY-DSE-IVA	High Energy Physics II	4

X	PHY-DSE-IVB	Astrophysics and Cosmology II	4
	PHY-DSE-IVC	Physics of Black Holes	4
	PHY-DSE-IVD	Condensed Matter Physics II	4
	PHY-DSE-IVE	Digital and Optical Electronics	4
	PHY-DSE-IVF	Physics of Planetary Atmospheres	4
	Group V (In lieu of Dissertation, any one to be chosen**)**		
	PHY-DSE-VA	String Theory	4
	PHY-DSE-VB	Quantum Field Theory in Solids	4
	PHY-DSE-VC	Electronics Lab	4
	PHY-DSE-VD	Space Physics Lab	4
	Group VI (In lieu of Dissertation, any one to be chosen**)**		
	PHY-DSE-VIA	Advanced Mathematical Physics	4
	PHY-DSE-VIB	Advanced Quantum Mechanics	4
	PHY-DSE-VIC	Laser and Spectroscopy	4
	PHY-DSE-VID	Condensed Matter Physics Lab	4
	PHY-DSE-VIE	Atmospheric Physics Lab	4

List of Skill Enhancement Courses (SEC):

Semester	Course Code	Course Title	Credit
	Any one to be chosen		
I	PHY-SEC-IA	Electrical Circuits and Network Skills	3
	PHY-SEC-IB	Electrical Wiring and Maintenance	3
II	PHY-SEC-II	Basic Instrumentation Skills	3
	Any one to be chosen		
III	PHY-SEC-IIIA	Computational Physics Skills	3
	PHY-SEC-IIIB	Renewable Energy and Energy Harvesting	3

List of Generic Elective Courses (GEC):

Semester	Course Code	Course Title	Credit
	Any one to be chosen		
I	PHY-GEC-IA	Evolution of Science	3
	PHY-GEC-IB	Introduction to Communication Technology	3
	Any one to be chosen		
II	PHY-GEC-IIA	Materials Today	3
	PHY-GEC-IIB	Digital and Space Technologies	3
	Any one to be chosen		
III	PHY-GEC-IIIA	The Universe	3
	PHY-GEC-IIIB	Atmosphere of the Earth and Climate Change	3

List of Minor Courses:

Semester	Course Code	Course Title	Credit
I	PHY-MIN-1	Mechanics	4
II	PHY-MIN-2	Waves and Optics	4
III	PHY-MIN-3	Physics Lab I (Minor)	4
IV	PHY-MIN-4	Electricity and Magnetism	4
V	PHY-MIN-5	Thermal Physics	4
VI	PHY-MIN-6	Physics Lab II (Minor)	4
VII	PHY-MIN-7	Elements of Modern Physics	4
VIII	PHY-MIN-8	Condensed Matter Physics	4

DETAILED SYLLABUS OF CORE COURSES

SEMESTER I

Course title: Mechanics and Properties of Matter
Course code: PHY-C-1
Nature of the course: Core
Total credits: 4
Distribution of marks: 60 (End-sem) **+ 40** (In-sem)

Course Description: This course comprises Newtonian mechanics and the fundamental laws of motion. It focuses on important topics in mechanics such as reference frames, work-energy theorems, conservation laws, matter and its properties, types of oscillations, and fundamental ideas about the special theory of relativity for undergraduate students. It aims to provide students with a deep understanding of the laws governing the motion of objects and the nature of space and time.

Course Objectives: The course aims to impart knowledge of Newtonian mechanics, the properties of matter, oscillations, and rotating frames, as well as their role in relevant areas of physics. It will help the students develop the concepts of the special theory of relativity and help them understand space and time more.

Course Outcomes (COs): After the completion of the course, a student will be able to

CO1: Understand the basic concepts of mechanics, reference frames, and conservation laws.

- **LO1.1:** Define key terms related to mechanics.
- **LO1.2:** Explain linear dynamics and rotational dynamics.
- **LO1.3**: Interpret relative transformations and the invariance of laws of physics.

CO2: Analyze simple harmonic oscillators in detail.

- **LO2.1:** Explain simple harmonic motion in an oscillatory system.
- **LO2.2:** Solve the differential equation of simple harmonic motion.

CO3: Correlate the consequences of non-inertial frame to our real world.

- **LO3.1:** Identify the nature of fictitious forces and their effect on the real world.
- **LO3.2:** Classify these forces arising due to non-inertial frames.
- **LO3.3:** Solve problems related to non-inertial frames and fictitious forces.

CO4: Compare special relativity with Newtonian relativity.

- **LO4.1:** Define key terms related to special theory of relativity.
- **LO4.2:** Contrast the changes in motion occurred due to relativistic speed and non-relativistic speed.
- **LO4.3:** Interpret equivalence of mass and energy, relativistic transformation of momentum and energy and relativistic effects such as relativistic doppler effect.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	**Remember**	**Understand**	**Apply**	**Analyze**	**Evaluate**	**Create**
Factual						
Conceptual	LO1.1 LO4.1	LO1.2 LO1.3	LO2.1 LO2.2	CO2		

		LO2.1 LO3.2 LO4.2 LO4.3 CO1	LO3.1			
Procedural		CO4		CO3		
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S			M	M		S
CO2	S	S	S	S			M	M		S
CO3	S	S	S	S			M	M		S
CO4	S	S	S	S			M	M		S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit 1: Newtonian Mechanics

Frames of Reference, Inertial Frames, Galilean Transformations, Galilean Invariance; Dynamics of a System of Particles, Center of Mass, Principle of Conservation of Linear Momentum.

(L 6, H 6, M 6)

The Work-Energy Theorem, Conservative and Non-conservative Forces, Conservation of Mechanical Energy, Work done by non-conservative forces, Force as gradient of potential energy, Energy Diagram, Stable and Unstable Equilibrium. **(L 6, H 6, M 6)**

Principle of Conservation of Angular Momentum, Rotation about a fixed axis, Moment of Inertia, Calculation of Moment of Inertia for rectangular, cylindrical and spherical bodies, Kinetic Energy of Rotation, Motion involving both translation and rotation. **(L 8, H 8, M 8)**

Unit 2: Properties of Matter

Relation between Elastic constants, Twisting torque on a Cylinder or Wire. **(L 4, H 4, M 4)**

Kinematics of Moving Fluids, Poiseuille's Equation for Flow of a Liquid through a Capillary Tube.

(L 4, H 4, M 4)

Unit 3: Oscillations

Simple Harmonic Motion (SHM) and Oscillations, Differential Equation of SHM and its solution, Kinetic Energy, Potential Energy, Total energy and their time-average values, Damped oscillation, Forced oscillations, Resonance, Power Dissipation and Quality Factor. **(L 8, H 8, M 8)**

Unit 4: 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. **(L 8, H 8, M 8)**

Unit 5: Special Theory of Relativity

Michelson-Morley Experiment and its outcome, Postulates of Special Theory of Relativity, Lorentz Transformations, Simultaneity and order of events, Lorentz contraction, Time dilation. Relativistic Transformation of Velocity, Frequency and Wave-number, Relativistic addition of Velocities, Variation of Mass with Velocity, Massless Particles, Mass-energy Equivalence. Relativistic Kinematics, Transformation of Energy and Momentum, Relativistic Doppler effect.

(L 16, H 16, M 16)

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. An introduction to Mechanics, *D. Kleppner, R. J. Kolenkow*, Cambridge University Press.
2. Mechanics: Berkeley Physics Course Vol. 1, *C. Kittel, W. Knight, et.al.*, Tata McGraw-Hill.
3. Fundamentals of Physics, *Halliday, Resnick, Walker,* John Wiley & Sons.
4. University Physics, *R. L. Reese*, Brooks/Cole Publishing Company.
5. Introduction to Special Relativity, *R. Resnick*, John Wiley & Sons.
6. Mechanics, *D. S. Mathur*, S. Chand and Company Ltd.
7. Theoretical Mechanics (Schaum's Outline series), *M. R. Spiegel,* Tata McGraw Hill.
8. Analytical Mechanics, *G. R. Fowles and G. L. Cassiday*, Thomson Brooks/Cole.

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SEMESTER II

Course title: Waves and Optics
Course code: PHY-C-2
Nature of the course: Core
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This course provides an introduction to the basic concepts of waves, oscillation, and optics. It aims to provide knowledge about superposition principles, give comprehensive ideas about simple harmonic oscillations, and introduce wave concepts, including group velocities and phase velocities. It depicts the electromagnetic nature of light and enters the domain of optics by providing in depth knowledge of optical phenomena and optical instruments based on these phenomena to undergraduate students.

Course Objectives: This course aims to develop theoretical knowledge of waves, oscillations, and the superposition principle. The course provides fundamental concepts in the study of wave phenomena and the behavior of light, especially in thin films. To acquaint the learner with the principles behind various optical instruments and to build a theoretical knowledge of them.

Course Outcomes (COs): At the completion of the course, a student will be able to
CO1: Analyze the principle of linearity and superposition, concepts of wave motion and standing waves.
- **LO1.1:** Define superposition, plane and spherical waves, and stationary waves.
- **LO1.2:** Explain the superposition of waves, the velocity of longitudinal and transverse waves in different media, and the role of standing waves in different physical systems.
- **LO1.3:** Construct Lissajous figures and develop the differential equation of a wave.

CO2: Connect the knowledge obtained from the wave with the behavior of light.
- **LO2.1:** Explain the phenomenon of interference in thin films.
- **LO2.2:** Develop theoretical knowledge of various optical instruments.
- **LO2.3:** Illustrate key concepts of diffraction.

CO3: Understand the basic concept of holography.
- **LO3.1:** Define key terms related to holography.
- **LO3.2:** Demonstrate the construction of holography.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual	LO1.1 LO3.1	LO1.2 LO2.1 LO2.3 LO3.2 CO3	LO1.3 LO2.2	CO1 CO2		

Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S			M	M		S
CO2	S	S	S	S			M	M		S
CO3	S	S	S	S			M	M		S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit 1: Superposition of Harmonic Oscillations

Linearity and Superposition Principle. Superposition of two collinear harmonic oscillations having equal frequencies and different frequencies (Beats). Superposition of N collinear harmonic oscillations with equal phase differences and equal frequency differences. **(L 5, H 5, M 5)**

Graphical and Analytical Methods: Lissajous Figures with equal and unequal frequency and their use. **(L 3, H 3, M 3)**

Unit 2: Wave Motion

Plane and Spherical Waves, Longitudinal and Transverse Waves, Plane Progressive (Travelling) Waves, Wave Equation, Particle and Wave Velocities, Differential Equation of a Wave. **(L 3, H 3, M 3)**

Velocity of transverse vibrations of stretched strings, Velocity of longitudinal waves in a fluid in a pipe, Pressure of a longitudinal wave, Newton's formula for velocity of sound, Laplace's correction, Comparison of velocity of sound in different media: air, liquid, solid. Energy, power transport and intensity of wave. **(L 8, H 8, M 8)**

Unit 3: Standing Waves

Standing (Stationary) Waves, Standing Waves in a String: Fixed and Free ends, Normal Modes of Stretched Strings, Comparison of Standing Wave with Travelling Waves, Displacement and Velocity of a Particle in a Standing Wave, Plucked and Struck Strings, Melde's Experiment, Longitudinal Standing Waves in Open and Closed Pipes, Normal Modes of Longitudinal Waves, Phase and Group Velocities. **(L 7, H 7, M 7)**

Unit 4: Wave optics

Electromagnetic nature of light, definition and properties of wave front, Huygens' principle, Temporal and Spatial coherence. **(L 3, H 3, M 3)**

Unit 5: Interference

Division of amplitude and wavefront, Young's double slit experiment, Phase change on reflection: Stokes' treatment, Lloyd's Mirror and Fresnel's Biprism, Interference in Thin Films: parallel and wedge-shaped films. Newton's Rings: Measurement of wavelength and refractive index

(L 8, H 8, M 8)

Michelson Interferometer- (i) Idea of form of fringes (No theory required), (ii) Determination of Wavelength, (iii) Wavelength Difference, (iv) Refractive Index and (v) Visibility of Fringes. Introduction to Fabry-Perot interferometer. **(L 4, H 4, M 4)**

Unit 6: Diffraction

Kirchhoff's Integral Theorem, Fresnel-Kirchhoff's Integral formula (Qualitative discussion only). **(L 2, H 2, M 2)**

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. **(L 7, H 7, M 7)**

Fraunhofer Diffraction: Single slit, Circular aperture. Resolving Power of a telescope, Double slit, Multiple slits. Diffraction grating, Resolving power of grating. **(L 6, H 6, M 6)**

Unit 7: Holography

Principle of Holography, Recording and Reconstruction Method, Theory of Holography as Interference between two Plane Waves, Point Source Holograms. **(L 4, H 4, M 4)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Waves: Berkeley Physics Course, *F. Crawford*, Tata McGraw-Hill.
2. Fundamentals of Optics, *F. A. Jenkins and H. E. White*, McGraw-Hill.
3. Principles of Optics, *M. Born and E. Wolf,* Pergamon Press.
4. Optics, *A. Ghatak,* Tata McGraw Hill.
5. Modern Optics, *A. B. Gupta*,Books & Allied (P) Ltd.
6. The Physics of Vibrations and Waves, *H. J. Pain*, John Wiley and Sons.
7. The Physics of Waves and Oscillations, *N. K. Bajaj*,Tata McGraw Hill.
8. Fundamental of Optics, *A. Kumar, H. R. Gulati and D. R. Khanna*,R. Chand Publications.

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SEMESTER III

Course title: Mathematical Physics – I
Nature of the course: Core
Course code: PHY-C-3
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This course is an ensemble of mathematical tools and methods which are necessary to study different branches in physics. As a first course of mathematical physics at the undergraduate level, it covers a number of elementary topics such as calculus, vector calculus, orthogonal curvilinear co-ordinates, Dirac delta function and matrices. Apart from rigorous and detailed discussions on these topics, the course directs the students about their applications in physics.

Course Objectives: The aim of this course is to

1. Introduce a learner to a number of mathematical tools and methods.
2. Develop a basic understanding of these mathematical tools and methods.
3. Acquaint a learner with application of these mathematical tools and methods in physics.
4. Develop an adequate amount of mathematical skill among the learners to navigate through different areas in physics.

Course Outcomes (COs): At the completion of this course, a learner will be able to

CO1: Understand a few mathematical concepts and their importance in physics.

- **LO1.1:** Define key terms and operations in calculus, vector calculus, curvilinear coordinates, Dirac delta function and matrices.
- **LO1.2:** Explain the properties and rules of calculus, vector calculus, curvilinear coordinates, Dirac delta function and matrices.
- **LO1.3:** Describe a problem in physics in terms of calculus, vector calculus, curvilinear coordinates, Dirac delta function and matrices.

CO2: Apply the above mathematical concepts to solve problems.

- **LO2.1:** Solve advanced level mathematical problems based on the key concepts in calculus, vector calculus, curvilinear coordinates, Dirac delta function and matrices.
- **LO2.2:** Use calculus, vector calculus, curvilinear coordinates, Dirac delta function and matrices to solve problems in elementary branches of physics like mechanics, electromagnetic theory, thermal physics etc.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	**Remember**	**Understand**	**Apply**	**Analyze**	**Evaluate**	**Create**
Factual						
Conceptual	LO1.1	LO1.2 LO1.3 CO1	LO2.1 LO2.2 CO2			

Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S			M	M		S
CO2	S	S	S	S			M	M		S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit 1: Calculus

Functions and their plotting, Continuity and Differentiability of functions, Approximation methods: Taylor series, Maclaurin series. **(L 2, H 2, M 2)**

First Order Differential Equations, Integrating Factor, Second Order Differential Equations, Homogeneous and Inhomogeneous Equations with constant coefficients. Wronskian and general solution. Statement of existence and Uniqueness Theorem for Initial Value Problems. Particular Integral. **(L 10, H 10, M 10)**

Calculus of functions of more than one variable: Partial Derivatives, Exact and Inexact Differentials, Integrating Factor, Constrained Maximization using Lagrange Multipliers. **(L 6, H 6, M 6)**

Unit 2: Vector Calculus

Recapitulation of Vector algebra, Dot Product, Cross Product, Scalar Triple Product, Cartesian Components of a vector, Scalar and Vector Fields. **(L 2, H 2, M 2)**

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. **(L 8, H 8, M 8)**

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 (no rigorous proofs). **(L 14, H 14, M 14)**

Unit 3: Orthogonal Curvilinear Coordinates

Orthogonal Curvilinear Coordinates, Spherical Polar Coordinates, Cylindrical Coordinates; Derivation of Gradient, Divergence and Curl in Cartesian, Spherical and Cylindrical Coordinate Systems. **(L 8, H 8, M 8)**

Unit 4: Dirac Delta Function

Definition of Dirac Delta Function, Representation as limit of a Gaussian function and rectangular function, Properties of Dirac Delta Function. **(L 4, H 4, M 4)**

Unit 5: Matrices

Definition, Addition and Multiplication of matrices, Transpose of a matrix, Hermitian conjugate of a matrix, Trace and Determinant, Inverse of a matrix, Special types of square matrices- Diagonal, Symmetric and Skew-symmetric, Hermitian and Skew-Hermitian. **(L 6, H 6, M 6)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended readings:

1. Mathematical Methods for Physicists, *G. B. Arfken, H. J. Weber, F. E. Harris*, Elsevier.
2. Mathematical Methods for Physics and Engineering, *K. F. Riley, M. P. Hobson, S. J. Bence,* Cambridge University Press.
3. An introduction to ordinary differential equations, *E. A. Coddington,* PHI learning.
4. Differential Equations, *G. F. Simmons,* McGraw Hill.
5. Mathematical Tools for Physics, *J. Nearing,* Dover Publications.
6. Mathematical methods for Scientists and Engineers, *D. A. McQuarrie,* University Science Books (USA).
7. Engineering Mathematics, *S. Pal and S. C. Bhunia,* Oxford University Press.
8. Advanced Engineering Mathematics, *Erwin Kreyszig,* Wiley India.

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Course title: Physics Lab I (Major)
Course code: PHY-C-4
Nature of the course: Core
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: The course on Physics Lab I (Major) comprises 10 experiments covering mechanics and properties of matter and 10 experiments from wave and optics. Experiments related to moment of inertia, coefficient of viscosity, Young's modulus, modulus of rigidity, bar pendulum and kater's pendulum are included to gain hands-on knowledge. Moreover, application of optical tools like prism, Michelson Interferometer, Fresnel biprism and Newton ring are included.

Course Objectives: The aims of the course are to

1. Develop experimental skills of a learner in mechanics as well as in waves and optics.
2. Develop the ability of a student to expertise oneself in the field of basic physics enabling him/her to get a better knowledge of the theory.
3. To learn error propagation and its role in making conclusions.

Course Outcomes (COs): At the completion of the course, the students will be able to

CO1: Understand the idea of different phenomena in mechanics and wave optic.

LO1.1: Explain the working of bar and Kater's pendulum and formation of Lissajous figures.

LO1.2: Classify between spring constant and elastic constant like Young's Modulus and modulus of rigidity.

LO1.3: Interpret the working of Michelson Interferometer, Fresnel biprism and Newton rings.

CO2: Apply theoretical knowledge of mechanics and wave optics in practical applications.

LO2.1: Develop principles of elasticity to analyze mechanical systems.

LO2.2 Experiment with methods and techniques to conduct measurements, analyze data related to wavelength, diffraction and interference, dispersive and resolving power.

LO2.3: Relate the experimental findings with the corresponding theory.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual		LO1.1 LO1.2 LO1.3	LO2.1			
Procedural			LO2.2 LO2.3			
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	M	M	M	S	M	M	M
CO2	S	S	M	S	M	M	M	M	M	M

(S: Strong, M: Medium, W: Weak)

List of Experiments

Unit 1: Mechanics

1. To determine the height of a building using a Sextant.
2. To study the Motion of Spring and calculate (a) Spring constant, (b) ***g*** and (c) Modulus of rigidity.
3. To determine the Moment of Inertia of a Flywheel.
4. To determine ***g*** and velocity for a freely falling body using Digital Timing Technique.
5. To determine Coefficient of Viscosity of water by Capillary Flow Method (Poiseuille's method).
6. To determine the Young's Modulus of a Wire by Optical Lever Method.
7. To determine the Modulus of Rigidity of a Wire by Maxwell's needle.
8. To determine the elastic Constants of a wire by Searle's method.
9. To determine the value of ***g*** using Bar Pendulum.
10. To determine the value of ***g*** using Kater's Pendulum.

Unit 2: Waves and Optics

1. To determine the frequency of an electric tuning fork by Melde's experiment and verify λ^2 – T law.
2. To determine the phase difference between two waves using Lissajous Figures.
3. To determine the refractive index of the Material of a prism using sodium source.
4. To determine the dispersive power and Cauchy constants of the material of a prism using mercury source.
5. To determine the wavelength of sodium source using Michelson's interferometer.
6. To determine wavelength of sodium light using Fresnel Biprism.
7. To determine wavelength of sodium light using Newton's Rings.
8. To determine the thickness of a thin paper by measuring the width of the interference fringes produced by a wedge-shaped Film.
9. To determine wavelength of (1) Na source and (2) spectral lines of Hg source using plane diffraction grating.
10. To determine dispersive power and resolving power of a plane diffraction grating.

(Total Practical Classes 60, Total Contact Hours 120, Total Marks 60)

At least 60% of the experiments must be performed from each unit.

Recommended Readings:

1. Advanced Practical Physics for students, *B. L. Flint and H. T. Worsnop*, Asia Publishing House.
2. Advanced level Physics Practicals, *M. Nelson and J. M. Ogborn*, Heinemann Educational Publishers.
3. A Text Book of Practical Physics, *I. Prakash & Ramakrishna,* Kitab Mahal.
4. Engineering Practical Physics, *S. Panigrahi & B. Mallick*, Cengage Learning India Pvt. Ltd.
5. Practical Physics, *G.L. Squires,* Cambridge University Press.
6. A Laboratory Manual of Physics for undergraduate classes, *D. P. Khandelwal,* Vani Pub.

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SEMESTER IV

Course title: Electricity and Magnetism
Nature of the course: Core
Course code: PHY-C-5
Total credit assigned: 4
Distribution of marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This course provides a comprehensive introduction to the fundamental principles of electromagnetism, focusing on both electrostatics and magnetostatics, as well as their potential applications in various contexts. The curriculum covers the behavior of electric fields, electric potential, and energy, exploring key concepts such as Gauss' law, Laplace's and Poisson's equations, and the method of images. It also delves into the dielectric properties of matter, the principles of magnetostatics, and the magnetic properties of materials. The course also examines electromagnetic induction, including Faraday's and Lenz's laws, and introduces Maxwell's equations. In addition, students will study electrical circuits, network theorems, and their applications to both AC and DC circuits. Through a combination of theoretical discussions and practical examples, this course aims to build a strong foundation in electromagnetism and its relevance to real-world phenomena and technological applications.

Course Objectives: The basic objective of this course is to

1. Introduce learners to the fundamental principles of electromagnetism.
2. Develop a basic understanding of electrostatics, magnetostatics, and electromagnetic induction.
3. Introduce learners to the dielectric properties of matter and the magnetic properties of materials.
4. Acquaint learners with key topics including network theorems, AC and DC circuits, and their potential applications in real-world problems.

Course Outcomes (COs): After completion of the course the students will be able to
CO1: Understand the fundamental laws of electromagnetism and their importance in Physics.
- **LO1.1**: Define the key concepts of electric and magnetic fields.
- **LO1.2**: Explain the basic laws of electrostatics, magnetostatics and electromagnetic induction.
- **LO1.3:** Describe the behavior of electric fields in matter and explain polarization phenomena.
- **LO1.4:** Discuss magnetic properties of materials, including hysteresis, using B-H curves and magnetization concepts.

CO2: Apply fundamental laws to solve practical problems.
- **LO2.1:** Use Gauss's law to solve problems involving symmetrical charge distributions.
- **LO2.2:** Solve different problems based on Laplace's, Poisson's equations and method of images.

CO3: Evaluate the behavior of electrical circuits and networks using different approaches
- **LO3.1:** Apply Thevenin's and Norton's Theorems to simplify complex circuits.
- **LO3.2:** Analyze AC circuits using Kirchhoff's laws and solve for complex impedances and reactance.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual	LO1.1	LO1.2 LO1.3 LO1.4 CO1				
Procedural			LO2.1 LO2.2 LO3.1 CO2	LO3.2	CO3	
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	M	S	S	M		M	M		M
CO2	S	S	S	S			S	S		M
CO3	S	S	S	S	S		S	S		S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit 1: Electrostatics

Electric Field, Electric Lines of Force, Electric Flux, Gauss' Law with applications to charge distributions with Spherical, Cylindrical and Planar symmetry. **(L 6, H 6, M 6)**

Conservative nature of Electrostatic Field, Electrostatic Potential, Laplace's and Poisson equations, The Uniqueness Theorem, Potential and Electric Field of a dipole, Force and Torque on a Dipole. **(L 5, H 5, M 5)**

Electrostatic Energy of System of Charges, Electrostatic Energy of a Charged Sphere, Conductors in an electrostatic field, Surface charge and force on a conductor, Capacitance of a system of charged conductors, Parallel-plate Capacitor, Capacitance of an isolated conductor, Method of Images and its application to (i) Plane Infinite Sheet and (ii) Sphere. **(L 10, H 10, M 10)**

Unit 2: Dielectric Properties of Matter

Electric Field in matter, Polarization, Polarization Charges, Electrical Susceptibility and Dielectric Constant; Capacitor (parallel plate, spherical, cylindrical) filled with dielectric; Displacement vector **D**, Relations between Electric field vector **E**, Polarization vector **P** and **D**, Gauss' Law in dielectrics. **(L 8, H 8, M 8)**

Unit 3: Magnetostatics

Magnetic force between current elements and definition of Magnetic Field **B**, Biot-Savart's Law and its simple applications (straight wire and circular loop), Current Loop as a Magnetic Dipole and its

Dipole Moment (Analogy with Electric Dipole), Ampere's Circuital Law and its application to (i) Solenoid and (ii) Toroid, Properties of **B**: curl and divergence, Vector Potential, Lorentz Force Law, Magnetic Force on (i) point charge (ii) current carrying wire (iii) between current elements, Torque on a current loop in a uniform Magnetic Field. **(L 10, H 10, M 10)**

Torque on a current loop, Ballistic Galvanometer, Current and Charge Sensitivity, Electromagnetic Damping, Logarithmic Damping, CDR. **(L 3, M 3, H 3)**

Unit 4: Magnetic Properties of Matter
Magnetization vector (**M**), Magnetic Intensity (**H**), Magnetic Susceptibility and permeability. Relation between **B, H** and **M**. Ferromagnetism. B-H curve and hysteresis. **(L 4, H 4, M 4)**

Unit 5: Electromagnetic Induction
Faraday's Law, Lenz's Law, Self-Inductance and Mutual Inductance, Reciprocity Theorem, Energy stored in a Magnetic Field, Introduction to Maxwell's Equations, Charge Conservation and Displacement current. **(L 6, H 6, M 6)**

Unit 6: Electrical Circuits
AC Circuits, Kirchhoff's Laws for AC circuits, Complex Reactance and Impedance, Series LCR Circuit: (i) Resonance, (ii) Power Dissipation (iii) Quality Factor and (iv) Band Width. Parallel LCR Circuit. **(L 4, H 4, M 4)**

Unit 7: Network Theorems
Ideal voltage and current Sources, Network Theorems: Thevenin Theorem, Norton Theorem, Superposition Theorem, Reciprocity Theorem, Maximum Power Transfer theorem, Applications to DC circuits**.** **(L 4, H 4, M 4)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Electricity, Magnetism & Electromagnetic Theory, *S. Mahajan and Choudhury*, Tata McGraw.
2. Electricity and Magnetism, *E. M. Purcell*, McGraw-Hill Education.
3. Introduction to Electrodynamics*, D. J. Griffiths*, Pearson Education.
4. Feynman Lectures Vol.2, *R. P. Feynman, R. B. Leighton, M. Sands*, Pearson Education.
5. Elements of Electromagnetics*, M. N. O. Sadiku*, Oxford University Press.
6. Electricity and Magnetism, *J. H. Fewkes & J. Yarwood*. Vol. I, Oxford University Press.

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Course title: Thermal Physics
Nature of the course: Core
Course code: PHY-C-6
Total credits: 4
Distribution of marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This course covers fundamental thermodynamic principles and kinetic theory of gasses. The course starts with the main laws of Thermodynamics, energy conservation, isothermal and adiabatic processes, and the relationship between specific heats. Heat engines, Carnot cycles, and entropy concepts are also explored thereafter. Thermodynamic potentials like internal energy, enthalpy, and Gibbs free energy are studied, alongside Maxwell's relations and their applications. The kinetic theory section addresses the Maxwell-Boltzmann distribution, molecular collisions, and real gas behavior. By course end, students will understand and will be able to apply thermodynamic principles to various physical systems.

Course Objectives: Thermal physics is essential as it provides foundational knowledge of energy transformation and conservation principles crucial for various scientific and engineering disciplines. Understanding thermodynamics is crucial for designing and optimizing engineering systems like engines, refrigerators, and power plants. The course is equipped to provide students with analytical and problem-solving skills, enabling them to apply thermodynamic laws to real-world situations. Additionally, thermodynamics intersects with fields like chemistry, biology, and materials science, making it highly relevant for interdisciplinary applications. This course prepares students for advanced studies and careers in science and engineering by equipping them with essential theoretical and practical skills.

Course Outcomes (COs): After the completion of this course the students will be able to
CO1: Understand the fundamental principles of thermodynamics.
- **LO1.1:** Define extensive and intensive thermodynamic variables and their significance.
- **LO1.2:** Explain the Zeroth Law of Thermodynamics and its role in defining temperature.
- **LO1.3:** Interpret the First Law of Thermodynamics to analyze processes and calculate energy changes.

CO2: Experiment with apparatus for practical thermodynamic applications.
- **LO2.1:** Develop explanations for entropy changes in reversible and irreversible processes.
- **LO2.2:** Illustrate the implications of entropy in the context of the Second Law of Thermodynamics.

CO3: Apply thermodynamic potentials and their applications.
- **LO3.1:** Apply thermodynamic potentials such as internal energy, enthalpy, and Gibbs free energy to solve problems.
- **LO3.2:** Construct equations and relations using Clausius-Clapeyron and Ehrenfest equations.
- **LO3.3:** Summarize the performance of various thermodynamic cycles.

CO4: Analyze the behavior of gases and related phenomena.
- **LO4.1:** Describe the Maxwell-Boltzmann distribution and its significance.
- **LO4.2:** Analyze the behavior of real gases using the Van der Waals equation.
- **LO4.3:** Apply the Joule-Thomson effect to analyze gas cooling processes.
- **LO4.4:** Distinguish between reversible and irreversible processes and their implications.
- **LO4.5:** Identify the efficiency of heat engines and refrigerators using the Second Law of Thermodynamics.

LO4.6: Explain the concept of entropy and its role in energy transformations.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual	LO1.1	CO1, LO1.2	LO3.1, LO4.5	LO4.2		
Conceptual		LO1.3, LO2.2, LO3.3, LO4.1,	LO2.1, CO3, LO4.3	CO4, LO4.4		
Procedural		LO4.6	CO2, LO3.2			
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	M	W	W	W	W	M	W
CO2	S	S	M	S	M	W	W	W	M	M
CO3	S	S	M	S	M	W	S	M	M	S
CO4	S	S	M	S	M	M	S	M	W	S
CO5	S	S	M	S	M	W	M	M	W	M

(S: Strong, M: Medium, W: Weak)

Course Contents:

Thermodynamics

Unit 1: Zeroth and First Law of Thermodynamics

Extensive and intensive Thermodynamic Variables, Thermodynamic Equilibrium, Zeroth Law of Thermodynamics & Concept of Temperature, Temperature Coefficient of Resistance, Concept of Work & Heat, Mechanical Equivalent of Heat, State Functions, First Law of Thermodynamics and its differential form, Internal Energy, First Law & various processes, Applications of First Law: General Relation between C_P and C_V, Work Done during Isothermal and Adiabatic Processes, Compressibility and Expansion Coefficient. **(L 8, H 8, M 8)**

Unit 2: Second Law of Thermodynamics

Reversible and Irreversible process with examples. Conversion of Work into Heat and Heat into Work. Heat Engines. Carnot's Theorem, Carnot's Cycle, Carnot engine & efficiency. Refrigerator & coefficient of performance, 2^{nd} Law of Thermodynamics: Kelvin-Planck and Clausius Statements and their Equivalence. Applications of Second Law of Thermodynamics: Thermodynamic Scale of Temperature and its Equivalence to Perfect Gas Scale.

(L 10, H 10, M 10)

Unit 3: Entropy

Concept of Entropy, Clausius Theorem. Clausius Inequality, Second Law of Thermodynamics in terms of Entropy. Entropy of a perfect gas. Principle of Increase of Entropy. Entropy Changes in Reversible and Irreversible processes with examples. Entropy of the Universe. Temperature–Entropy diagrams for Carnot's Cycle. Third Law of Thermodynamics. Unattainability of Absolute Zero.

(L 7, H 7, M 7)

Unit 4: Thermodynamic Potentials

Thermodynamic Potentials: Internal Energy, Enthalpy, Helmholtz Free Energy, Gibbs Free Energy. Their Definitions, Properties and Applications. Surface Films and Variation of Surface Tension with Temperature. Magnetic Work, Cooling due to adiabatic demagnetization, First and second order Phase Transitions with examples, Clausius Clapeyron Equation and Ehrenfest equations. **(L 7, H 7, M 7)**

Unit 5: Maxwell's Thermodynamic Relations

Derivations and applications of Maxwell's Relations, Maxwell's Relations: (i) Clausius Clapeyron equation, (ii) Values of C_p-C_v, (iii) TdS Equations, (iv) Joule-Kelvin coefficient for Ideal and Van der Waal Gases, (v) Energy equations, (vi) Change of Temperature during Adiabatic Process.

(L 7, H 7, M 7)

Kinetic Theory of Gases

Unit 6: Distribution of Velocities

Maxwell-Boltzmann Law of Distribution of Velocities in an Ideal Gas and its Experimental Verification. Doppler Broadening of Spectral Lines and Stern's Experiment. Mean, RMS and Most Probable Speeds. Degrees of Freedom. Law of Equipartition of Energy (No proof required). Specific Heats of Gases. **(L 7, H 7, M 7)**

Unit 7: Molecular Collisions

Mean Free Path. Collision Probability. Estimates of Mean Free Path. Transport Phenomenon in Ideal Gases: (i) Viscosity, (ii) Thermal Conductivity and (iii) Diffusion. Brownian Motion and its Significance. **(L 4, H 4, M 4)**

Unit 8: Real Gasses

Behavior of Real Gases: Deviations from the Ideal Gas Equation. The Virial Equation. Andrew's Experiments on CO_2 Gas. Critical Constants. Continuity of Liquid and Gaseous State. Vapour and Gas. Boyle Temperature. Van der Waals Equation of State for Real Gases. Values of Critical Constants. Law of Corresponding States. Comparison with Experimental Curves. P-V Diagrams. Free Adiabatic Expansion of a Perfect Gas. Joule-Thomson Porous Plug Experiment. Joule-Thomson Effect for Real and Van der Waal Gases. Temperature of Inversion. Joule- Thomson Cooling.

(L 10, H 10, M 10)

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Heat and Thermodynamics, *M.W. Zemansky and R. Dittman,* McGraw-Hill.
2. A Treatise on Heat, *M. Saha, and B. N. Srivastava*, Indian Press.
3. Thermal Physics, *S. Garg, R. Bansal and Ghosh*, Tata McGraw-Hill.
4. Modern Thermodynamics with Statistical Mechanics, *C. S. Helrich*, Springer.

5. Thermodynamics, Kinetic Theory & Statistical Thermodynamics, *Sears & Salinger*, Narosa.
6. Concepts in Thermal Physics, *S. J. Blundell and K. M. Blundell*, 2012, Oxford University Press.
7. Thermal Physics, *A. Kumar and S. P. Taneja*, R. Chand Publications.

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Course title: Elements of Modern Physics
Course code: PHY-C-7
Nature of the course: Core
Total credits: 4
Distribution of marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This course offers the fundamental principles of Physics from classical to quantum realms beginning by the nature of blackbody radiation, applying Kirchhoff's law, Stefan-Boltzmann law, and understanding the implications of Wien's displacement and distribution laws. It will explore deeper into quantum theory with investigations into the photoelectric effect, Compton scattering, and the wave-particle duality, including the De Broglie wavelength and matter waves. Moreover, to analyze nuclear reactions, energy release mechanisms in fission and fusion, and their applications in nuclear reactors and stellar energy processes will provide a comprehensive overview. Overall, this course integrates theoretical knowledge with practical applications, preparing students for advanced studies in physics and related disciplines.

Course Objectives:
1. To acquaint the learner with the theoretical developments of modern physics.
2. To deliver the key concepts of modern physics.
3. To impart the knowledge of nuclear physics.
4. To introduce the basics of laser physics.

Course Outcomes (COs): After the completion of this course the students will be able to
CO1: Analyze and apply concepts of both thermal radiation and quantum mechanics.
- **LO1.1:** Explain and apply fundamental laws and principles such as blackbody Radiation, Kirchhoff's law, Stefan-Boltzmann law, and Planck's Quantum Hypothesis.
- **LO1.2:** Analyze the wave properties such as probability, amplitude, and functions.

CO2: Apply quantum mechanics principles.
- **LO2.1:** Explain and apply the concept of wave-particle duality.
- **LO2.2:** Use the uncertainty principle to estimate the minimum energy of confined particles.

CO3: Analyze of the fundamental properties of atomic nuclei.
- **LO3:1:** Examine the theoretical nuclear models like the Liquid Drop Model and the Nuclear Shell Model.
- **LO3.2:** Explain the nuclear stability, isotopic trends (N-Z graph), and the role of nuclear forces in atomic nuclei.

LO3.3: State advanced concepts such as mass defect, binding energy, nuclear spin, and magnetic moment.

CO4: Assess the principles of laser physics.

LO4.1: State basic lasing elements and concepts such as population inversion, optical pumping, and their role in achieving and maintaining laser operation.

LO4.2: Describe the operational principles of three-level and four-level lasers.

LO4.3: Distinguish the design considerations for different types of lasers and evaluate their suitability for various applications in technology.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual	LO4.1 LO3.3					
Conceptual		LO1.1 LO2.1 LO3.2 LO4.2	LO2.2 CO2	LO1.2 LO2.3 LO3.1 LO4.3 CO1 CO3	CO4	
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	M	S	S	M	M	M	M	M	M
CO2	S	M	S	S	S	M	S	M	M	S
CO3	S	S	M	M	M	M	M	S	M	S
CO4	S	S	M	S	M	M	S	S	S	S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit 1: Radiation Laws and Quantum Behaviours of Radiation

Blackbody Radiation, Kirchhoff's law, Stefan-Boltzmann law, Wien's Displacement law, Wien's Distribution Law, Rayleigh-Jeans Law, Ultraviolet Catastrophe, Planck's Quantum Hypothesis, Planck's Constant. **(L 7, H 7, M 7)**

Quantum theory of Light- Photo-electric Effect and Compton Scattering. De Broglie Wavelength and Matter Waves; Davisson-Germer experiment. Wave description of particles by wave packets. Group and Phase Velocities and relation between them. Two-Slit experiment with electrons. Probability. Wave Amplitude and Wave Functions. **(L 9, H 9, M 9)**

Unit 2: Quantum Mechanical Principles

Position measurement-gamma ray microscope thought experiment, Wave-particle duality, Heisenberg uncertainty principle (Uncertainty relations involving Canonical pair of variables), Estimating minimum energy of a confined particle using uncertainty principle, Energy-time uncertainty principle. **(L 6, H 6, M 6)**

Unit 3: Basic Properties and Models of Nucleus

Basic properties of Atomic Nucleus: Structure, Size, Mass, Density, Charge, Mass Defect, Binding Energy, Spin, Magnetic moment, Nonexistence of electrons in the nucleus as a consequence of the Uncertainty Principle, Properties of Nuclear Force, N-Z Graph, Liquid Drop Model: Semi-empirical Mass Formula, Nuclear Shell Model and Magic Numbers. **(L 10, H 10, M 10)**

Unit 4: Radioactivity and Nuclear Reactions

Radioactivity: Stability of the Nucleus; Law of Radioactive Decay; Mean-life and Half-life; Alpha decay, Beta decay and Energy Spectrum, Pauli's Neutrino Hypothesis; Gamma Ray Emission, Electron-Positron Pair Creation by Gamma Photons in the vicinity of a nucleus. **(L 6, H 6, M 6)**

Nuclear reaction, Q-value, conservation laws; Fission and Fusion; Fission- nature of fragments and emission of neutrons. Nuclear reactor: slow neutrons interacting with Uranium-235; Fusion and Thermonuclear Reactions driving stellar energy (brief qualitative discussions). **(L 14, H 14, M 14)**

Unit 5: Basics of Lasers

Einstein’s A and B Coefficients, Metastable States, Spontaneous and Stimulated Emissions, Optical Pumping and Population Inversion, Three-Level and Four-Level Lasers, Ruby Laser and He-Ne Laser, Basic lasing. **(L 8, H 8, M 8)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Concepts of Modern Physics, *A. Beiser*, Tata McGraw-Hill.
2. Introduction to Modern Physics, *F. K. Richtmyer, K. H. Kennard, J. N. Cooper*, Tata McGraw Hill.
3. Introduction to Quantum Mechanics, *D. J. Griffith*, Pearson Education.
4. Physics for Scientists and Engineers with Modern Physics, *Jewett and Serway*, Cengage Learning.
5. Modern Physics, *G. Kaur, G. R. Pickrell*, McGraw Hill.
6. Quantum Mechanics: Theory & Applications, *A. K. Ghatak, S. Lokanathan*, Macmillan.
7. Modern Physics, *J. R. Taylor, C. D. Zafiratos, M. A. Dubson*, PHI Learning.
8. Theory and Problems of Modern Physics, Schaum's outline, *R. Gautreau, W. Savin*, Tata McGraw-Hill.
9. Quantum Physics, Berkeley Physics, *E. H. Wichman*, Tata McGraw-Hill.

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Course title: Physics Lab II (Major)
Course code: PHY-C-8
Nature of the course: Core
Total credit assigned: 4
Distribution of marks: 60 (End sem) + **40** (In-sem)

Course Description: The course on Physics Lab II (Major) comprises experiments covering Electricity and magnetism, thermal physics and modern physics.

Course Objectives: This course will enable the students to

1. Understand and appreciate the theory of modern physics as well as thermal physics and optics.
2. Develop the ability to relate the theories into everyday applications.

Course Outcomes (COs): At the completion of the course, the students will be able to

CO1: Understand the basic concepts in hands-on mode through the basic electricity and magnetism. Thermal physics and modern physics experiments

LO1.1: Recall the concepts of series and Parallel LCR circuits
LO1.2: Explain the characteristics of RC circuit, Thevenin and Norton theorem
LO1.3: Recall the basics of thermal conductivity and thermos emf.
LO1.4: Explain the basics of lasers.

CO2: Experiment with various electrical circuits and electronic instruments.

LO2.1: Execute the experiment to measure the wavelength of He-Ne laser light.
LO2.2: Conduct the experiment to study photoelectric effect
LO2.3 Perform the experiment to determine Plank's constant

CO3: Analyze different electronic components and circuits to understand its functioning and apply

LO3.1: Analyze Q factor and bandwidth
LO3.2: Analyze the frequency response curve to determine impedance and resonance

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual	LO1.1	LO1.1 LO1.2 LO1.3 LO1.4		LO3.1 LO3.2		
Procedural			LO2.1 LO2.2 LO2.3			
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	M	M	M	S	M	M	M
CO2	S	S	M	S	M	M	M	M	M	M
CO3	M	S	M	S	M	M	S	M	M	M

(S: Strong, M: Medium, W: Weak)

Lists of Experiments:

Unit 1: Electricity and Magnetism

1. To study the characteristics of a series RC circuit.
2. To determine an unknown Low Resistance using Potentiometer/Carey Foster's Bridge.
3. To verify the Thevenin and Norton theorems.
4. To verify the Superposition, and Maximum power transfer theorems.
5. To determine self-inductance of a coil by Anderson's bridge.
6. To study the response curve of a series and parallel LCR circuit and determine its (a) Resonant frequency (b) Impedance at resonance, (c) Quality factor Q, and (d) Band width.
7. Measurement of charge and current sensitivity and CDR of Ballistic Galvanometer
8. Determine a high resistance by leakage method using Ballistic Galvanometer.

Unit 2: Thermal Physics

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/Angstrom's Method.
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 (PRT).
5. To study the variation of Thermo-Emf of a Thermocouple with Difference of Temperature of its Two Junctions.

Unit 3: Modern Physics

1. Measurement of Planck's constant using black body radiation and photo-detector.
2. Photo-electric effect: photo current versus intensity and wavelength of light; maximum energy of photo-electrons versus frequency of light.
3. To determine the work function of the material of filament of directly heated vacuum diodes.
4. To determine the Planck's constant using LEDs of at least 4 different colors.
5. To determine the ionization potential of mercury.
6. To determine the value of e/m by (a) Magnetic focusing or (b) Bar magnet.
7. To set up the Millikan oil drop apparatus and determine the charge of an electron.
8. To determine the wavelength of a laser source using diffraction of a single slit and double slit.
9. To determine (i) wavelength and (ii) angular spread of He-Ne laser using plane diffraction grating.

(Total Practical Classes 60, Total Contact Hours 120, Total Marks 60)

At least 60% of the experiments must be performed from each unit.

Recommended Readings:

1. Advanced Practical Physics for students, *B. L. Flint and H. T. Worsnop*, Asia Publishing House.
2. A Text Book of Practical Physics, *I. Prakash & Ramakrishna,* Kitab Mahal.
3. Advanced Level Physics Practicals, *M. Nelson and Jon M. Ogborn*, Heinemann Educational Publishers.
4. A Laboratory Manual of Physics for undergraduate classes, *D. P. Khandelwal*, Vani Publication.

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SEMESTER V

Course title: Mathematical Physics - II
Course code: PHY-C-9
Nature of the course: Core
Total credit assigned: 4
Distribution of marks: 60 (End sem) + **40** (In-sem)

Course Description: This course is a continuation of Mathematical Physics-I course covering relatively advanced topics than those in Mathematical Physics-I. It mainly covers four topics: 1. Fourier series, 2. second order differential equation and special functions such as Legendre, Bessel, Hermite and Laguerre polynomials, 3. some special integrals such as beta and gamma functions and 4. partial differential equations. These topics along with their applications in physics constitute the central theme of the course.

Course Objectives: The aim of this course is to

1. Introduce a learner to a number of mathematical tools and methods.
2. Develop a basic understanding of these mathematical tools and methods.
3. Acquaint a learner with application of these mathematical tools and methods in physics.
4. Develop an adequate amount of mathematical skill among the learners to navigate through different areas in physics.

Course Outcomes (COs): At the completion of this course, a learner will be able to

CO1: Understand a few mathematical concepts and their importance in physics.

- **LO1.1:** Define key terms and operations in Fourier series, second order differential equations and special functions such as Legendre, Bessel, Hermite and Laguerre polynomials, some special integrals such as beta and gamma functions and partial differential equations.
- **LO1.2:** Explain the properties and rules of Fourier series, second order differential equations and special functions such as Legendre, Bessel, Hermite and Laguerre polynomials, some special integrals such as beta and gamma functions and partial differential equations.
- **LO1.3:** Describe a problem in physics in terms of Fourier series, second order differential equations and special functions such as Legendre, Bessel, Hermite and Laguerre polynomials, some special integrals such as beta and gamma functions and partial differential equations.

CO2: Apply the above mathematical concepts to solve problems.

- **LO2.1:** Solve advanced level mathematical problems based on the key concepts in Fourier series, second order differential equation and special functions such as Legendre, Bessel, Hermite and Laguerre polynomials, some special integrals such as beta and gamma functions and partial differential equations.
- **LO2.2:** Use Fourier series, second order differential equation and special functions such as Legendre, Bessel, Hermite and Laguerre polynomials, some special integrals such as beta and gamma functions and partial differential equations to solve problems in

branches of physics like quantum mechanics, electromagnetic theory, thermal physics, electronics etc.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual	LO1.1	LO1.2 LO1.3 CO1	LO2.1 LO2.2 CO2			
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S			M	M		S
CO2	S	S	S	S			M	M		S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit 1: 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. **(L 15, H 15, M 15)**

Unit 2: Second Order Differential Equation and Special Functions

Second Order Linear Differential Equations and their importance. Singular Points, 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. **(L 25, H 25, M 25)**

Unit 3: Some Special Integrals

Beta and Gamma Functions and Relation between them. Expression of Integrals in terms of Gamma Functions. Error Function (Probability Integral). **(L 6, H 6, M 6)**

Unit 4: Partial Differential Equations

Solutions to Partial Differential Equations using Separation of Variables Method, Laplace's Equation in problems of Rectangular, Cylindrical and Spherical symmetry. Wave equation, Laplace Equation, Diffusion Equation, Examples of boundary value problems in physics.

(L 14, H 14, M 14)

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Mathematical Methods for Physicists, *G. B. Arfken, H. J. Weber, F. E. Harris*, Elsevier.
2. Fourier Analysis, *M. R. Spiegel,* Tata McGraw-Hill.
3. Mathematics for Physicists, *S. M. Lea,* Thomson Brooks/Cole.
4. Differential Equations, *G. F. Simmons,* Tata McGraw-Hill.
5. Partial Differential Equations for Scientists and Engineers, *S. J. Farlow,* Dover Publication.
6. Engineering Mathematics, *S. Pal and S. C. Bhunia*, Oxford University Press.
7. Mathematical methods for Scientists & Engineers, *D. A. McQuarrie*, Viva Books.

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Course title: Quantum Mechanics - I
Course code: PHY-C-10
Nature of the course: Core
Total credits: 4
Distribution of marks: 60 (End sem) **+40** (In-sem)

Course Description: This is an introductory level course on modern quantum mechanics and its applications. The first three units of the syllabus is dedicated to the basics in quantum mechanics covering time dependent Schrodinger's equation, time independent Schrodinger's equation and bound states in arbitrary potentials in details. The last four units deal with the application of the basics in the contexts of hydrogen like atoms, atoms in electric and magnetic fields and many electron atoms.

Course Objectives: The aim of this course is to

1. Introduce a learner to elementary quantum mechanics.
2. Develop a understanding of basic quantum mechanical framework among the learners.
3. Acquaint a learner with application of quantum mechanics.

Course Outcomes (COs): At the completion of this course, a learner will be able to

CO1: Understand the key concepts in quantum mechanics and their importance in physics.

LO1.1: Define key terms and concepts associated with time dependent Schrodinger's equation, time independent Schrodinger's equation and bound states in arbitrary potentials.

LO1.2: Explain the formalism of quantum mechanics in particular those associated with time dependent Schrodinger's equation, time independent Schrodinger's equation and bound states in arbitrary potentials.

LO1.3: Describe a quantum mechanical problem in terms of time dependent Schrodinger's equation, time independent Schrodinger's equation and bound states in arbitrary potentials.

CO2: Apply the above quantum mechanical concepts to solve problems.

LO2.1: Describe the application of quantum mechanics in the contexts of hydrogen atoms, atom in electric and magnetic field and many electron atoms.

LO2.2: Solve quantum mechanical problems based on the key concepts learnt.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual	LO1.1	LO1.2 LO1.3 LO2.1 CO1	LO2.2 CO2			
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S			M	S		S
CO2	S	S	S	S			M	S		S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit 1: Time Dependent Schrodinger Equation

Time dependent Schrodinger equation and dynamical evolution of a quantum state; Properties of Wave Function. Interpretation of Wave Function Probability and probability current densities in three dimensions; Conditions for Physical Acceptability of Wave Functions. Normalization. Linearity and Superposition Principles. Eigenvalues and Eigenfunctions. Position, momentum and Energy operators; commutator of position and momentum operators; Expectation values of position and momentum. Wave Function of a Free Particle. **(L 8, H 8, M 8)**

Unit 2: Time Independent Schrodinger Equation

Hamiltonian, stationary states and energy eigenvalues; expansion of an arbitrary wavefunction as a linear combination of energy eigenfunctions; General solution of the time dependent Schrodinger equation in terms of linear combinations of stationary states; Application to spread of Gaussian wave- packet for a free particle in one dimension; wave packets, Fourier transforms and momentum space wavefunction; Position-momentum uncertainty principle. **(L 10, H 10, M 10)**

Unit 3: General Discussion of Bound States in an Arbitrary Potential

Continuity of wave function, boundary condition and emergence of discrete energy levels; application to one-dimensional problem-square well potential; Quantum mechanics of simple harmonic oscillator- energy levels and energy eigenfunctions using Frobenius method; Hermite polynomials; ground state, zero-point energy & uncertainty principle. **(L 12, H 12, M 12)**

Unit 4: Quantum Theory of Hydrogen-like Atoms

Time independent Schrodinger equation in spherical polar coordinates; separation of variables for second order partial differential equation; angular momentum operator & quantum numbers; Radial wave functions from Frobenius method; shapes of the probability densities for ground & first excited states; Orbital angular momentum quantum numbers l and m; s, p, d, ... shells. **(L 8, H 8, M 8)**

Unit 5: Atoms in Electric & Magnetic Fields

Electron angular momentum. Space quantization. Electron Spin and Spin Angular Momentum. Larmor's Theorem. Spin Magnetic Moment. Stern-Gerlach Experiment. Zeeman Effect: Electron Magnetic Moment and Magnetic Energy, Gyromagnetic Ratio and Bohr Magneton.

(L 8, H8, M 8)

Atoms in External Magnetic Fields

Normal and Anomalous Zeeman Effect, Paschen Back and Stark Effect (Qualitative Discussion only). **(L 4, H 4, M 4)**

Unit 7: Many Electrons Atoms

Pauli's Exclusion Principle. Symmetric & Antisymmetric Wave Functions. Periodic table. Fine structure. Spin orbit coupling. Spectral Notations for Atomic States. Total angular momentum. Vector Model. Spin-orbit coupling in atoms-L-S and J-J couplings. Hund's Rule. Term symbols. Spectra of Hydrogen and Alkali atoms (Na etc.) **(L 10, H 10, M 10)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. A Text book of Quantum Mechanics, *P. M. Mathews and K. Venkatesan*, McGraw Hill.
2. Quantum Mechanics, *R. Eisberg and R. Resnick*, Wiley.
3. Quantum Mechanics, *L. I. Schiff,* Tata McGraw Hill.
4. Quantum Mechanics, *G. Aruldhas,* 2nd Edition, PHI Learning of India.
5. Quantum Mechanics, *B. C. Reed,* Jones and Bartlett Learning.
6. Quantum Mechanics: Foundations & Applications, *A. Bohm,* Springer.
7. Quantum Mechanics for Scientists & Engineers, *D. A. B. Miller,* Cambridge University Press.
8. Quantum Mechanics, *E. Merzbacher,* John Wiley and Sons.
9. Introduction to Quantum Mechanics, *D. J. Griffith,* Pearson Education.

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Course title: Statistical Mechanics - I
Course code: PHY-C-11
Nature of the course: Core
Total credits: 4
Distribution of marks: 60 (End sem) **+ 40** (In-sem)

Course Description: Statistical mechanics is the branch of physics that addresses the thermodynamic properties of a system from microscopic considerations. This is an introductory course in Statistical mechanics which covers the key topics such as ensemble theories, partition function, classical statistics (Maxwell-Boltzmann) and quantum statistics (Bose-Einstein and Fermi-Dirac). It deals with the concepts, formulations and applications of the above elements of Statistical mechanics.

Course Objectives: Objectives of the course is to

1. Illustrate the purpose of statistical mechanics.
2. Build up a strong foundation in the methods of statistical mechanics.
3. Illustrate the role of statistical mechanics in other areas such as solid-state physics, modern physics, astrophysics etc. which involve the studies of statistical systems.

Course Outcomes (COs): At the completion of this course, a learner will be able to

CO1: Explain the connection between thermodynamics and statistical mechanics.

- **LO1.1:** Explain the concepts of basic ingredients such as macro state, microstate, phase space, Gibbsian ensemble etc. that builds up the foundation of statistical mechanics.
- **LO1.2:** Explain Boltzmann's entropy formula.

CO2: Explain the concepts of key elements of statistical mechanics.

- **LO2.1:** Explain the concept of three ensemble theories- micro-canonical, canonical and grand-canonical.
- **LO2.2:** Illustrate the concept of partition function.
- **LO2.3:** Summarize the basic features of each ensemble theory.
- **LO2.4:** Explain the concept of three types of statistics- Maxwell-Boltzmann (MB), Bose Einstein (BE) and Fermi-Dirac (FD).

CO3: Apply the theories of statistical mechanics to explain physical properties of statistical system.

- **LO3.1:** Construct (canonical/ grand-canonical) partition function for a given physical system.
- **LO3.2:** Calculate physical quantities such as average energy, average entropy, average number of particles, free energy etc. from partition function.
- **LO3.3:** Apply ensemble theory and partition function to derive entropy of an ideal gas.
- **LO3.4:** Apply BE statistics to explain physical properties of a BE gas (such as properties of blackbody radiation, BE condensation etc.).
- **LO3.5:** Apply FD statistics to explain physical properties of a FD gas (such as properties of the electron gas in a metal and in a white dwarf star etc.).

CO4: Analyze the use of different ensemble theories and different types of statistics in relevant physical situations.

- **LO4.1:** Distinguish between different ensemble theories.
- **LO4.2:** Distinguish between different types of statistics.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual		LO1.1, LO1.2, LO2.1, LO2.2, LO2.3, LO2.4 CO1, CO2	LO3.1, LO3.2, LO3.3, LO3.4, LO3.5 CO3	LO4.1, LO4.2 CO4		
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	M		M						
CO2	S	M		M						
CO3	S	S		S						
CO4	S	S		S						

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit 1: Classical Statistics
Macrostate and Microstate, Phase Space, Elementary Concept of Ensemble, Postulates of classical statistical mechanics, Liouville's theorem, Number of microstates, Connection between Entropy and Thermodynamic Probability: Boltzmann entropy formula, Microcanonical ensemble, Classical Ideal Gas in Microcanonical ensemble, Classical Entropy Expression, Gibbs Paradox, Sackur Tetrode equation, Canonical ensemble, Classical Canonical Partition Function, Classical Ideal Gas in Canonical ensemble, Grand canonical ensemble, Chemical Potential, Classical Grand canonical Partition Function; Maxwell-Boltzman distribution law. **(L 18, H 18, M 18)**

Unit 2: Partition Function
Quantized systems and discrete energy levels, Canonical and Grand Canonical Partition Functions (PF), Boltzman factor, Free Energy and Entropy in terms of PF, Average energy and Average number of particles; PF of a two-level system, PF of linear harmonic oscillator, Single particle PF, N particle PF (non-interacting); Degeneracy, Density of states. **(L 12, H 12, M 12)**

Unit 3: Bose - Einstein Statistics
Bose-Einstein distribution law, Thermodynamic functions of a Strongly Degenerate Bose Gas, Bose Einstein condensation, Properties of liquid He (qualitative description), Radiation as a Photon Gas, Thermodynamic functions of Photon Gas, Derivation of Planck's law. **(L 15, H 15, M 15)**

Unit 4: Fermi - Dirac Statistics

Fermi-Dirac Distribution Law, Thermodynamic functions of a Completely and Strongly Degenerate Fermi Gas, Fermi Energy, Electron gas in a Metal, Specific Heat of Metals, Relativistic Fermi gas, White Dwarf Stars, Chandrasekhar Mass Limit. **(L 15, H 15, M 15)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Statistical Mechanics, *R. K. Pathria,* Oxford University Press.
2. Statistical Physics: Berkeley Physics Course, *F. Reif,* Tata McGraw-Hill.
3. Thermal Physics, *S. C. Garg, R. M. Bansal, C. K. Ghosh,* Tata McGraw-Hill.
4. Statistical Mechanics, *K. Huang,* Wiley.
5. Thermodynamics and Statistical Mechanics, *W. Greiner, L. Niese, H. Stocker*, Springer.
6. Statistical and Thermal Physics, *S. Lokanathan and R. S. Gambhir,* Prentice Hall India.
7. Thermodynamics, Kinetic Theory and Statistical Thermodynamics, *F. W. Sears and G. L. Salinger,* Narosa.
8. Modern Thermodynamics with Statistical Mechanics, *C. S. Helrich*, Springer.
9. An Introduction to Statistical Mechanics & Thermodynamics, *R. H. Swendsen,* Oxford University Press.

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SEMESTER VI

Course Title: Electromagnetic Theory
Course code: PHY-C-12
Nature of the Course: Core
Total credits: 4
Distribution of marks: 60 (End sem) + **40** (In-sem)

Course Description: This course covers the laws and concepts governing electromagnetic fields and waves. Key topics include: Maxwell's equations, propagation of electromagnetic waves in different media, polarization of electromagnetic waves, waveguides and optical fibers.

Course Objectives: The aim of the course is to

1. Familiarize a learner with Maxwell's equations to describe the behavior of electromagnetic waves in vacuum as well as medium.
2. Impart knowledge on the concepts of electromagnetic waves and transmission lines.
3. Introduce a learner to waveguides and optical fibers.

Course Outcomes (COs): At the completion of this course, a learner will be able to

CO1: Understand the basic concepts associated with Maxwell's equations, propagation of electromagnetic waves in different media, polarization of electromagnetic waves, waveguides and optical fiber

- **LO1.1:** Define key terms and operations in electromagnetic theory.
- **LO1.2:** Explain the laws governing electromagnetic theory.
- **LO1.3:** Describe the interaction of electromagnetic radiation with matter.
- **LO1.4:** Illustrate the working of optical fiber and waveguide.
- **LO1.5:** Explain the polarization of Electromagnetic Waves.

CO2: Apply the basic concepts in electrodynamics to solve problems.

- **LO2.1:** Use electromagnetic wave theory to explain wave propagation in different media, including reflection, refraction, and transmission characteristics.
- **LO2.2:** Use Maxwell's equations to solve problems related to transmission lines and uniform plane wave propagation.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual	LO1.1	LO1.2 LO1.3 LO1.4 LO1.5 CO1	LO2.1 LO2.2 CO2			
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S			M	M		S
CO2	S	S	S	S			M	M		S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit 1: Maxwell Equations

Review of Maxwell's equations. Displacement Current. Vector and Scalar Potentials. Gauge Transformations: Lorentz and Coulomb Gauge. Boundary Conditions at Interface between Different Media. Wave Equations. Plane Waves in Dielectric Media. Poynting Theorem and Poynting Vector. Electromagnetic (EM) Energy Density. Physical Concept of Electromagnetic Field Energy Density, Momentum Density and Angular Momentum Density. **(L 12, H 12, M 12)**

Unit 2: EM Wave Propagation

Plane EM waves through vacuum and isotropic dielectric medium, transverse nature of plane EM waves, refractive index and dielectric constant, wave impedance. Propagation through conducting media, relaxation time, skin depth. Wave propagation through dilute plasma, Electrical conductivity of ionized gases, Plasma frequency, Refractive index, Skin depth, application to propagation through ionosphere. **(L 10, H 10, M 10)**

Unit 3: EM Wave in Bounded Media

Boundary conditions at a plane interface between two media. Reflection & Refraction of plane waves at plane interface between two dielectric media-Laws of Reflection & Refraction. Fresnel's Formula for perpendicular & parallel polarization cases, Brewster's law. Reflection & Transmission coefficients. Total internal reflection, evanescent waves. Metallic reflection (normal Incidence). **(L 10, H 10, M 10)**

Unit 4: Polarization of Electromagnetic Waves

Description of Linear, Circular and Elliptical Polarization. Propagation of E.M. Waves in Anisotropic Media. Symmetric Nature of Dielectric Tensor. Fresnel's Formula. Uniaxial and Biaxial Crystals. Light Propagation in Uniaxial Crystal. Double Refraction. Polarization by Double Refraction. Nicol Prism. Ordinary & extraordinary refractive indices. Production & detection of Plane, Circularly and Elliptically Polarized Light. Phase Retardation Plates: Quarter-Wave and Half-Wave Plates. Babinet Compensator and its Uses. Analysis of Polarized Light. Rotatory Polarization: Optical Rotation. Biot's Laws for Rotatory Polarization. Fresnel's Theory of optical rotation. Calculation of angle of rotation. Experimental verification of Fresnel's theory. Specific rotation. Laurent's half-shade polarimeter. **(L 17, H 17, M 17)**

Unit 5: Wave Guides

Planar optical waveguides. Planar dielectric waveguide. Condition of continuity at interface. Phase shift on total reflection. Eigenvalue equations. Phase and group velocity of guided waves, Field energy and power transmission. **(L 8, H 8, M 8)**

Unit 6: Optical Fibers

Numerical aperture, Step and Graded Indices (Definitions only), Single and Multimode fibers (Concepts and Definition Only). **(L 3, H 3, M 3)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Introduction to Electrodynamics, *D. J. Griffiths*, Benjamin Cummings.
2. Elements of Electromagnetics, *M. N. O. Sadiku*, Oxford University Press.
3. Introduction to Electromagnetic Theory, *T. L. Chow*, Jones & Bartlett Learning.
4. Fundamentals of Electromagnetics, *M. A.W. Miah*, Tata McGraw Hill.
5. Electromagnetic field Theory, *R. S. Kshetrimayun*, Cengage Learning.
6. Engineering Electromagnetic, *Willian H. Hayt*, McGraw Hill.
7. Electromagnetic Field Theory for Engineers & Physicists, *G. Lehner*, Springer.
8. Electromagnetic Fields & Waves, *P. Lorrain & D. Corson*, W. H. Freeman & Co.
9. Electromagnetics, J. A. Edminster, *Schaum Series*, Tata McGraw Hill.
10. Electromagnetic field theory fundamentals, *B. Guru and H. Hiziroglu*, Cambridge University Press.

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Course title: Condensed Matter Physics I
Course code: PHY-C-13
Nature of the course: Core
Total credits: 4
Distribution of marks: 60 (End sem) **+ 40** (In-sem)

Course Description: The course on Condensed Matter Physics I encompasses various aspects of crystal structures, free electron theory, lattice dynamics, magnetic and dielectric properties of materials. The goal of this course is to teach students the fundamentals of condensed matter physics which will enable them to work in both theoretical and experimental facets thereby broadening the educational goals of developing a strong foundation in condensed matter physics.

Course Objectives: The objective of the course is to:

1. Equip students with a comprehensive understanding of the essential principles and concepts that dictate the physical properties of solid materials.
2. Introduce students to the theoretical frameworks and experimental techniques essential for studying condensed matter systems.
3. Enable students to learn the application of quantum mechanical concepts to solve problems specific to condensed matter physics and utilize experimental tools for investigating these systems.
4. To cultivate within themselves the interest in pursuing advanced studies in condensed matter physics, armed with both the theoretical knowledge and practical skills necessary for success in the field.

Course Outcomes (COs): After the completion of this course, a learner will be able to

CO1: Understand a few basic topics in condensed matter physics.

- **LO1.1:** Define the key concepts and phenomena linked to crystallography, electron theory, elementary lattice dynamics, magnetic and dielectric characteristics of materials.
- **LO1.2:** Explain crystallographic physics, electron theory, elementary lattice dynamics, magnetic materials, and dielectric materials.
- **LO1.3:** Describe the physical phenomena associated with crystallography, electron theory, elementary lattice dynamics, magnetic characteristics of materials, and dielectric properties.

CO2: Apply the fundamental concepts learned to tackle condensed matter challenges.

- **LO2.1:** Solve physics issues using the key principles learned.
- **LO2.2:** Use the basic condensed matter concepts to interpret the related experimental observations.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual	LO1.1	LO1.2 LO1.3 CO1	LO2.1 LO2.2 CO2			
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S			M	M		S
CO2	S	S	S	S			M	M		S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit 1: Crystallography

Solids: symmetry elements. Unit Cell. Crystal systems Lattice Translation Vectors. Bravais Lattice, Lattice with a Basis. Miller Indices. Packing Fraction, Crystal Types. Examples of crystal structures: SC, FCC, BCC, HCP, Diamond, NaCl etc.

Reciprocal Lattice, Brillouin Zones. Diffraction of X-Rays by Crystals. Bragg's Law. Atomic Scattering Factor. Structure Factor.

Introduction to Glasses and Liquid crystals. **(L 12, H 12, M 12)**

Unit 2: Electron Theory

Free Electron Theory: Basic ideas, Classical Free electron theory – Drude Model, Free electron Fermi Gas-Sommerfeld theory, Boltzmann Transport Equation, Basic ideas of Electron Energy

Bands, Energy Spectra in atoms, molecules and solids, Qualitative ideas of Bloch Theorem, Kronig Penny Model, Metals, Insulators and Semiconductors. **(L 12, H 12, M 12)**

Unit 3: Elementary Lattice Dynamics

Lattice Vibrations and Phonons: Linear Monatomic and Diatomic Lattice. Acoustical and Optical Phonons. Qualitative Description of the Phonon Spectrum in Solids, Einstein and Debye theories of specific heat of solids. T^3 law. **(L 12, H 12, M 12)**

Unit 4: Magnetic Properties of Materials

Origin of Magnetic Moment, Gyromagnetic Ratio, Lande-g factor, Dia-, Para-, Ferri- and Ferromagnetic Materials. Classical Langevin Theory of dia– and Paramagnetic Domains. Quantum Mechanical Treatment of Paramagnetism. Curie's law, Weiss's Theory of Ferromagnetism, Domains, Hysteresis and Energy Loss. **(L 12, H 12, M 12)**

Unit 5: Dielectric Properties of Materials

Polarization. Types of Polarization, Static Dielectric Constant. Local Electric Field at an Atom. Depolarization Field. Electric Susceptibility. Polarizability. Clausius Mossotti Equation. Classical Theory of Electric Polarizability. **(L 12, H 12, M 12)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Introduction to Solid State Physics, *C. Kittel*, Wiley India Pvt. Ltd.
2. Elements of Solid-State Physics, *J. P. Srivastava*, Prentice-Hall of India.
3. Introduction to Solids, *L. V. Azaroff*, Tata Mc-Graw Hill.
4. Solid State Physics, *N. W. Ashcroft and N. D. Mermin*, Cengage Learning.
5. Solid-state Physics, *H. Ibach and H. Luth*, Springer.
6. Solid State Physics, *R. John*, McGraw Hill.
7. Elementary Solid-State Physics, *M. A. Omar*, Pearson India.
8. Solid State Physics, *M. A. Wahab*, Narosa Publications.

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Course title: Electronics I
Course code: PHY-C-14
Nature of the course: Core
Total credits: 4
Distribution of marks: 60 (End sem) **+ 40** (In-sem)

Course Description: The course provides a comprehensive understanding of semiconductor devices, analog and digital circuits, and their practical implementation in various electronic systems. It will give a basis for understanding and constructing simple systems of analog and digital electronic circuit elements. Key Topics: Semiconductor Devices, Bipolar junction transistor, Amplifiers, Basic gates, Boolean Algebra, Basic computer organization.

Course Objectives: This course aims to

1. Impart the context of electronic science in perspective of modern instruments and measurement techniques.
2. Provide the fundamental and working principles of semiconductor devices.
3. Introduce the concepts and working of analog electronics systems.
4. Introduce the concepts digital electronics and microprocessors.
5. To allow students to apply their knowledge for designing small electronic systems.

Course Outcomes (CO)s: At the completion of this course, a student will be able to

CO1: Understand the basic components of analog and digital electronics.

- **LO1.1:** Define the basic components.
- **LO1.2:** Explain the basic principle of semiconductors and semiconductor devices.
- **LO1.3:** Classify the different components according to their applications.
- **LO1.4:** Explain the basic computer organization.
- **LO1.5:** Explain the basic features of microprocessors.

CO2: Apply the concepts of analog and digital analysis.

- **LO2.1:** Use of semiconductor devices like diode, transistors in building simple electronic circuits.
- **LO 2.2:** Construct different types of analog and digital circuits and to experiment with them.
- **LO 2.3:** Identify the basic components of a computer.

CO3: Analyze electronic circuits to understand its functioning.

- **LO3.1:** Distinguish between analog and digital circuit.
- **LO3.2:** Simplify electronic circuits to its equivalent form.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual		LO1.1 LO1.2 LO1.3 LO1.4 LO1.5 CO1		LO 3.1		
Procedural			LO2.1 LO2.2 LO2.3 CO2	CO3 LO 3.2		
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S	S	S	M	S	S	M
CO2	S	S	S	S	S	S	M	S	S	S
CO3	S	S	S	S	S	S	M	S	S	S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit 1: Semiconductor Devices
P and N type semiconductors. Energy Level Diagram. Conductivity and Mobility, Concept of Drift velocity. Barrier Formation in PN Junction Diode. Current Flow Mechanism in Forward and Reverse Biased Diode. Drift Velocity. Application in switching, rectification (with ripple factor calculations), clipping and clamping etc. Special diodes: (1) Zener diode, (2) photodiode and photocell (3) LED. **(L 10, H 10, M 10)**

Unit 2: Bipolar Junction Transistor
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, Cutoff and Saturation Regions. **(L 4, H 4, M 4)**

Unit 3: BJT as 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. RC coupled amplifier and frequency response. **(L 10, H 10, M 10)**

Unit 4: Feedback in Amplifiers and Oscillators
Effect of positive and negative feedback on Input impedance, Output impedance, Gain, Stability, Distortion and noise. Four types of negative feedback and analysis, Barkhausen's Criterion for self-sustained oscillations. RC Phase shift oscillator. **(L 5, H 5, M 5)**

Unit 5: Operational Amplifiers
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.
Applications of OPAMP: (1) Inverting and non-inverting amplifiers, (2) Adder, (3) Subtractor, (4) Differentiator, (5) Integrator, (6) Log amplifier, (7) Zero crossing detector. **(L 4, H 4, M 4)**

Unit 6: Digital Electronics
Difference between Analog and Digital Circuits. Binary Numbers. Decimal to Binary and Binary to Decimal Conversion. BCD, Octal and Hexadecimal numbers. Boolean algebra AND, OR, NOT gates, NAND and NOR Gates as Universal Gates, XOR gate; De Morgan's Theorems. Boolean Laws. Simplification of Logic Circuit using Boolean Algebra. Fundamental Products. Idea of Minterms and Maxterms. **(L 6, H 6, M 6)**

Unit 7: Arithmetic and Data Processing Circuits

Binary Addition. Binary Subtraction using 2's Complement. Half and Full Adders. Half & Full Subtractors, 4-bit binary Adder/Subtractor. Basic idea of Multiplexers, De-multiplexers, Decoders, Encoders with examples. **(L 6, H 6, M 6)**

Unit 8: 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 Flip-Flop. Basic idea of Shift registers (serial and parallel form) Counters: Ring Counter. Asynchronous and Synchronous Counter.

(L 10, H 10, M 10)

Unit 8: Basic Computer Organization

Vonn Newmann and Havard architecture, Input/Output Devices. Data storage (idea of RAM and ROM). Computer memory types, speed and organization. Basic features of 8085 as examples of CPU. Components: Buses, Registers, ALU. **(L 5, H 5, M 5)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Integrated Electronics, *J. Millman and C. C. Halkias*, Tata Mc-Graw Hill.
2. Electronics: Fundamentals and Applications, *J. D. Ryder*, Prentice Hall.
3. Solid State Electronic Devices, *B. G. Streetman & S. K. Banerjee*, PHI Learning.
4. Electronic Devices & circuits, *S. Salivahanan & N. S. Kumar*, Tata Mc-Graw Hill.
5. OP-Amps and Linear Integrated Circuit, *R. A. Gayakwad*, Prentice Hall.
6. Electronic circuits: Handbook of design and applications, *U. Tietze, C. Schenk*, Springer.
7. Semiconductor Devices: Physics and Technology, *S. M. Sze*, Wiley India.
8. Microelectronic Circuits, *M. H. Rashid*, Cengage Learning.
9. Electronic Devices, 7/e *Thomas L. Floyd*, Pearson India.
10. Digital Principles and Applications, *A. P. Malvino, D. P. Leach and Saha*, Tata McGraw.
11. Fundamentals of Digital Circuits, *Anand Kumar*, PHI Learning Pvt. Ltd.
12. Digital Circuits and Systems, *Venugopal*, Tata McGraw Hill.
13. Digital Electronics *G. K. Kharate*, Oxford University Press.
14. Digital Systems: Principles & Applications, *R. J. Tocci, N. S. Widmer*, PHI Learning.
15. Logic circuit design, *S. P. Vingron*, Springer.
16. Digital Electronics, *S. Ghoshal*, Cengage Learning.
17. Digital Electronics, *S. K. Mandal*, McGraw Hill.

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Course title: Physics Lab III (Major)
Course code: PHY-C-15
Nature of the course: Core
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: The course aims to provide students with hands-on experience in understanding and analyzing the characteristics of electronic components, designing and implementing amplifier and logic circuits, and developing microprocessor programs. Students will measure and plot V-I characteristics of diodes, examine BJT characteristics, and design transistor amplifiers. They will also create and test Op-amp amplifiers, logic gates, and various combinational and sequential circuits. Additionally, students will write and execute microprocessor programs and study the magnetic, dielectric, and optical properties of materials, enhancing their practical skills and foundational knowledge in electronics and material science.

Course Objectives: This course is essential for developing practical skills and foundational knowledge in electronics and material science. By engaging in hands-on experiments, students will understand the characteristics and behavior of electronic components and materials. They will learn to design and implement various circuits, enhancing their problem-solving and critical-thinking abilities. Additionally, the course provides experience in microprocessor programming and the analysis of material properties, which are crucial for advanced studies and professional work in electronics, physics, and engineering fields. This comprehensive lab experience prepares students for careers in technology, research, and development.

Course Outcomes (COs): After the completion of this course, the student will be able to
CO1: Understand the characteristics of electronic components.
- **LO1.1:** Demonstrate and plot the V-I characteristics of a PN junction diode, Light Emitting Diode, and Zener diode, including its use as a voltage regulator.
- **LO1.2:** Explain the characteristics of a Bipolar Junction Transistor in CE configuration.

CO2: Build amplifier and logic circuits.
- **LO2.1:** Sketch logic gates and inverting and non-inverting amplifiers using Op-amps for DC voltage of a given gain.
- **LO2.2:** Construct and test Half Adder/Subtractor, Full Adder/Subtractor, 4-bit binary Adder circuits, and various Flip-Flop circuits.

CO3: Analyze the magnetic, dielectric, optical, and semiconductor properties of materials.
- **LO3.1:** Inspect the susceptibility of paramagnetic solutions and solids using Quinck's Tube Method and other techniques.
- **LO3.2:** Examine the band gap and resistivity of semiconductors.
- **LO3.3:** Test the Hall coefficient of a semiconductor sample.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	**Remember**	**Understand**	**Apply**	**Analyze**	**Evaluate**	**Create**
Factual		LO1.2	LO2.1	CO3		

Conceptual		CO1	LO2.2	LO3.1, LO3.2		
Procedural		LO1.1	CO2	LO3.3		
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	M	M	M	S	S	M	S
CO2	S	S	M	S	M	M	M	M	M	M
CO3	S	M	M	S	M	M	S	M	M	S
CO4	M	M	M	M	M	M	S	M	M	S

(S: Strong, M: Medium, W: Weak)

List of Experiments:

Unit 1: Electronics

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 study the frequency response of voltage gain of a RC-coupled transistor amplifier.
6. To design an inverting and non-inverting amplifier using Op-amp (741,351) for dc voltage of given gain.
7. To verify and design AND, OR, NOT and XOR gates using NAND gates.
8. To design a combinational logic system for a specified Truth Table.
9. To minimize a given logic circuit and design it using logic gate ICs.
10. Half Adder/Subtractor, Full Adder/Subtractor.
11. To build Flip-Flop (RS, Clocked RS, D-type and JK) circuits using NAND gates.
12. To build JK Master-slave flip-flop using Flip-Flop ICs.

Unit 2: Solid State Physics

1. Measurement of susceptibility of paramagnetic solution (Quinck's Tube Method).
2. To measure the Magnetic susceptibility of Solids.
3. To determine the Coupling Coefficient of a Piezoelectric crystal.
4. To measure the Dielectric Constant of a dielectric Materials with frequency.
5. To draw the BH curve of Fe using Solenoid & determine energy loss from Hysteresis.
6. To measure the resistivity of a semiconductor (Ge) with temperature by four-probe method (room temperature to 150 ^{o}C) and to determine its band gap.
7. To determine the Hall coefficient of a semiconductor sample.
8. To determine the band gap of a semiconductor by P-N junction method.

(Total Practical Classes 60, Total Contact Hours 120, Total Marks 60)

At least 60% of the experiments must be performed from each unit.

Recommended Readings:

1. Basic Electronics: A text lab manual, *P. B. Zbar, A. P. Malvino, M. A. Miller,* Mc-Graw Hill.
2. OP-Amps and Linear Integrated Circuit, *R. A. Gayakwad*, Prentice Hall.
3. Electronic Principle, *A. Malvino*, Tata Mc-Graw Hill.
4. Electronic Devices and Circuit Theory, *R. L. Boylestad & L. D. Nashelsky*, Pearson.
5. Advanced Practical Physics for students, *B. L. Flint and H.T. Worsnop*, Asia Publishing House.
6. Advanced level Physics Practicals, *M. Nelson and Jon M. Ogborn*, Heinemann Educational Publishers.
7. A Text Book of Practical Physics, *I. Prakash and Ramakrishna*, Kitab Mahal.
8. Elements of Solid State Physics, *J. P. Srivastava*, Prentice-Hall of India.

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SEMESTER VII

Course title: Mathematical Physics III
Course code: PHY-C-16
Nature of the course: Core
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This course is a continuation of Mathematical Physics-I and Mathematical Physics-II courses covering the a few very important topics. It covers: 1. integral transforms, 2. linear vector spaces, 3. complex analysis 4. group theory and 5. tensor analysis and their applications in physics in a detailed manner.

Course Objectives: The aim of this course is to

1. Develop a basic understanding of these mathematical tools and methods.
2. Acquaint a learner with application of these mathematical tools and methods in physics.
3. Develop an adequate amount of mathematical skill among the learners to navigate through quantum mechanics, statistical mechanics, quantum field theory, general relativity, condensed matter physics, electrodynamics and a number of other areas in physics.

Course Outcomes (COs): At the completion of this course, a learner will be able to

CO1: Understand a few mathematical concepts and their importance in physics.

- **LO1.1:** Define key terms and operations in integral transforms, linear vector spaces, complex analysis, group theory and tensor analysis.
- **LO1.2:** Explain the rules governing integral transforms, linear vector spaces, complex analysis, group theory and tensor analysis.
- **LO1.3:** Describe a problem in physics in terms of integral transforms, linear vector spaces, complex analysis, group theory and tensor analysis.

CO2: Apply the above mathematical concepts to solve problems.

- **LO2.1:** Solve advanced level mathematical problems based on the key concepts in integral transforms, linear vector spaces, complex analysis, group theory and tensor analysis.
- **LO2.2:** Use the concepts in integral transforms, linear vector spaces, complex analysis, group theory and tensor analysis to solve problems in quantum mechanics, general relativity and electrodynamics.

CO3: Analyze a problem in physics by relating it with the above mathematical concepts.

- **LO3.1:** Relate the learnt mathematical concepts with problems in physics.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual	LO1.1	LO1.2 LO1.3 CO1	LO2.1 LO2.2 CO2	LO3.1 CO3		

Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S			S	S		M
CO2	S	S	S	S			S	S		M
CO2	S	S	S	S			S	S		M

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: Integral Transforms

Fourier Transform: Fourier Integral theorem, Fourier transform of Trigonometric, Gaussian, finite wave train and other functions. Representation of Dirac delta functions as a Fourier Integral. Fourier transform of derivatives, Inverse Fourier transform, Convolution theorem. Properties of Fourier transforms (translation, change of scale, complex conjugation, etc.). Application of Fourier Transforms to differential equations: One dimensional Wave and Diffusion/Heat Flow Equations. **(L 8, H 8, M 8)**

Laplace Transform (LT): LT of Elementary functions. Properties of LTs: Change of Scale Theorem, Shifting Theorem. LTs of 1^{st} and 2^{nd} order Derivatives and Integrals of Functions, LT of Unit Step function, Dirac Delta function, Periodic Functions. Convolution Theorem. Inverse LT. Application of Laplace Transforms to 2^{nd} order Differential Equations: Damped Harmonic Oscillator, Simple Electrical Circuits, Coupled differential equations of 1^{st} order. Solution of heat flow along an infinite bar using Laplace transform. **(L 8, H 8, M 8)**

Unit II: Linear Vector Spaces Linear vector spaces- definition and examples, linear independence, basis and dimension, inner product, norm of a vector, orthonormal basis, Gram-Schmidt orthogonalization method, Schwarz's and Bessel's inequalities; linear operators, matrix representation of linear operators; special types of matrices- symmetric and antisymmetric, orthogonal, Hermitian and anti-Hermitian, unitary, normal; eigenvalues and eigenvectors; change of basis, similarity transformation, orthogonal and unitary transformations, diagonalization of matrices; infinite dimensional vector spaces, Hilbert space. **(L 12, H 12, M 12)**

Unit III: 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 regions. Laurent and Taylor’s expansion. Residues and Residue Theorem. Application in solving Definite Integrals.
(L 12, H 12, M 12)

Unit IV: Group Theory
Groups- definition and examples, groups of symmetry transformation- cyclic group, dihedral group, permutation group; subgroups, Lagrange's theorem, cosets, conjugacy classes; group representation; Continuous or Lie groups, generators of continuous group, special orthogonal groups- SO(2), SO(3); unitary groups- U(1), SU(2). **(L 10, H 10, M 10)**

Unit V: Tensor Analysis
Basics of tensor algebra, contravariant and covariant tensors, line element and metric tensor, associated tensors, Christoffel's symbols, geodesics, covariant derivatives, Riemannian Christoffel's tensor or curvature tensor, Bianchi identities. **(L 10, H 10, M 10)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Complex Variables, *A. S. Fokas, M. J. Ablowitz*, Cambridge University Press.
2. Complex Variables, *A. K. Kapoor*, Cambridge University Press.
3. Complex Variables and Applications, *J. W. Brown, R. V. Churchill*, Tata McGraw-Hill.
4. First course in complex analysis with applications, *D. G. Zill and P. D. Shanahan*, Jones & Bartlett.
5. Mathematical Methods for Physicists, *G. B. Arfken, H. J. Weber*, Elsevier Academic Press.
6. Mathematical Method for Physics and Engineering, *K. F. Riley, M. P. Hobson and S. J. Bence*, Cambridge University Press.
7. Mathematical Methods in the Physical Sciences, *M. L. Boas*, John Wiley & Sons.
8. Mathematical Physics: Basics, *S. D. Joglekar,* Universities Press.
9. Mathematical Physics: Advance, *S. D. Joglekar*, Universities Press.
10. Mathematical Physics with Application, Problems and Solution, *U. Balakrishnan,* Ane Books Pvt. Ltd.
11. Elements of Group Theory for Physicists, *A.W. Joshi,* New Age International.
12. Group Theory in Physics, *J. F. Cornwell*, Academic Press.
13. Group Theory in a Nutshell for Physicists, *A. Zee*, Princeton University Press.
14. Tensor Calculus, *B. Spain*, Radha Publishing House (Kolkata).

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Course title: Classical Mechanics
Course code: PHY-C-17
Nature of the course: Core
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: The course on Classical Mechanics aimed at developing in the students an understanding of variational principles in physics and their applications, Integrable and Nonintegrable systems, and various aspects of nonlinear dynamics.

Course Objectives: Objectives of the course is to

1. Acquaint the learners with the subject of classical mechanics in the context of the language and methods of modern nonlinear dynamics.
2. Enable the learners to make a smooth transition from classical mechanics to quantum mechanics and nonlinear dynamics.

Course Outcomes (COs): The students will able to

CO1: Explain the integrable and nonintegrable systems in classical mechanics.

- **LO1.1:** Understand the basic principles of Newtonian Dynamics.
- **LO1.2:** Apply the concept of symmetry to understand conservations laws in physics.
- **LO1.3:** Understand the concepts of Flows in phase space, solvable vs integrable, equilibria and linear stability theory, and bifurcations in Hamiltonian systems.

CO2: Apply Lagrangian and Hamiltonian Formulations of Classical Mechanics.

- **LO2.1:** Understand the difference between the Lagrangian and Hamiltonian approach to classical mechanics.
- **LO2.2:** Understand the transition from classical to quantum mechanics.

CO3: Develop the understanding of the dynamics of non-canonical systems.

- **LO3.1:** Understand the various aspects of non-linear dynamics.
- **LO3.2:** Apply the method of dynamical systems to outstanding problems in physics.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual		LO1.1 LO1.3 LO3.1 CO1	LO1.2 LO2.1 LO2.2 CO2	LO3.2		
Procedural					CO3	
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	S	M	M	S	M	M	M
CO2	S	S	M	S	M	M	S	M	M	M
CO3	S	S	M	S	M	M	S	M	M	M

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: Newtonian Dynamics

Review of Newtonian mechanics, Mechanics of a system of particles, Constraints of motion and their classification, Generalized coordinates, D' Alembert's principle, Lagrange's equations of motion, Hamilton's principle, Symmetries and conservation theorems, Cyclic coordinates. Flows in phase space, solvable vs integrable, equilibria and linear stability theory, bifurcations in Hamiltonian systems. **(L 8, H 8, M 8)**

Unit II: Motion in Central Force System

Motion in a central potential, Maps, winding numbers and orbital stability, Hidden symmetry in the Kepler problem, Small Oscillations, Solution of one-dimensional harmonic oscillator problem, Forced oscillations in one dimension, Damped harmonic motion in one dimension- general solution of the problem, Displacement as a function of time, Systems with many degrees of freedom, Eigenvalue equation and normal coordinates. Integrable and chaotic oscillations, return maps, area preserving maps, deterministic chaos. **(L 12, H 12, M 12)**

Unit III: Lagrangian and Hamiltonian Formalism

Lagrangian dynamics and transformations in configuration space, geometry of motion in configuration space, canonical moment and covariance of Lagrange's equation in configuration space. Hamiltonian dynamics and transformations in phase space, Generating functions, Poisson brackets, Integrable canonical flows, Hamilton-Jacobi equation, Action-angle variables.

(L 15, H 15, M 15)

Unit IV: Transformations and Rigid Body Dynamics

Linear transformations, rotations and rotating frames, similarity transformations, linear transformations and eigenvalue problem, dynamics in rotating reference frames.

Rigid Body Dynamics, Definition of Rigid body, Eulerian Angles, Euler's theorem, Angular momentum and kinetic energy, Moment of inertia tensor, Euler's equation of motion, Symmetrical top, Integrable and nonintegrable problems. **(L 15, H 15, M 15)**

Unit V: Non-canonical Systems Dynamics

Noncanonical flows, flows on spheres, local vs complete integrability, globally integrable non canonical flows, attractors, Damped driven Euler-Lagrange dynamics, Liapunov exponents, geometry and integrability. Damped driven Newtonian systems, period doubling, fractal and multifractal orbits in phase space, strange attractors, the two-frequency problem.

(L 10, H 10, M 10)

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Classical Mechanics, *J. L. McCauley*, Cambridge University Press.
2. Classical Mechanics, *H. Goldstein,* Addison Wesley.
3. Classical Mechanics, *N. C. Rana & P. S. Joag,* Tata McGraw Hill.
4. Classical Mechanics of Particles and Rigid Bodies, *K. C. Gupta,* Wiley Eastern Limited.

5. Introduction to Classical Mechanics, *R. G. Takwale & P. S. Puranic,* Tata McGraw Hill.

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Course title: Quantum Mechanics II
Course code: PHY-C-18
Nature of the course: Core
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This is a continuation of Quantum Mechanics-I course covering more advanced topics than those covered in Quantum Mechanics I. It covers the formalism of quantum mechanics, symmetry in quantum mechanics and approximation methods in quantum mechanics.

Course Objectives: The objectives of this course are to

1. Introduce the learners with the formalism of Quantum Mechanics.
2. Acquaint the learners with Dirac notation.
3. Enable the learners to solve simple quantum mechanical problems.
4. Introduce the learners with symmetry and conservation laws.
5. Introduce the learners with angular momentum algebra.
6. Acquaint the learners with approximation methods in quantum mechanics.

Course Outcomes (COs): At the completion of this course, a learner will be able to

CO1: Understand the key concepts in quantum mechanics and their importance in physics.

LO1.1: Explain the formalism, the role of symmetry and approximation methods in quantum mechanics.

LO1.2: Recognize the approximation method suitable for a quantum mechanical problem.

CO2: Apply the above quantum mechanical concepts.

LO2.1: Solve quantum mechanical problems based on the key concepts learnt.

LO2.2: Use approximation methods to solve real world physics problems like fine structure of hydrogen atom, Stark effect, Zeeman effect etc.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	**Remember**	**Understand**	**Apply**	**Analyze**	**Evaluate**	**Create**
Factual						
Conceptual		LO1.1 LO1.2 CO1	LO2.1 LO2.2 CO2			
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S			M	S		S
CO2	S	S	S	S			M	S		S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: Formalism
Overview of wave mechanics, Schrödinger equation, application to some important physical problems: particle in a box, simple harmonic oscillator, delta function potential, hydrogen atom, t Kets, Bras and Operators, Base Kets and Matrix Representations, Measurements, Observables and Uncertainty Relations, Change of basis, Generalized Uncertainty Principle. Time evolution and the Schrödinger equation, the Schrödinger versus the Heisenberg picture, time evolution of the simple harmonic oscillator. **(L 20, H 20, M 20)**

Unit II: Symmetry in Quantum Mechanics
Symmetries, Conservation laws and Degeneracy, Space and Time displacements, Rotation, Angular Momentum and Unitary groups, commutation relations, Eigenvalues and Eigenstates of Angular Momentum, Addition of Angular momentum, Stern Gerlach Experiment, Spin, Clebcsh Gordon Coefficients. **(L 8, M 8, M 8)**

Unit III: Time Independent Approximation Methods
Time independent perturbation theory and its application: Non degenerate case, Degenerate case, Stark effect, Fine structure and Zeeman Effect, Hyperfine splitting, Variational method and its application, Ground state of helium, Hydrogen molecule ion, WKB Approximation and its application. **(L 22, H 22, M 22)**

Unit IV: Time Dependent Approximation Methods
Time dependent potentials: the Interaction picture, Time dependent perturbation theory, two level systems, Emission and absorption of radiation, Spontaneous emission, Applications to Interactions with Classical Radiation field, Adiabatic approximation, Sudden approximation. **(L 10, M 10)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Modern Quantum Mechanics, *J. J. Sakurai,* Addison Wesley.
2. Quantum Mechanics, *L. I. Schiff*, McGraw Hill.
3. Quantum Mechanics, *Bransden and Joachain*, Pearson Education.
4. Quantum Mechanics, *Powell and Craseman*, Narosa Publishing House.
5. Quantum Mechanics, *R. Shankar,* Kluwer Academic.
6. Quantum Mechanics, *D. J. Griffiths*, Pearson Education.
7. Quantum Mechanics, *Mathews and Venkatesan*, McGraw Hill.
8. Quantum Mechanics, *R. L. Liboff,* Pearson Education.

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SEMESTER VIII

Course title: Condensed Matter Physics II
Course code: PHY-C-19
Nature of the course: Core
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: The course deals primarily with electronic properties of solids. Starting from the crystallographic defects, the course emphasizes other basic electronic behavior of solids, viz. diffraction techniques, Electronic Energy Band theory, Magnetic Properties, Ferroelectric properties and Superconductivity.

Course Objectives: The primary objective of the course is to equip a student with basic concepts of Condensed Matter Physics so that the knowledge can be applied for further development of the subject, enable a student to work in both theoretical and experimental aspects of Condensed Matter Physics and help the students in thorough learning of the concepts associated with the course through numerical problems.

Course Outcomes (COs): After completion of the course, the students will able to

CO1: Understand the electronic phenomena, importance of diffraction techniques, electrical and magnetic behavior of solids and superconductivity.

- **LO 1.1:** Summarize different types of defects in crystals.
- **LO 1.2:** Compare X-ray diffraction, Electron diffraction and Neutron Diffraction techniques.
- **LO 1.3:** Illustrate the effect of crystal periodic potential on electronic behavior.

CO2: Apply basic quantum mechanics to explain the formation of electronic energy bands, magnetic behavior and basic reason of superconductivity.

- **LO 2.1:** Identify the primary reason of energy band formation.
- **LO 2.2:** Make use of the concepts of paramagnetism for gases and conduction electrons in explaining the paramagnetic behavior in appropriate situations.

CO3: Analyze the difference among various defects with their importance, application domain of various diffraction techniques, importance of potential on crystal behavior, various magnetic theories, electric behavior, London and BCS approach of superconductivity.

- **LO 3.1:** Inspect the differences and importance among diverge defects in crystals.
- **LO 3.2:** Distinguish among different diffraction techniques.
- **LO 3.3:** Examine the importance of potential on crystal behavior.
- **LO 3.4:** Classify materials according to their electrical behavior.
- **LO 3.5:** Analyze the London and BCS approach in the explanation of superconductivity.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual		LO 1.1	LO 2.1	LO 3.1		
Conceptual		LO 1.2 LO 1.3 CO1	LO 2.2 CO2	LO 3.2 LO 3.3 LO 3.4 LO 3.5		
Procedural					CO3	
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	S	M	M	S			M
CO2	S	S	M	S	M	M	S			M
CO3	S	S	M	S	S	M	S			S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit 1: Defects and Imperfections in Crystals
Introductory concepts, Origin of Defects, Point Defect, Line Defect, Volume Defect, Activation Energy for Defect Formation, Schottky, Frenkel defects, Color centers, Dislocations, Diffusion, Fick's law. **(L 10, H 10, M 10)**

Unit 2: XRD, Electron Diffraction, Neutron Diffraction/ Crystal Structure Determination
Crystal Structure Determination, Interaction of X-Rays with matter, absorption of X-Rays, Elastic scattering from a perfect lattice, X-Ray diffraction, Laue, Powder and Rotating Crystal method, Scattering Factor, Structure Factor, Electron Diffraction, Neutron Diffraction. **(L 12, H 12, M 12)**

Unit 3: Electron Energy Band Theory and Related Ideas
Electrons in a periodic potential, Kronig Penny model. E-k diagram, Brillouin Zone, Effective Mass, Conductor, Semiconductor and insulator.

Semiconductors: Conductivity, Mobility, Hall Effect. Hall coefficient, Measurement of conductivity, Four probe method. **(L 10, H 10, M 10)**

Unit 4: Magnetic Properties of Materials
Review of origin of magnetic moments, paramagnetism due to free ions (Quantum Theory) and conduction electrons (Pauli paramagnetism), Molecular field theory of Ferromagnetism, Domains, Hysteresis loop, Anti ferromagnetism, Ferrimagnetism, Magnetic Anisotropy. **(L 10, H 10, M 10)**
Unit 5: Ferroelectric Properties of Materials
Structural phase transition, Classification of crystals, Piezoelectric effect, Pyroelectric effect,

Ferroelectric effect, Electrostrictive effect, Curie-Weiss Law, Ferroelectric domains, PE hysteresis loop. **(L 6, H 6, M 6)**

Unit 6: Superconductivity

Introductory concepts, Critical Temperature. Critical magnetic field., Meissner Effect, Type-I & Type-II superconductors, London equations, Penetration Depth, Thermodynamics of superconducting transition, Isotope effect, introduction to BCS theory, Cooper pair, Basic idea on High temperature superconductivity. **(L 12, H 12, M 12)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Introduction to Solid State Physics, *C. Kittel,* John Wiley & Sons.
2. Solid State Physics, *A. J. Dekker,* Macmillan India Ltd.
3. Elementary Solid State Physics, *M. A. Omar,* Pearson Education.
4. Crystallography Applied to Solid State Physics, *A. R. Verma and O. N. Srivastava,* New Age International.
5. Solid State Physics, *N. W. Ashcroft and N. D. Mermin,* Brooks/cole.

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Course title: Electronics II
Course code: PHY-C-20
Nature of the course: Core
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: The course on Electronics-II begins with a review of Bipolar junction Transistor and then discusses about the Field Effect Transistors. It describes the Differential amplifiers, and application of OPAMPS in different fields. The course also covers the concept of microprocessor and microcontrollers. This course is designed for the students to learn and apply electronics in different fields of electronic and communication technologies.

Course Objectives: Objectives of this course is to

1. Disseminate working knowledge of electronic principle using semiconductor devices.
2. Allow students to learn the fundamentals of both analog and digital electronic devices.
3. Allow students to apply their knowledge for designing small electronic systems.
4. Introduce students to advanced digital systems like microprocessor and microcontroller.
5. Imbibe the spirit of application-oriented learning.

Course Outcomes (COs): The students will able to

CO1: Explain the operation and application of Transistor, OPAMP and microprocessor.

LO1.1: Understand the basic principle of FET, OPAMP, Microprocessors.

LO1.2: Discuss the use of FET and OPAMP in different circuits.

CO2: Apply electronics to design circuit for different applications.

LO2.1: Understand circuit analysis techniques.

LO2.2: Build electronic circuits.

LO2.3 Develop circuit for specific applications.

CO3: Analyze electronic circuits to understand its functioning.

LO3.1: Explain the working of electronic components.

LO3.2: Apply OPAMP to design various circuits.

LO3.3: Apply microprocessor to perform various operation.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual		LO1.2				
Conceptual		LO1.1 LO2.1 LO3.1 CO1	LO2.2 LO3.2 CO2	LO3.3 CO3		
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	M	M	M	S	M	M	S
CO2	S	S	M	S	M	M	M	M	M	M
CO3	M	S	M	S	M	M	S	M	M	S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit-I: Transistor Fundamentals and Special Purpose Electronic Devices

Review of BJT amplifier, Emitter follower, impedance matching application, ac models: T and π, analysis, IC circuit current mirror, open collector, Bootstrapped and Darlington amplifier.

Field effect transistors: JFET, MESFET and MOSFET, structure, working, derivation of the equations of IV characteristics under different conditions, JFET as amplifiers and switch- MOSFET, E- MOSFET, Digital switching, active load, introduction to CMOS and FINFET technology.

(L 20, H 20, M 20)

Unit II: Integrated Circuits: Operational Amplifier

Differential amplifier: circuit configuration, dual input, balanced output differential amplifier, DC-AC analysis, inverting and non-inverting inputs, Review of applications of Operational amplifiers.

Linear digital ICs, Comparator, A/D, D/A, Timer IC, VCO, PLL, Instrumentation amplifier, Schmitt Trigger Circuits, Active filters (Filter approximation). **(L 20, H 20, M 20)**

Unit III: Introduction to Microprocessor and Microcontroller

Central Processing Unit, Arithmetic & Logic Unit, Timing and Control Unit, Registers, types of memory, RAM and ROM, Cache memory.

Types of microprocessors, architecture, pin diagram, different bus, programming model using intel 8085, register set, memory organization, opcode and operands, instruction cycle, Timing diagram. Instruction set of 8085, instruction classification, addressing modes, instruction format, data transfer instructions, arithmetic instructions. Assembly language programming examples (addition, subtraction, multiplication etc.), stack operations, subroutines.

Types of microcontrollers, Introduction to 8051 microcontroller, architecture, input/output pins, ports instruction set, addressing modes. **(L 20, H 20, M 20)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Electronic Principles, *A. P. Malvino and D. J. Bates*, Tata McGraw Hill.
2. Electronic Devices and Circuit Theory, *R. L. Boylestad and L Nashelsky*, Pearson India.
3. Op Amps and Linear Integrated Circuits, *R. K. Gaekwad*, Prentice Hall of India.
4. Modern Digital Electronics, *R. P. Jain*, Tata Mcgraw Hill.
5. Integrated Electronics: Analog and Digital Circuit Systems, *J. Millman and C. Halkias*, McGraw Hill.
6. Digital Principles and Applications, *D. P. Leach and A. P. Malvino*, Tata McGraw Hill.
7. Semiconductor Physics and Devices, *D.A. Neamen*, Tata McGraw Hill.
8. The Art of Electronics, *P. Horowitz and W. Hill,* Cambridge University Press.
9. Microprocessor Architecture Programming & applications with 8085, *R.Gaonkar*, Prentice Hall.
10. The 8051 Microcontroller and Embedded System, *Mazidi, Mazidi and McKinlay,* Pearson Education.

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SEMESTER IX

Course title: Electrodynamics
Course code: PHY-C-21
Nature of the course: Core
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This course covers classical electrodynamics utilizing physical and relevant mathematical principles to provide the students to learn in-depth analysis of the behavior of electricity and magnetism in matter. Key topics include: propagation of electromagnetic waves in different media, electromagnetic radiation and its interaction with matter, and relativistic electrodynamics.

Course Objectives: The aim of this course is to

1. Acquaint a learner with the fundamental principles of classical electrodynamics.
2. Introduce a learner with the covariant formulation of electrodynamics.

Course Outcomes (COs): At the completion of this course, a learner will be able to

CO1: Understand the basic concepts in classical electrodynamics.

LO1.1: Define key terms and operations in classical electrodynamics.
LO1.2: Explain the laws governing classical electrodynamics.
LO1.3: Describe the interaction of electromagnetic radiation with matter.

CO2: Apply the basic concepts in electrodynamics to solve problems.

LO2.1: Solve advanced level physics problems based on the key concepts in classical electrodynamics.
LO2.2: Use relativistic formulation of electrodynamics to solve problems in other branches of physics.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual	LO1.1	LO1.2 LO1.3 CO1	LO2.1 LO2.2 CO2			
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S			M	M		S	S

CO2	S	S	S	S			M	M		S	S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: Propagation of Electromagnetic Waves
Introductory ideas, Propagation of electromagnetic waves in different media, Dispersion, Frequency dependence of σ, μ and ε, dispersion in non-conductors, anomalous dispersion, free electrons in conductors and plasma, Wave Guides, TE waves in rectangular waveguide. Coaxial transmission lines. **(L 13, H 13, M 13)**

Unit II: Electromagnetic Radiation
Retarded potentials, electric dipole radiation, radiation from an arbitrary distribution of charges and current, Lienard-Wiechert potentials, fields due to uniformly moving charge, and accelerated charge, Linear and circular acceleration, angular distribution of radiated power, Bremsstrahlung and Synchrotron radiation, Radiation reaction, Abraham-Lorentz formula. **(L 22, H 22, M 22)**

Unit III: Covariant Formalism
Structure of space-time, Four vectors and Lorentz transformation, Proper time and velocity, Relativistic energy and momentum.

Magnetism as relativistic phenomena, Potential formulation of relativistic electrodynamics Electromagnetic field tensor, Dual tensor, Covariant formulation of electrodynamics.
(L 25, H 25, M 25)

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Introduction to Classical Electrodynamics, *D. J. Griffiths,* Prentice Hall of India.
2. Classical Electrodynamics, *J. D. Jackson*, John Wiley.
3. Electromagnetic waves and Radiating systems, *Edward C Jordan and Keith G. Balmain,* PHI Pvt. Ltd.
4. Electromagnetic Wave and radiating systems, *E. C. Jordan and K. G. Balmain,* Prentice Hall of India.

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Course title: Nuclear and Particle Physics
Course code: PHY-C-22
Nature of the course: Core
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: The course on nuclear physics begins with a review of basic nuclear properties such as nuclear size, mass, density, units, stability etc. It proceeds with the characteristics of nuclear force along with the introduction of the concept of isospin and also the definition of Pauli's exclusion principle using isospin. The description of the actual nature of nuclear force is provided on the basis of the deuteron problem as well as the general nucleon-nucleon scattering problem. Discussion on nuclear models such as liquid drop model and nuclear shell model are also included. Types of nuclear mechanisms with special emphasis on beta decay are also important components of this course. The nuclear physics course contains a unit on elementary particles, their properties, classification, conservation laws etc. In a separate unit, working principles of the basic nuclear detectors are explained. This course is designed for the students to understand and analyze the ideas of nuclear and particle physics and apply them for dealing with related problems.

Course Objectives:

1. To impart basic knowledge of the nuclear force and its properties
2. To acquaint the learners with the nature of interaction of nucleons inside deuteron nucleus as well as in general nucleon-nucleon scattering
3. To familiarize the learners about different theoretical models regarding nucleus as well as to apply those in determining nuclear properties
4. To transmit knowledge about nuclear reactions and their various mechanisms along with a wide understanding of the decay process
5. To make understand the basic forces in nature and classification of particles and study in detail conservations laws and quark models in detail
6. To introduce the basic working principles of various nuclear detectors and apply them in practical working situations.

Course Outcomes (COs): After successful completion of the course, the student will be able to

CO1: Explain characteristics of nuclear force.
- **LO1.1:** Define nuclear properties.
- **LO1.2:** Classify different characteristics of nuclear force.

CO2: Categorize nuclear properties.
- **LO2.1:** Analyze the spin dependent nature of nuclear force.
- **LO2.2:** Utilize the evidences in support of non-central nature of nuclear force.
- **LO2.3:** Apply nuclear models in determination of various nuclear properties.

CO3: Distinguish nuclear reaction mechanisms.
- **LO3.1:** Define different types of nuclear reactions.
- **LO3.2:** Interpret the theory of beta decay process.
- **LO3.3:** Solve problems related to beta decay.

CO4: Classify elementary particles and nuclear detectors.
- **LO4.1:** Label elementary particles, their properties, nature of interaction.
- **LO4.2:** Compare the working principles of nuclear detectors.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	**Remember**	**Understand**	**Apply**	**Analyze**	**Evaluate**	**Create**
Factual	LO1.1 LO3.1 LO4.1	LO1.2 LO4.2 CO1 CO4	LO2.2	LO2.1		

Conceptual			LO2.3 LO3.3	CO2		
Procedural		LO3.2		CO3		
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	M	S	S	S	M	S	S	S	M	S
CO2	S	S	S	S	S	S	S	M	S	M	S
CO3	S	S	S	S	S	S	S	S	S	S	S
CO4	S	M	S	S	S	S	S	M	S	S	S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: Basics of Nuclear Forces
Review of nuclear properties, nuclear forces: properties of nuclear forces, isotopic spin formalism, generalized Pauli's exclusion principle, meson theory of nuclear forces.

(L 8, H 8, M 8)

Unit II: Nucleon Interactions and Nuclear Models
Two body problem: General form of nucleon-nucleon forces, the deuteron problem (ground states and excited states), central and tensor forces, nucleon-nucleon scattering at low energies.
Nuclear models: Review of liquid drop model and its applications, shell model, L-S coupling, magnetic moment and Schmidt lines. **(L 15, H 15, M 15)**

Unit III: Nuclear Reactions
Reaction channels, nuclear reaction mechanisms, scattering cross-section, compound nucleus, partial wave analysis of nuclear reaction, resonance, Breit-Wigner single level formula, B-W formula incorporating spin, neutrino hypothesis and general features of β-ray spectrum, Fermi's theory of β-decay, Curie plot, selection rules. **(L 15, H 15, M 15)**

Unit IV: Elementary Particle Physics

Fundamental forces, elementary particles and their classification, of the elementary particles, quantum numbers, behaviour under charge conjugation, time reversal and parity operation, isotopic multiplet and Gellmann-Nishijima scheme, SU (3) classification and quark model, standard model characteristics. **(L 10, H 10, M 10)**

Unit V: Radiation Detectors
Detection of radiations: gas filled counters, scintillation detectors, semiconductor detectors.

(L 12, H 12, M 12)

(Total Lectures 60, Total Contact Hours 120, Total Marks 60)

Recommended Readings:

1. Nuclear Structure (Vol. 1), *A. Bohr and B.R Motteison*, World Scientific.
2. Introductory Nuclear Physics, *Kenneth S. Krane*, Wiley India Pvt. Ltd.
3. Introduction to High Energy Physics, *P. H. Perkins*, Addison Wesley London.
4. Nuclear Physics Vol. 1 & 2, *Shirokov Yudin*, Mir Publishers Moscow.
5. Introduction Elementary Particles, *D. J. Griffiths*, Harper and Row, New York.
6. Introduction to Nuclear Physics, *H. A. Enge*, Addison-Wesley.
7. Nucleon-Nucleon Interaction, *G. E. Brown and A. D. Jackson,* North-Holland, Amsterdam.
8. Introductory Nuclear Physics, *Y. R. Wagmare*, Oxford University Press.
9. Elementary Particles, *J. N. Longo*, McGraw Hill.
10. Atomic Nucleus, *R. D. Evans*, McGraw Hill.
11. Nuclear Physics, *I. Kaplan*, Narosa.
12. Concepts of Nuclear Physics, *B.L. Cohen*, Tata McGraw Hill.
13. Nuclear Physics: Theory and Experiments, R.*R. Roy and B.P. Nigam*, New Age International.
14. Radiation Detection and Measurement, *Glenn F. Knoll,* John Wiley & Sons Inc.

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Course title: Atomic and Molecular Physics
Course code: PHY-C-23
Nature of the course: Core
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: The course on atomic and molecular physics begins with the quantum mechanical treatment of hydrogen atoms with its fine and hyperfine structure of spectral lines. It describes the details of atomic and molecular spectra; the interaction of atoms and molecules with electric and magnetic fields; and basics of lasers. This course is designed for the students to learn and apply atomic and molecular spectroscopy techniques in various disciplines like Physics, Chemistry, Atmospheric Science, Life Science, Astronomy, and Laser Science.

Course Objectives: It is important to recognize the key laws of physics explaining the behavior of atoms, molecules and laser phenomena which play a significant role in the modern technological world. The spectroscopic detection and characterization of atomic and molecular species have become an important field not only for academics but also for environmental scientists, defence personnel, medical professionals and space scientists. As such, this course is designed to acquaint the students with the principles of spectroscopic techniques where they understand the relevant theories of atomic spectra, molecular spectra and laser phenomena.

Course Outcomes (COs): The students will able to
CO1: Explain the operation and application of laser.
    LO1.1: Understand the basic principle of lasing action.
    LO1.2: Classify different types of laser.

LO1.3: Discuss the use of laser for trapping atoms and molecules.

CO2: Apply quantum mechanics to explain atomic and molecular spectra.

LO2.1: Understand fine structure of the atomic energy levels.

LO2.2: Explain atomic transitions using the LS and JJ coupling schemes.

LO2.3: Interpret between the vibrational and rotational motion of a molecule quantum mechanically.

CO3: Assess material properties through various spectroscopy.

LO3.1: Explain the rotational and vibrational spectra of molecules.

LO3.2: Apply Raman, photoluminescence, and FTIR spectroscopy techniques in various disciplines to identify elements, compounds and their properties.

LO3.3: Examine atomic and molecular spectral lines and their shape functions.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	**Remember**	**Understand**	**Apply**	**Analyze**	**Evaluate**	**Create**
Factual	LO1.1	LO1.2 LO2.1				
Conceptual		LO1.3 LO2.2 LO3.1 CO1	LO2.3 LO3.2 CO2	LO3.3		
Procedural					CO3	
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	S	S	M	M	M	M	S	S	M	S
CO2	S	S	M	S	M	M	M	M	M	M
CO3	M	S	M	S	M	M	S	S	M	S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: Atomic Physics

Fine structure of hydrogen atom, relativistic correction, Lamb shift, Spectra of alkali atoms, spin-orbit interaction and fine structure in alkali atoms, level scheme of two electron atoms-equivalent and nonequivalent electrons, ground and excited states of two electron atoms, interaction energy in L-S and j-j coupling for two electrons, Zeeman effect, Paschen-Back effect, Stark effect, hyperfine structure of hydrogen and alkali atoms, spectra of multi-electron atoms, X-ray spectra, width and shape of spectral lines. **(L 23, H 23, M 23)**

Unit II: Molecular Physics

Regions of the spectrum, types of molecules, Rotational Spectra for rigid and non-rigid rotators, isotopic effect in rotational spectra, intensity of spectral lines, information derived from rotational spectra, microwave spectrometer, Vibrational spectra for anharmonic oscillator, vibration-rotation spectra, Infra-red spectrometer, Electronic spectra of molecules-Born- Oppenheimer approximation, vibrational analysis of electronic band spectra, fine structure of electronic band spectra, Fortrat Diagram, Raman spectra, Raman spectrometer, Photoelectron spectroscopy, Spin resonance spectroscopy- NMR, ESR, Mössbauer spectroscopy, Fourier Transform Spectroscopy.

(L 25, H 25, M 25)

Unit III: Lasers

Fundamentals of Lasers-properties, basic elements, threshold condition, rate equations: two, three and four levels. Population inversion, Laser resonator and modes, Ammonia Masters, types of laser: solid state laser, gas laser, semiconductor laser, applications of laser spectroscopy, Laser Cooling.

(L 12, H 12, M 12)

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Physics of Atoms and Molecules, *B. H. Bransden and C. J. Joachain*, Pearson Education.
2. Atomic Spectra, *H. E. White*, McGraw Hill.
3. Atomic Physics, *Max Born*, Dover Publications.
4. Molecular spectroscopy, *Banwell and McCash*, Tata McGraw Hill.
5. Molecular Structure and Spectroscopy, *G. Aruldhas*, Prentice Hall of India.
6. Molecular Spectra and Molecular Structure, *G. Herzberg*, McGraw Hill.
7. Lasers and Nonlinear Optics, *B. B. Laud*, New Age International.
8. Laser Spectroscopy-Basic Concepts and Instrumentation, *Wolfgang Demtröder*, Springer.
9. Modern Spectroscopy, *J. M. Hollas*, John wiley & Sons.
10. Elements of Laser and Non-Linear Optics, *G. D. Baruah*, Meerut Prakashan.

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SEMESTER X

Course title: Statistical Mechanics II
Course code: PHY-C-24
Nature of the course: Core
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This is an advanced-level course in Statistical Mechanics for students who have completed four years of this programme. It starts from the introduction and formulation of quantum statistical mechanics with a revision of the early-stage course (Statistical Mechanics I) of this important subject including some advanced ideas of quantum particles' systems. The remaining parts of it are designed for students to learn about the ideal as well as interacting Bose and Fermi gas systems, and higher-order phase transition processes in the complex physical systems. The students will also be able to learn the applications of all these ideas to understand some of the interesting physical processes occurring in nature under certain conditions.

Course Objectives: Statistical Mechanics is one of the most important core branches of physics which is required to understand the properties of matter in bulk based on the dynamical behaviors of its microscopic constituents. Keeping this point in mind the objectives of this course are set as

1. To introduce the advanced concepts of Statistical Mechanics so that students will be equipped with a sufficient knowledge of the subject.
2. To develop the critical thinking ability of students to understand diverse physical phenomena.
3. To develop the interest and ability among students to solve challenging physical problems by the application of techniques of Statistical Mechanics in the future.

Course Outcomes (COs): The students will able to

CO1: Understand quantum statistical mechanics and its applications.
- **LO1.1:** Explain the historical perspective and basic principles of quantum statistical mechanics.
- **LO1.2:** Classify different partition functions and different quantum statistics.
- **LO1.3:** Relate the use of quantum statistical mechanics in various situations.

CO2: Apply quantum statistical mechanics to explain various physical problems.
- **LO2.1:** Understand ideal and interacting quantum particle systems.
- **LO2.2:** Explain different physical phenomena occurring in bulk systems.
- **LO2.3:** Interpret higher-order phase transition processes in dynamical systems of particles, such as superfluidity.
- **LO2.4:** Relate fluctuations of parameters of a system with the statistical nature of the constituents of the system.

CO3: Evaluate material properties in different states and phases through theories of quantum statistical mechanics.
- **LO3.1:** Apply theories of quantum statistical mechanics to a system near absolute

zero.

LO3.2: Examine the natures of imperfect Bose and Fermi gasses through the second quantization process.

LO3.3: Analyze any complex physical problem related to any state or phase of matter.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual	LO1.1	LO1.2 LO2.1				
Conceptual		LO1.3 LO2.2 CO1	LO2.3 LO3.1 LO3.2 CO2	LO2.4 LO3.3		
Procedural					CO3	
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	S			S	M		M
CO2	S	S	M	S			S	M		M
CO3	S	S	M	S			S	S		M

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: Introduction and Formulation of Quantum Statistics
Historical introduction of statistical mechanics, ergodic hypothesis, ensembles, partition function, grand partition function, postulates of quantum statistical mechanics, density matrix, pure and mixed states, density matrix and partition function of a system of free particles, classical limit of the partition function, BE and FD statistics. **(L 10, H 10, M 10)**

Unit II: Ideal Bose and Fermi Systems
Ideal Bose gasses, Bose-Einstein condensation, thermodynamic behavior of an ideal Fermi gas, Pauli paramagnetism, Landau diamagnetism. **(L 15, H 15, M 15)**

Unit III: Statistical Mechanics of Interacting Systems
Clusters, classical cluster expansion, formalism of second quantization, creation and annihilation operators and their properties for bosons and fermions, Hamiltonian in terms of second quantized operators, imperfect Bose and Fermi gasses. **(L 18, H 18, M 18)**

Unit IV: Phase Transitions
Dynamical model of phase transition, the Ising model (one dimension), liquid helium, He-4and He-3, the lambda-transition, Tisza's two-fluid model, the theories of Landau and Feynman, equilibrium properties near absolute zero, superfluidity. **(L 10, H 10, M 10)**

Unit V: Fluctuations
Mean square deviation, fluctuation in ensembles, thermodynamic fluctuations, spatial correlation in a fluid, Einstein-Smoluchowski theory of Brownian motion, approach to equilibrium: the Fokker-Planck equation. **(L 7, H 7, M 7)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Statistical Mechanics, *R. K. Patharia*, Butterwork Heinemann.
2. Statistical Mechanics, *K. Huang*, John Wiley and Sons.
3. Statistical Mechanics, *K. M. Khanna*, Today and Tomorrow, New Delhi.
4. Statistical Mechanics, *B. K. Agarwal, M. Eisner*, New Age International Publishers.
5. Fundamentals of Statistical Mechanics, *B. B. Laud*, New Age International Publishers.
6. A Primer of Statistical Mechanics, *R. B. Singh*, New Age International Publishers.

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Course title: Numerical Methods and Programming
Course code: PHY-C-25
Nature of the course: Core
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: The course on Numerical Methods and Programming begins with the introduction to numerical methods and its applications in dealing with various mathematical or physical problems. A wide variety of numerical methods are tested to solve problems such as solution of linear and non-linear equations, interpolation, polynomials, differentiation, integration, solution of differential equations etc. The idea of probability and related problems are also covered. In a separate unit, the useful programming commands in LINUX are included along with a detailed discussion on FORTRAN 77 language.

Course Objectives:

1. To acquaint the learners with FORTRAN 77 programming language and LINUX operating system.
2. To familiarize the problem solving in FORTRAN 77.
3. To introduce numerical methods to solve problems.

Course Outcomes (COs): After successful completion of the course, the student will be able to

CO1: Distinguish the numerical method.

LO1.1: Define numerical methods.

LO1.2: Compare the efficiencies of different numerical methods for each mathematical problem.

LO1.3: Apply different numerical methods for solving mathematical problems.

CO2: Make use of FORTRAN 77 and LINUX operating system.

LO2.1: List the LINUX commands.

LO2.2: Outline the basic syntax of FORTRAN programme.

LO2.3: Apply FORTRAN 77 for writing programmes in LINUX.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual	LO1.1 LO2.1	LO1.2 LO2.2				
Conceptual			LO1.3 LO2.3 CO1 CO2			
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S	S	S	S	S	S	S
CO2	S	S	S	S	S	S	S	S	S	S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: **Basic Numerical Techniques and Curve Fitting**

Determination of root of functions, solution of nonlinear equations: Bisection method, method of False Position, Newton-Raphson method.

Curve fitting: Interpolation, Lagrange Interpolation, Newton Interpolation, Interpolation with Equidistant Points. **(L 10, P 5, M 15)**

Unit II: Numerical Differentiation and Solutions

Numerical Differentiation: Finite difference methods, Richardson Extrapolation, Interpolation based methods. Numerical Integration by trapezoidal and Simpson's rule. Solution of Linear Algebraic Equations: Iterative Methods, Inverse of a Square. Matrix Solution of first order ordinary differential equation: Runge-Kutta method. **(L 12, P 8, M 20)**

Unit III: Probability Theory

Elementary probability theory, Binomial, Poisson and Normal distributions. **(L 10, M 10)**

Unit IV: **FORTRAN 77**

LINUX commands, FORTRAN 77 programming, integer and floating-point arithmetic, expressions, built-in functions, executable and non-executable statements, assignment, control and input, output elements, subroutines and functions, operation with files, Programming examples of numerical methods. **(L 10, P 5, M 15)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Numerical Recipes in C/Fortran, *William H. Press et al.*, Cambridge University Press.
2. Computer Programming in Fortran 77, *V. Rajaraman*, Prentice Hall of India.
3. Fortran 77 and Numerical Methods, *C. Xavier*, New Age International.
4. Numerical Methods, *E. Balaguruswamy*, McGraw Hill Education.
5. How to Solve it by Computer, *H. Drowmey*, Prentice Hall of India.

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DETAILED SYLLABUS OF DISCIPLINE SPECIFIC ELECTIVE COURSES

SEMESTER VIII

Group I (in lieu of Dissertation)
(Any one from this group to be chosen)

Course title: Nuclear and Particle Physics
Course code: PHY-DSE-IA
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In sem)

Course Description: The course on nuclear physics begins with a review of basic nuclear properties such as nuclear size, mass, density, units, stability etc. It proceeds with the characteristics of nuclear force along with the introduction of the concept of isospin and also the definition of Pauli's exclusion principle using isospin. The description of the actual nature of nuclear force is provided on the basis of the deuteron problem as well as the general nucleon-nucleon scattering problem. Discussion on nuclear models such as liquid drop model and nuclear shell model are also included. Types of nuclear mechanisms with special emphasis on beta decay are also important components of this course. The nuclear physics course contains a unit on elementary particles, their properties, classification, conservation laws etc. In a separate unit, working principles of the basic nuclear detectors are explained. This course is designed for the students to understand and analyze the ideas of nuclear and particle physics and apply them for dealing with related problems.

Course Objectives:
1. To impart basic knowledge of the nuclear force and its properties
2. To acquaint the learners with the nature of interaction of nucleons inside deuteron nucleus as well as in general nucleon-nucleon scattering
3. To familiarize the learners about different theoretical models regarding nucleus as well as to apply those in determining nuclear properties
4. To transmit knowledge about nuclear reactions and their various mechanisms along with an wide understanding of the decay process
5. To make understand the basic forces in nature and classification of particles and study in detail conservations laws and quark models in detail
6. To introduce the basic working principles of various nuclear detectors and apply them in practical working situations.

Prerequisites: Units and dimensions of physical quantities, Quantum Mechanics, Differential Equations.

Course Outcomes (COs): After successful completion of the course, the student will be able to
CO1: Explain characteristics of nuclear force.
  LO1.1: Define nuclear properties.
  LO1.2: Classify different characteristics of nuclear force.

CO2: Categorize nuclear properties.

LO2.1: Analyze the spin dependent nature of nuclear force.

LO2.2: Utilize the evidences in support of non-central nature of nuclear force.

LO2.3: Apply nuclear models in determination of various nuclear properties.

CO3: Distinguish nuclear reaction mechanisms.

LO3.1: Define different types of nuclear reactions.

LO3.2: Interpret the theory of beta decay process.

LO3.3: Solve problems related to beta decay.

CO4: Classify elementary particles and nuclear detectors.

LO4.1: Label elementary particles, their properties, nature of interaction.

LO4.2: Compare the working principles of nuclear detectors.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual	LO1.1 LO3.1 LO4.1	LO1.2 LO4.2 CO1 CO4	LO2.2	LO2.1		
Conceptual		LO3.2	LO2.3 LO3.3	CO2 CO3		
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	M	S	S	S	M	S	S	S	M
CO2	S	S	S	S	S	S	S	M	S	M
CO3	S	S	S	S	S	S	S	S	S	S
CO4	S	M	S	S	S	S	S	M	S	S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: General Properties of Nuclei

Constituents of nucleus and their Intrinsic properties, quantitative facts about mass, radii, charge density (matter density), binding energy, average binding energy and its variation with mass number, main features of binding energy versus mass number curve, N/A plot, angular momentum, parity, magnetic moment, electric moments, nuclear excited states.

(L10, H10, M10)

Unit II: Nuclear Models

Liquid drop model approach, 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. **(L 10, H 10, M 10)**

Unit III: Radioactivity

(a) Alpha decay: basics of α-decay processes, theory of α-emission, Gamow factor, Geiger Nuttall law, α-decay spectroscopy. (b) β-decay: energy kinematics for β-decay, positron emission, electron capture, neutrino hypothesis. (c) Gamma decay: Gamma rays emission & kinematics, internal conversion. **(L 10, H 10, M 10)**

Unit IV: Nuclear Reactions

Types of Reactions, Conservation Laws, kinematics of reactions, Q-value, reaction rate, reaction cross section, Concept of compound and direct Reaction, resonance reaction, Coulomb scattering (Rutherford scattering). **(L 8, H 8, M 8)**

Unit V: Detector for Nuclear Radiations

Gas detectors: estimation of electric field, mobility of particle, for ionization chamber and GM Counter. Basic principle of Scintillation Detectors and construction of photo-multiplier tube (PMT). Semiconductor Detectors (Si and Ge) for charge particle and photon detection (concept of charge carrier and mobility), neutron detector. **(L 6, H 6, M 6)**

Unit VI: Particle Accelerator

Accelerator facility available in India: Van-de Graaff generator (Tandem accelerator), Linear accelerator, Cyclotron, Synchrotrons. **(L 6, H 6, M 6)**

Unit VII: Particle Physics

Particle interactions; basic features, types of particles and its families. Symmetries and Conservation Laws: energy and momentum, angular momentum, parity, baryon number, Lepton number, Isospin, Strangeness and charm, concept of quark model, color quantum number and gluons. **(L 10, H 10, M 10)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Introductory nuclear Physics, *K. S. Krane*, Wiley India.
2. Concepts of nuclear Physics, *B. L. Cohen*, Tata McGraw Hill.
3. Introduction to the Physics of nuclei & particles, *R. A. Dunlap*, Thomson Asia.
4. Introduction to High Energy Physics, *D. H. Perkins*, Cambridge University Press.
5. Introduction to Elementary Particles, *D. J. Griffith*, John Wiley & Sons.
6. Quarks and Leptons, *F. Halzen and A.D. Martin*, Wiley India, New Delhi.
7. Basic ideas and concepts in Nuclear Physics - An Introductory Approach, *K. Heyde,* Institute of Physics Publishing.

8. Radiation detection and measurement, *G. F. Knoll,* John Wiley & Sons.
9. Physics and Engineering of Radiation Detection, *S. N. Ahmed*, Elsevier.
10. Theoretical Nuclear Physics, *J. M. Blatt & V. F. Weisskopf*, Dover Publication.

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Course Title: Plasma Physics
Course code: PHY-DSE-IB
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: The course on plasma physics includes the laws of electrostatics, magnetostatics, electrodynamics, electromagnetic waves and fluid dynamics. This course describes the dynamics of charge and neutral particles under the influence of static; non-static; uniform; and non-uniform electric and magnetic fields. This course is designed for the students to learn and apply relevant theories of physics to understand and explain the behavior of natural and artificial plasma; to diagnose and control laboratory plasma.

Prerequisites: Electrostatics, Magnetostatics, Electrodynamics, Electromagnetic waves, Differential equations, Linearization of differential equations**.**

Course Objectives: With the recent increase in interest towards controlled fusion and widespread use of plasma in optoelectronic devices, space research, and relativistic astrophysics demands for the study of plasma physics. To fulfill this demand, the course on plasma physics is designed for the students to develop theoretical knowledge about plasma.

Course Outcomes (COs): The students will able to
CO1: Understand the physical nature of the plasma.
- **LO1.1:** Define plasma and fundamental parameters.
- **LO1.2:** Classify different types of plasma.

CO2: Analyze the motion of charged particles under the influence of electric and magnetic field
- **LO2.1:** Recognize appropriate forces balance equations governing the motion of charged particles.
- **LO2.2:** Calculate the drift velocities of charged particles under the influence of static; non-static, uniform; and non-uniform electric and magnetic fields.

CO3: Apply laws of fluid dynamics to describe the collective motion of plasma.
- **LO3.1:** Discuss fluid equation of motion and compare with ordinary hydrodynamics.
- **LO3.2:** Interpret the relation of plasma physics to ordinary electromagnetics.

CO4: Asses the plasma waves and instabilities.
- **LO4.1:** Interpret the electrostatic and electromagnetic waves that can propagate in plasma.
- **LO4.2:** Examine the physical mechanism responsible for plasma waves.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual	LO1.1	LO3.1	LO4.1 LO3.2			
Conceptual		LO1.2, LO2.1 CO1	CO3	LO4.2		
Procedural				LO2.2 CO2	CO4	
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	M	M	M	M	M	M	S
CO2	M	S	M	M	M	M	M	M	M	M
CO3	M	S	M	M	M	M	S	M	M	S
CO4	M	S	M	S	M	M	S	M	S	S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: Basics of Plasma
Definition of plasma, concept of temperature, Debye shielding, quasineutrality, collective behaviour, plasma parameters, the criterion for plasma, classification of plasma, applications of plasma physics. **(L 08, H 08, M 08)**

Unit II: Charged Particles in Electromagnetic Fields
Motion of charged particles in electromagnetic fields, uniform E and B fields, non-uniform fields, diffusion across magnetic fields, time-varying E and B fields, adiabatic invariants, magnetic mirror. **(L 20, H 20, M 20)**

Unit III: Plasma as Fluids
Introduction, convective derivative, Navier-Stokes equations, relation of plasma physics to ordinary electromagnetics, fluid equation of motion, Fluid drifts perpendicular and parallel to B, plasma approximation. **(L 14, H 14, M 14)**

Unit IV: Wave Phenomena in Plasma
Phase and group velocities, plasma oscillation, electron plasma waves, ion-acoustic waves, propagation parallel and perpendicular to the magnetic field, dispersion relations of elementary plasma waves, cutoffs and resonances, propagation through ionosphere and magnetosphere, space and astrophysical plasma, Van Allen belts. **(L 18, H 18, M 18)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Introduction to plasma physics, *F. F. Chen*, Springer.
2. Fundamentals of plasma physics, *R. A. Bittencourt*, Springer.
3. Principles of plasma diagnostics, *I. H. Hutchinson*, Cambridge University Press.

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Course title: Physics of Devices and Instruments
Course code: PHY-DSE-IC
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: The course on Physics of Devices and Instruments includes discussion about various types of power devices like SCR, DIAC, TRAIC etc.. Discussion about MOS and its application is also included. The course covers the designing and working of power supply circuits and SMPS circuits. A detailed discussion about phase locked loop and its application in various communication circuits can be learnt through this course. The course also covers the various IC fabrication techniques which will help the student gain knowledge about the Semiconductor fabrication and related fields. Discussion about data communication and analog communication has also been included in the curse.

Course Objective:

1. Know about various devices like UJT, DIAC, TRAIC, CMOS etc. and its application to different electronic circuits.
2. Design rectifiers, passive and active filters, multivibrators etc.
3. Familiarize with the IC fabrication techniques.
4. Learn about digital data communication standards and also about communication systems.

Prerequisites: Knowledge of semiconductor, Basic circuit analysis techniques, Transistor fundamentals, Digital electronics.

Course Outcomes (COs): The students will able to

CO1: Understand the operation and application of various power electronic and MOS devices

- **LO1.1:** Explain the basic concepts and characteristics of different semiconductor devices such as SCR, DIAC, TRIAC, UJT, Schottky diode, Varactor diode, Tunnel diode, Gunn diode, and MOS devices.
- **LO1.2:** Explain the working of power supply circuits.
- **LO1.3:** Classify the types of IC fabrication techniques.
- **LO1.4:** Explain the types of modulation schemes.

CO2: Apply electronic components to design circuit for power supply and communication systems.

LO2.1: Identify the steps in the IC fabrication process and the materials used, such as electronic grade silicon.

LO2.2: Identify the standards and protocols for serial and parallel communication, such as RS232 and USB.

LO2.3: Identify the components of an electronic communication system and the need for modulation.

CO3: Analyze different electronic components and circuits to understand its functioning and apply.

LO3.1: analyze voltage multiplier circuits and switch mode power supplies (SMPS).

LO3.2: Compare the effectiveness of different filtering techniques in power supplies.

LO3.3: Analyze the working of the Phase locked loop circuit.

LO3.4: Compare the serial and parallel communication standards.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual		LO1.1 LO1.3 LO1.4	LO2.1			
Conceptual		LO1.2	LO2.2 LO2.3	LO3.1 LO3.2 LO3.3		
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	M	M	M	S	M	M	S
CO2	S	S	M	S	M	M	M	M	M	M
CO3	M	S	M	S	M	M	S	M	M	S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: Devices

Silicon Controlled Rectifier (SCR), SCR applications, Light Activated SCR, DIAC, TRIAC, UJT, Schottky diode, Varactor diode, Tunnel diode, Gunn diode, Metal oxide semiconductor (MOS) device. Ideal MOS and Flat Band voltage, CMOS. Charge coupled devices.

(L 14, H 14, M 14)

Unit II: Power Supply

Power supply and Filters: Block Diagram of a Power Supply, Qualitative idea of C and L Filters. IC Regulators, Line and load regulation, short circuit protection. Voltage Multiplier circuit, Switch Mode Power Supply. **(L 9, H 9, M 9)**

Unit III: Phase Locked Loop (PLL)
Applications of Phase Locked Loop (PLL): Frequency Demodulation, Frequency Synthesis, Interfacing Circuit. Phase detector (XOR & edge triggered), transient response, Basic idea of PLL IC (565 or 4046). **(L 5, H 5, M 5)**

Unit IV: IC Fabrication
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. **(L 12, H 12, M 12)**

Unit V: Serial and Parallel Communication
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. **(L 5, H 5, M 5)**

Unit VI: Analog Communication
Introduction to communication systems: Block diagram of electronic communication system, Need for modulation. Amplitude modulation. Modulation Index. Analysis of Amplitude Modulated waves. Sideband frequencies in AM waves. CE Amplitude Modulator. Demodulation of AM waves using Diode Detector.AM Transmitter and Receiver, Frequency Modulation, Modulation index, Modulator and Demodulator circuit, FM Transmitter and Receiver.
(L 15, H 15, M 15)

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

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

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Course title: Physics Lab IV (Major)
Course code: PHY-DSE-ID
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In sem)

Course Description: The course on Physics Lab IV (Major) comprises 13 experiments covering the domain of optics, spectroscopy, magnetism, Atomic Physics, Electronics, and Nuclear Physics. Jamins, Febry-Perot and Michelson Interferometers are used to obtain the wavelength of monochromatic sources, e/m measurements by magnetron methods, velocity of sound using CRO, are included in the course. Experiments related to study of CE transistor amplifiers and Geiger muller counters are also included in the course for providing hands-on experience of electronic circuits and counters.

Course Objectives:

1. To develop practical knowledge by applying the experimental methods and to correlate with the Physics theory.
2. To learn the usage of electrical and optical systems for various measurements.
3. To apply the analytical techniques and graphical analysis to interpret the experimental data.
4. To learn error propagation and its role in making conclusions.

Prerequisites: Knowledge of wave optics and Ray optics, Atomic Physics and Spectroscopy, Transistor fundamentals, Nuclear Physics and Particle detectors.

Course Outcomes (COs): The students will able to

CO1: Understand the interference, diffraction of light and sound wave propagation

- **LO1.1:** Explain the components and setup of Jamin's interferometer. Fabry-Perot Interferometer and Michelson Interferometer.
- **LO1.2:** Recall the concept of energy band gap in semiconductors.
- **LO1.3:** Explain the components and function of a Geiger-Müller counter.
- **LO1.4:** Explain the principles and procedure of the magnetron method.
- **LO1.5:** Describe the procedure to determine the band gap using a p-n junction diode.

CO2: Experiment with various optical instruments, electronic instruments and particle detectors

- **LO2.1:** Execute the experiment to measure the wavelength of He-Ne laser light.
- **LO2.2:** Conduct the experiment to study the normal and anomalous Zeeman effects.
- **LO2.3:** Perform the experiment to determine the plateau and optimal operating voltage.

CO3: Analyze different electronic components and circuits to understand its functioning and apply.

- **LO3.1:** Analyze the I-V characteristics to calculate the band gap.
- **LO3.2:** Analyze the frequency response curve to determine the bandwidth and gain.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual		LO1.1 LO1.2 LO1.3 LO1.4 LO1.5		LO3.1 LO3.2 LO3.3		
Procedural			LO2.1 LO2.2 LO2.3			
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	M	M	M	S	M	M	S
CO2	S	S	M	S	M	M	M	M	M	M
CO3	M	S	M	S	M	M	S	M	M	S

(S: Strong, M: Medium, W: Weak)

List of Experiments:

1. To draw the calibration curve of the Jamin's interferometer and then to find the refractive index of air at room temperature and pressure.
2. To determine the wavelength of light from a monochromatic source using Michelson's interferometer and then to determine the difference of wavelength for Sodium D lines.
3. To determine the wavelength of light from a monochromatic source using Fabry-Perot interferometer and then to determine the difference of wavelength for Sodium D lines.
4. To study the normal and anomalous Zeeman effects.
5. To determine the value e/m by magnetron method.
6. To determine the energy band gap of a semiconductor using a p-n junction diode.
7. To draw the frequency response curve of a CE transistor amplifier and also to find the input impedance of the amplifier.
8. To determine the velocity of sound using CRO.
9. To study the plateau and optimal operating voltage of a Geiger-Müller counter.
10. To measure the half-life of a meta-stable radioactive source.
11. To determine the complex dielectric constant and plasma frequency of metal using Surface Plasmon resonance (SPR).
12. To determine the refractive index of a dielectric layer using SPR.
13. To study the PE Hysteresis loop of a Ferroelectric Crystal.

(Total Practical Classes 60, Total Contact Hours 120, Total Marks 60)

At least 60% of the experiments must be performed from the list.

Recommended Readings:

1. Advanced Practical Physics, *B. L. Worsnop and H. T. Flint*, Asia Publishing House.
2. Optics, *A. K. Ghatak*, Tata McGraw Hill.
3. Fundamentals of Optics, *Jenkins and White*, McGraw Hill.
4. Optics, *A. R Ganesan*, Eugune Hecht.

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Group II (in lieu of Dissertation)
(Any One from this group to be chosen)

Course title: Astronomy and Astrophysics
Course code: PHY-DSE-IIA
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: As the first course of astronomy and astrophysics in this programme, this course is designed for students to learn about the ideas of astronomical scales, basic concepts of positional astronomy, important techniques used in astronomy as well as the physical principles applied in astrophysics. Then they can learn about the structure of the Sun and its family, the stellar spectra and classification schemes, our galaxy, the general galaxy morphology and their morphology-based classification. Finally, students can learn about the basic ideas and laws related to large scale structures and the expanding Universe.

Course Objectives: Recognizing the importance of astronomy and astrophysics as the emerging areas of academic and research activities at the current time, this basic course has been introduced with the following two prime objectives:

1. Introduce the fundamental concepts of astronomy and astrophysics to the interested students.
2. Motivate students to pursue further study in the future in these challenging, fascinating and important fields of physics.

Course Outcomes (COs): The students will able to

CO1: Explain the basic requisites of astronomy and astrophysics.

LO1.1: Define the astronomical scales, stellar parameters, celestial geometry and physical principles.

LO1.2: Describe astronomical techniques used in astronomical observations.

CO2: Understand the basics of stellar structures (including the Sun), galaxies and their classifications as well as the structure of the Universe and its evolution.

LO2.1: Describe our galaxy, the Milky Way.
LO2.2: Explain the structure of the Sun, stars, galaxies and the Universe.
LO2.3: Interpret the structure of the Universe and its expansion.

CO3: Apply the concepts of this course for further study in these and related areas.
LO3.1: Use the ideas for the advanced-level studies of astronomy and astrophysics.
LO3.2: Develop the basis for the study of cosmology.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	**Remember**	**Understand**	**Apply**	**Analyze**	**Evaluate**	**Create**
Factual	LO1.1 CO1	LO1.2				
Conceptual		LO2.1 LO2.2 LO2.3 CO2	LO3.1 LO3.2 CO3			
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	S	M	M	M			S			M
CO2	S	S	M	M			M			M
CO3	S	M	S	M			W			M

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit 1: Astronomical Scales, Basic Stellar Parameters and Measurements
Astronomical distances, determination of distance by parallax method, mass and time scales, measurement of time, sidereal time, apparent solar time, mean solar time, equation of time, calendar, brightness, radiant flux and luminosity, apparent and absolute magnitude scales, distance modulus, stellar radius, masses of stars, determination of masses from binary orbits, stellar temperature, determination of temperature and radius of a star. **(L 13, H 13, M 13)**

Unit 2: Basic Concepts of Positional Astronomy
Celestial sphere, geometry of a sphere, spherical triangle, astronomical coordinate systems, geographical coordinate systems, horizon system, equatorial system, diurnal motion of the stars, conversion of coordinates. **(L 7, H 7, M 7)**

Unit 3: Astronomical Techniques
Basic definitions for optical astronomy: magnification, light Gathering power, resolving power and diffraction limit, atmospheric windows; optical telescopes: types of reflecting telescopes,

telescope mountings, space telescopes; detectors and their use with telescopes: types of detectors, detection limits with telescopes. **(L 6, H 6, M 6)**

Unit 4: Physical Principles: Gravitation in astrophysics: Virial theorem, Newton versus Einstein; systems in thermodynamic equilibrium. **(L 5, H 5, M 5)**

Unit 5: The Sun

Solar parameters, solar photosphere, solar atmosphere, chromosphere, corona, solar activity, basics of solar magneto-hydrodynamics, helioseismology.

The solar family: Solar system: facts and figures; origin of the solar system: the nebular model; tidal forces and planetary rings, extrasolar planets. **(L 5, H 5, M 5)**

Unit 6: Stellar Spectra and Classification Structure

Atomic spectra revisit, stellar spectra, spectral types and their temperature dependence, black body approximation, H-R diagram, luminosity classification. **(L 5, H 5, M 5)**

Unit 7: The Milky Way

Basic structure and properties of the Milky Way, 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, properties in and around the galactic nucleus. **(L 5, H 5, M 5)**

Unit 8: Galaxies

Galaxy morphology, Hubble's classification of galaxies, elliptical galaxies: intrinsic shapes of elliptical, de Vaucouleurs law, stars and gas; spiral and lenticular galaxies: bulges, disks, galactic halo, gas and dust, spiral arms. **(L 7, H 7, M 7)**

Unit 9: Large Scale Structure and Expanding Universe

Cosmic distance ladder (an example from terrestrial physics), distance measurement using Cepheid variables; Hubble's law, clusters of galaxies and dark matter. **(L 7, H 7, M 7)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Modern Astrophysics, *B. W. Carroll, D. A. Ostlie*, Addison-Wesley Publishing Co.
2. Introductory Astronomy and Astrophysics, *M. Zeilik, S. A. Gregory*, Saunders College Publishing.
3. The Physical Universe: An Introduction to Astronomy, *F. Shu, Mill Valley*, University Science Books.
4. Fundamentals of Astronomy, *H. Karttunen et al.*, Springer.
5. Astrophysics from a Modern Perspective, *K. S. Krishnasamy*, New Age International (p) Ltd.
6. An introduction to Astrophysics, *B.Basu*, Prentice-Hall of India Private Ltd.
7. Textbook of Astronomy and Astrophysics with Elements of Cosmology, *V. B. Bhatia*, Narosa Publication.

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Course title: Nanomaterials and Applications
Course code: PHY-DSE-IIB
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: The course on Nanomaterials and Applications begins with the introduction to nanomaterials along with the description of the factors governing the unique properties of these materials compared to their bulk counterparts. Various synthesis and characterization techniques of nanomaterials have been discussed. Interesting properties and important applications of various nanomaterials are also included in this course.

Course Objective:

1. To introduce the promising area of nanomaterials in order to facilitate the understanding of nature and prospects for the field.
2. To acquaint the learners with various synthesis and characterization techniques of nanomaterials.
3. To familiarize the learners about properties and applications of selected nanomaterials.

Prerequisites: Working knowledge of crystallography and solid state materials.

Course Outcomes (COs): After successful completion of the course, the student will be able to

CO1: Analyze characteristic features of nanomaterials.

- **LO1.1:** Define nanomaterials.
- **LO1.2:** Compare the properties of nanomaterials with those in bulk form.
- **LO1.3:** Discover the factors governing properties of nanomaterials.

CO2: Classify the synthesis and characterization methods of nanomaterials.

- **LO2.1:** List the synthesis and characterization methods of nanomaterials.
- **LO2.2:** Outline the working principles of the experimental methods.

CO3: Identify properties and application of nanomaterials.

- **LO3.1:** List properties and application of nanomaterials.
- **LO3.2:** Apply unique features of nanomaterials for a variety of applications.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	**Remember**	**Understand**	**Apply**	**Analyze**	**Evaluate**	**Create**
Factual	LO1.1 LO2.1 LO3.1	LO1.2	LO3.2 CO3			
Conceptual		LO2.2 CO2	LO2.3	LO1.3 CO1		
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S	S	M	M	S	S	M
CO2	S	M	S	M	S	S	S	S	S	S
CO3	S	M	S	M	S	S	S	S	S	S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit 1: Nanoscale Systems

Length scales in Physics, Nanostructures: 1D, 2D and 3D nanostructures (nanodots, thin films, nanowires, nanorods), Band structure and density of states of materials at nanoscale, Size Effects in nano systems, Quantum confinement: Applications of Schrodinger equation- Infinite potential well, potential step, potential box, quantum confinement of carriers in 3D, 2D, 1D nanostructures and its consequences. **(L 10, H 10, M 10)**

Unit 2: Synthesis of Nanostructure Materials

Top down and Bottom up approach, Photolithography. Ball milling. Gas phase condensation. Vacuum deposition. Physical vapor deposition (PVD): Thermal evaporation, E-beam evaporation, Pulsed Laser deposition. Chemical vapor deposition (CVD). Sol-Gel. Electro deposition. Spray pyrolysis. Hydrothermal synthesis. Preparation through colloidal methods. MBE growth of quantum dot. **(L 8, H 8, M 8)**

Unit 3: Characterization

X- ray diffraction, Optical Microscopy, Scanning electron Microscopy, Transmission Electron Microscopy, Atomic Force Microscopy, Scanning Tunneling Microscopy. **(L 8, H 8, M 8)**

Unit 4: Optical 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 quasi-particles and excitons, charging effects. Radiative Processes: General formalization-absorption, emission and luminescence, Optical properties of hetero structures and nanostructures. **(L 14, H 14, M 14)**

Unit 5: Electron Transport

Carrier transport in nanostructures. Coulomb blockade effect, thermionic emission, tunneling and hoping conductivity. Defects and impurities: Deep level and surface defects. **(L 6, H 6, M 6)**

Unit 6: Applications

Applications of nanoparticles, quantum dots, nanowires and thin films for photonic devices (LED, solar cells). Single electron transfer devices (no derivation). CNT based transistors. Nanomaterial Devices: Quantum dots heterostructure lasers, optical switching and optical data storage. Magnetic quantum well; magnetic dots - magnetic data storage. Micro Electromechanical Systems (MEMS), Nano Electromechanical Systems (NEMS). **(L 14, H 14, M 14)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Introduction to Nanotechnology, *C. P. Poole, Jr. Frank J. Owens* Wiley India Pvt. Ltd.
2. Nanotechnology: Principles & Practices, *S. K. Kulkarni*, Capital Publishing Company.
3. Introduction to Nanoscience and Technology, *K. K. Chattopadhyay and A. N. Banerjee,* PHI Learning Private Limited.
4. Nanotechnology, *R. Booker, E. Boysen,* John Wiley and Sons.
5. Nanoparticle Technology Handbook, *M. Hosokawa, K. Nogi, M. Naita, T. Yokoyama,* Elsevier
6. Introduction to Nanoelectronics, *V. V. Mitin, V. A. Kochelap and M. A. Stroscio*, Cambridge University Press.
7. *B. Bhushan*, Springer Handbook of Nanotechnology, Springer-Verlag, Berlin.

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Course title: Physics of The Earth
Course code: PHY-DSE-IIC
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) + 40 (In-sem)

Course Description: This course provides a comprehensive exploration of Earth and its cosmic context, integrating Astronomy, Geology, Meteorology, and Oceanography to offer a holistic understanding of our dynamic planet. Students will investigate the origin and structure of the universe, the Milky Way, and the solar system, with a special focus on Earth's unique attributes and its cosmic interactions. The curriculum covers Earth's solid structure, hydrosphere, atmosphere, cryosphere, and biosphere, emphasizing the dynamic processes that shape these systems. It also examines the geological and biological evolution of Earth, including stratigraphic records, geochronological methods, and the history of life. The course addresses contemporary environmental challenges such as climate change, pollution, and biodiversity loss, highlighting the significant impact of human activities on Earth's systems.

Course Objective: Develop critical and quantitative thinking of scientific issues related to the study of Cosmology and Earth Sciences.

1. Understand the basic principles of various processes of the Earth.
2. Apply the acquired knowledge on the study of the Universe
3. Pursue career in Earth Sciences, Cosmology etc.
4. Understand the contemporary dilemmas on Earth and Environmental issues like climate change, air pollution, deforestation etc.

Course Outcomes (COs): The students will able to
CO1: Explain the origin and evolution of the Universe and our Solar System.
    LO1.1: Explain the origin and evolution of the Universe.
    LO1.2: Recognize the structure and dynamics of the Solar System.
    LO1.3: State Earth's geological features and processes.

LO1.4: Recall atmospheric and oceanic dynamics.
LO1.5: Evaluate the impact of energy and particle fluxes on Earth.

CO2: Knowledge of the structure and dynamics of Earth's systems.
LO2.1: Recall the structure and composition of the Solid Earth.
LO2.2: Explain methods and technologies for studying Earth's interior.
LO2.3: Analyze atmospheric dynamics and composition.

CO3: Evaluate the dynamic processes and phenomena of the Earth's systems.
LO3.1: Understand the mechanisms behind Earth's magnetic field.
LO3.2: Explain seismic activity and volcanic processes.
LO3.3: Evaluate Earth's climate system.

CO4: Discuss the principles and applications of stratigraphy and geochronology.
LO4.1: State the concepts of uniformitarianism, catastrophism, and neptunism.
LO4.2: Relate the Law of Superposition and Faunal Succession.
LO4.3: Discuss the geology and geomorphology of the Indian subcontinent.

CO5: Analyze the environmental challenges and their implications.
LO5.1: Understand the drivers and consequences of human population growth.
LO5.2: Recall the impacts of greenhouse gas emissions on the atmosphere.
LO5.3: Evaluate the sources and effects of air pollution.
LO5.4: Examine the causes and consequences of freshwater depletion.
LO5.5: Understand the generation and management of chemical effluents and nuclear waste.
LO5.6: Interpret the impacts of biodiversity loss and deforestation on the biosphere.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual	LO1.2 LO1.3 LO1.4 LO2.1 LO4.1 LO4.2 LO5.2 CO2					
Conceptual		LO1.1 LO2.2 LO3.1 LO3.2 LO4.3 LO5.1 LO5.5 CO1 CO4	LO5.6	LO1.5 LO2.3 LO5.4 CO5	LO3.3 LO5.3 CO3	
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	M	M	S	S	M	S	M	M	M
CO2	S	M	M	M	S	M	S	M	M	M
CO3	S	M	M	S	S	M	S	M	M	M
CO 4	S	M	M	M	S	M	M	S	M	M
CO 5	S	S	S	S	S	M	S	S	M	S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit 1: The Earth and the Universe

Origin of universe, creation of elements and earth. A Holistic understanding of our dynamic planet through Astronomy, Geology, Meteorology and Oceanography. Introduction to various branches of Earth Sciences.

General characteristics and origin of the Universe. The Milky Way galaxy, solar system, Earth's orbit and spin, the Moon's orbit and spin. The terrestrial and Jovian planets. Meteorites & Asteroids. Earth in the Solar system, origin, size, shape, mass, density, rotational and revolution parameters and its age. Energy and particle fluxes incident on the Earth, The Cosmic Microwave Background.

(L 14, H 14, M 14)

Unit 2: Structure

The Solid Earth: Mass, dimensions, shape and topography, internal structure, magnetic field, geothermal energy. How do we learn about Earth's interior?

The Hydrosphere: The oceans, their extent, depth, volume, chemical composition. River systems.

The Atmosphere: variation of temperature, density and composition with altitude, clouds.

The Cryosphere: Polar caps and ice sheets. Mountain glaciers.

The Biosphere: Plants and animals. Chemical composition, mass. Marine and land organisms.

(L 14, H 14, M 14)

Unit 3: Dynamical Processes:

The Solid Earth: Origin of the magnetic field. Source of geothermal energy. Convection in Earth's core and production of its magnetic field. Mechanical layering of the Earth. Introduction to geophysical methods of earth investigations. Concept of plate tectonics; sea-floor spreading and continental drift. Geodynamic elements of Earth: Mid Oceanic Ridges, trenches, transform faults and island arcs. Origin of oceans, continents, mountains and rift valleys. Earthquake and earthquake belts. Volcanoes: types of products and distribution.

The Hydrosphere: Ocean circulations. Oceanic current system and effect of Coriolis forces. Concepts of eustasy, tend – air-sea interaction; wave erosion and beach processes. Tides. Tsunamis.

The Atmosphere: Atmospheric circulation. Weather and climatic changes. Earth's heat budget. Cyclones.

Climate: Earth's temperature and greenhouse effect, Paleoclimate and recent climate changes, The Indian monsoon system.

Biosphere: Water cycle, Carbon cycle, Nitrogen cycle, Phosphorus cycle. The role of cycles in maintaining a steady state. **(L 14, H 14, M 14)**

Unit 4: Evolution

Nature of stratigraphic records, Standard stratigraphic time scale and introduction to the concept of time in geological studies. Introduction to geochronological methods in their application in geological studies. History of development in concepts of uniformitarianism, catastrophism and neptunism. Law of superposition and faunal succession. Introduction to the geology and geomorphology of the Indian subcontinent.

- (i) Timeline of major geological and biological events.
- (ii) Origin of life on Earth.
- (iii) Role of the biosphere in shaping the environment.
- (iv) Future of evolution of the Earth and solar system: Death of the Earth.

(L 14, H 14, M 14)

Unit 5: Disturbing the Earth – Contemporary dilemmas

Human population growth,
Atmosphere: Greenhouse gas emissions, climate change, air pollution;
Hydrosphere: Fresh water depletion,
Geosphere: Chemical effluents, nuclear waste.
Biosphere: Biodiversity loss. Deforestation. Robustness and fragility of ecology.

(L 4, H 4, M 4)

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Planetary Surface Processes, *H. J. Melosh*, Cambridge University Press.
2. Consider a Spherical Cow: A course in environmental problem solving, *J. Harte*, University Science Books.
3. Holme's Principles of Physical Geology, Chapman & Hall.
4. Planet Earth, Cosmology, Geology and the Evolution of Life and Environment, *C. Emiliani,* Cambridge University Press.

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Course title: Computational Physics Lab
Course code: PHY-DSE-IID
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End-sem) **+ 40** (In-sem)

Course Description: The framework suggests a comprehensive course that amalgamates theoretical understanding of numerical methods with practical implementation through programming languages like C, C++, and SciLab. Students will gain both conceptual knowledge of numerical techniques and practical skills in programming which will enable them to apply their knowledge in scientific and technical domains that require computational solutions.

Course Objectives: The course objectives for a Computational Physics course typically aim to

1. Equip students with required skills and knowledge to effectively use computational methods

for solving physical problems.
2. Develop proficiency in computational skills and programming.

Course Outcomes (COs): After the completion of the course, the student will be able to
CO1: Understand the basic concepts of computation and programming.
LO1.1: Define truncation and round off-errors.
LO1.2: Illustrate the different programming fundamentals.
LO1.3: Solve numerical problems to effectively use computational methods to realise physical Problems.
CO2: Develop computational based skills using C, C++, SciLab.
LO2.1: Interpret the SciLab environment, console, and script editor.
LO2.2: Apply C, C++, SciLab to explore different numerical methods.
LO2.3: Utilize C, C++, SciLab to practice the hands-on exercises and implementing them in a programming environment.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual	LO1.1 LO2.1	LO1.2 LO2.2				
Conceptual			LO1.3 LO2.3 CO1 CO2			
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	M	M	M	S	M	M	M
CO2	S	S	M	S	M	M	M	M	M	M

(S: Strong, M: Medium, W: Weak)

Course Contents:

Theory Component

Unit 1: Errors
Truncation and round off errors, Absolute and relative errors, Floating point computations.

Unit 2: Review of Programming Fundamentals: C, C++, SciLab
Introduction to Programming, constants, variables and data types, operators and Expressions, I/O statements, Manipulators for data formatting, Control statements (decision making and looping statements) (If-statement. If-else Statement etc.).

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, Idea of classes and objects.

Solution of algebraic and transcendental equation by Bisection, Newton Raphson and Secant methods Interpolation by Newton Gregory Forward and Backward difference formula, Error estimation of linear interpolation

Numerical differentiation (Forward and backward interpolation formula) and Integration (Trapezoidal and Simpson rules), Monte Carlo method
Solution of Ordinary Differential Equations (ODE), First order Differential equation Euler, modified Euler and Runge- Kutta (RK) second and fourth order methods.

Practical Component

Hands on exercises:

1. Solve the differential equations of the type:
   i. $\frac{dy}{dx} = e^{-x}$ with $y = 0, x = 0$
   ii. $\frac{dy}{dx} + e^{-x}y = x^2$
   iii. $\frac{d^2y}{dt^2} + 2\frac{dy}{dt} = -y$
   iv. $\frac{d^2y}{dt^2} + e^{-t}\frac{dy}{dt} = -y$
2. Dirac delta function:
   Evaluate
   $$\frac{1}{\sqrt{2\pi\sigma^2}}\int e^{\frac{-(x-2)^2}{2\sigma^2}}(x+3)dx$$
   For $\sigma = 1, 0.1, 0.01$ and show that it tends to 5.
3. Fourier series:
   Program to sum $\sum_{n=1}^{\infty} (0.2)^n$
   Evaluate the Fourier coefficient for a given periodic function (Square wave)
4. Frobenius method and special functions:
   $$\int_{-1}^{+1} P_n(\mu)P_m(\mu)d\mu = \delta_{nm}$$
5. Plot $P_n(x), J_\vartheta(x)$. Show recursion relation.
6. Calculation of error for each data point of observations recorded in experiments done in previous semesters (choose any two).
7. Calculation of least square fitting manually without giving weightage to error. Confirmation of least square fitting of data through computer program.

8. Solve the s-wave radial Schrodinger equation for ground state and first excited state of hydrogen atom:

$$\frac{d^2u}{dr^2} = A(r)u(r), A(r) = \frac{2m}{ħ^2}[V(r) - E] \; where \; V(r) = -\frac{e^2}{r}$$

Here, m is the reduced mass of the electron. Obtain the energy eigen values and plot the corresponding wave functions. Remember that the ground state energy of the hydrogen atom is -13.6 eV. Take e = 3.795 $(eVÅ)^{1/2}$, ħc = 1973 (eVÅ) and m = 0.511×10^6 eV/c^2.

9. Solve the s- wave radial Schrodinger equation for an atom

$$\frac{d^2u}{dr^2} = A(r)u(r), A(r) = \frac{2m}{ħ^2}[V(r) - E]$$

where m is the reduced mass of the system (which can be chosen to be the mass of an electron), for the screened coulomb potential

$$V(r) = -\frac{e^2}{r}e^{-r/a}$$

Find the energy (in eV) of the ground state of the atom to an accuracy of three significant digits. Also, plot the corresponding wave function. Take e = 3.795 $(eVÅ)^{1/2}$, m = 0.511×10^6 eV/c^2, and a = 3 Å, 5 Å, 7 Å. In these units ħc = 1973(eVÅ). The ground state energy is expected to be above -12 eV in all three cases.

10. Solve the s-wave radial Schrodinger equation for a particle of mass m:

$$\frac{d^2u}{dr^2} = A(r)u(r), A(r) = \frac{2m}{ħ^2}[V(r) - E]$$

For the anharmonic oscillator potential

$$V(r) = \frac{1}{2}kr^2 + \frac{1}{3}br^3$$

for the ground state energy (in MeV) of a particle to an accuracy of three significant digits. Also, plot the corresponding wave function. Choose m = 940 MeV/c^2, k = 100 MeV fm^{-2}, b = 0, 10, 30 MeV $fm^{-3.}$ In these units, cħ = 197.3 MeV fm. The ground state energy I expected to lie between 90 and 110 MeV for all three cases.

11. Solve the s-wave radial Schrodinger equation for the vibrations of hydrogen molecule:

$$\frac{d^2u}{dr^2} = A(r)u(r), A(r) = \frac{2\mu}{ħ^2}[V(r) - E]$$

where m is the reduced mass of the two-atom system for the Morse potential

$$V(r) = D\left(e^{-2\alpha r'} - e^{-\alpha r'}\right), r' = \frac{r - r_o}{r}$$

Find the lowest vibrational energy (in MeV) of the molecule to an accuracy of three significant digits. Also plot the corresponding wave function.

Take: m = 940 $\times 10^6$eV/c^2, D = 0.755501 eV, α = 1.44, r_o = 0.131349 Å.

(Total Practical Classes 60, Total Contact Hours 120, Total Marks 60)

Recommended Readings:

1. Introductional Physics, *D. Walker*, Scientific International Pvt. Ltd.
2. Simulation of ODE/PDE Models with MATLAB, OCTAVE and SCILAB: Scientific & Engineering Numerical Analysis, *S. S. Sastry*, PHI Learning Pvt. Ltd.
3. Schaum's Outline of Programming with C++. *J. Hubbard*, McGraw-Hill Publication.
4. Numerical Recipes in C: The Art of Scientific Computing, *W.H. Pressetal*, Cambridge University Press.
5. A first course in Numerical Methods, *U. M. Ascher & C. Greif*, PHI Learning.
6. Elementary Numerical Analysis, *K.E. Atkinson*, Wiley India Edition.
7. Numerical Methods for Scientists & Engineers, *R. W. Hamming*, 1Courier Dover Pub.
8. An Introduction to Computational Physics, *T. Pang*, Cambridge Univ. Press.
9. Computational Applications: A. V. Wouwer, *P. Saucez, C. V. Fernández*, Springer.
10. Scilab (A Free Software to Matlab): *H. Ramchandran, A. S. Nair*, S. Chand & Co.
11. A Guide to MATLAB, *B. R. Hunt, R. L. Lipsman, J. M. Rosenberg*, Cambridge University Press.
12. Scilab Image Processing: *L. M. Surhone*, Betascript Publishing ISBN:978-6133459274.

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Course title: Physics Lab V
Course code: PHY-DSE-IIE
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: The course on Physics Lab (DSE) comprises experiments covering Digital and analog electronics.

Course Objectives: At the completion of this course, a student will be able to

1. Understand the basic techniques of design and analysis of simple transistors and OP-AMP circuits.
2. Apply the knowledge to design and study different electronic circuits.

Course Outcomes (COs): At the completion of the course, the students will be able to

CO1: Understand the basics of different analog and digital electronics components.
- **LO1.1:** Explain the basics of 555 IC, OP-AMP and RC coupled amplifier.
- **LO1.2:** Classify R-S, J-K AND J-K Master slave flip flop.
- **LO1.3:** Illustrate the concepts of SISO, SIPO, PIPO etc.

CO2: Apply the basics to real life stimulation problems.
- **LO2.1:** Make use of 555 IC as multivibrator.
- **LO2.2:** Conduct study of flip-flops as memory devices.
- **LO2.3:** Make use of shift register in various configuration.

CO3: Analyze different electronic components and circuits to understand its functioning.
- **LO3.1:** Analyze the frequency response curve of an RC coupled amplifier and compare the bandwidth.

LO3.2: Analyze the characteristic curves of JFET and MOSFET.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual	LO1.1	LO1.1 LO1.2 LO1.3		LO3.1 LO3.2		
Procedural			LO2.1 LO2.2 LO2.3			
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	M	M	M	S	M	M	M
CO2	S	S	M	S	M	M	M	M	M	M
CO3	M	S	M	S	M	M	S	M	M	M

(S: Strong, M: Medium, W: Weak)

List of Experiments:

1. To design astable and monostable multivibrator using 555 IC.
2. To design and study D/A converter using the R-2R Ladder network.
3. To design and study OP-AMP as a differentiator and integrator.
4. To draw the frequency response curve of an RC coupled amplifier with and without negative feedback and compare the bandwidth.
5. To design a transistor amplifier for a specific gain using Voltage divider biasing method.
6. To design a RC Oscillator and Wien Bridge Oscillator for generating Sinusoidal oscillation of frequency 200 Hz and 3 KHz.
7. To design and construct basic flip-flops R-S, J-K, J-K Master slave flip-flops using gates and verify their truth tables.
8. To realize One & Two-Bit Comparator and study the 7485 magnitude comparator.
9. To realize and study Shift Register.
    a. SISO (Serial in Serial out).
    b. SIPO (Serial in Parallel out).
    c. PIPO (Parallel in Parallel out).
    d. PISO (Parallel in Serial out).
10. To design and test 3-bit binary asynchronous counter using flip-flop IC 7476 for the given sequence.
11. To study the characteristic curves of JFET and MOSFET.
12. To design 1^{st} and 2^{nd} order low pass active filters for specific roll off and cut off.

(Total Practical Classes 60, Total Contact Hours 120, Total Marks 60)

At least 60% of the experiments must be performed from the list.

Recommended Readings:

1. Basic electronics- A Text -Lab Manual, *Zbar, Malvino, Miller*, Tata Mcgraw.
2. Electronic Principles, *A. Malvino*, Tata McGraw Hill Education.
3. Digital Principles and applications, *Leach, Malvino, Saha*, McGraw Hill Education.

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SEMESTER IX

Group III (Compulsory)
(Any one from this group to be chosen)

Course title: Theory of Relativity
Course code: PHY-DSE-IIIA
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: The course on Theory of Relativity starts with a discussion of the Special Theory of Relativity from the geometrical perspective and then tries to generalize the concepts to include accelerated frames of reference. In doing so, the students are introduced to geometric objects like vectors, one forms, tensors, etc. A flavor of differential geometry is also offered.

Course Objectives:

1. Acquaint the learners with the special theory of relativity, space-time continuum.
2. Introduce the basic concepts of tensor calculus
3. Introduce the learners to the general theory of relativity

Prerequisites: Tensor Calculus, Electrodynamics.

Course Outcomes (COs): The students will able to

CO1: Explain the fundamentals of the special theory of relativity.
- **LO1.1:** Understand the basics of special theory from a geometrical perspective.
- **LO1.2:** Apply the special theory of relativity to various problems.
- **LO1.3:** Interpret the results of the application of special theory of relativity.

CO2: Apply tensor calculus to special and general theory of relativity.
- **LO2.1:** Understand the geometric properties of tensors.
- **LO2.2:** Explain the curvature of Spacetme.
- **LO2.3:** Interpret space time curvature as a manifestation of gravitation.

CO3: Develop the understanding of outstanding problems in General Relativity.
- **LO3.1:** Interpret the various solutions of Einstein's Field equations.
- **LO3.2:** Apply Einstein's theory to understand various experimental observations in cosmology.
- **LO3.3:** Build an understanding of the various aspects of Gravitational Waves.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual		LO1.2				

Conceptual		LO1.1 LO2.1 CO1	LO1.3 LO2.2 LO3.1 LO3.2 CO2	LO2.3 LO3.3 CO3		
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	S	M	M	S	S	M	M
CO2	S	S	M	S	M	M	S	S	M	M
CO3	S	S	M	S	M	M	S	S	M	M

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: Special Theory of Relativity
Galilean transformation, Michelson-Morley experiment, Einstein's postulates, Lorentz Transformations and basic kinematical results of special relativity, addition of velocities, relativistic momentum and energy of a particle, four vectors, mathematical properties of the space-time of Special Relativity, matrix representation of Lorentz transformation, transformation of electromagnetic fields. **(L 20, H 20, M 20)**

Unit II: Tensor Calculus
Tensors, Tensors as geometrical objects, covariant, contravariant and mixed tensors, contraction, covariant differentiation, the metric tensor, Christoffel symbols, Riemann curvature tensor, metric tensor and gravity, geodesics, parallel transport, Lie Transport and Killing vectors.
(L 20, H 20, M 20)

Unit III: General Theory of Relativity
Curvature of spacetime, properties of the curvature tensor, Bianchi identity, Ricci Tensor, physics in curved space-time, Einstein field equation, general properties of gravitational field equations, spherically symmetric geometry, Schwarzschild metric, Freidman space-time, de Sitter space-time, Gravitational waves, generation of gravitational waves and properties.
(L 20, H 20, M 20)

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Suggested Readings:

1. Special Theory of Relativity, *R. Resnick,* McGraw Hill.
2. Tensor Calculus, *D.C. Kay*, Schaum's Outlines.
3. Tensor Calculus, *P. A. M. Dirac*, Prentice-Hall of India.

4. Gravitation and Cosmology, *S. Weinberg*, McGraw Hill.
5. Gravitation, *T. Padmanabhan,* Cambridge University Press.
6. Gravitation, *J. A. Wheeler*, *C. W. Misner and K. S.Thorne*, Princeton University.
7. Cosmology, *J. V. Narlikar,* Cambridge University Press.

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Course title: High Energy Physics I
Course code: PHY-DSE-IIIB
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This is the first course of high energy physics in this programme, which is an advanced-level physics course. It is designed for the students to learn about particle physics at the introductory level beginning from the historical perspective of the subject to symmetry properties of particles and the basics of the fundamental interactions of particles. Then it is designed in a systematic order so that they can learn about relativistic wave equations in the natural unit system and four vector notations followed by quantum field theory and quantum electrodynamics. The study of the relativistic wave equations is important for understanding quantum field theory and quantum electrodynamics. The quantum field theory is the natural theory of particle interactions and is the basis of all fundamental subatomic theories in physics. Quantum electrodynamics is the quantum field theory of one of the fundamental interactions, the electromagnetic interaction.

Course Objectives: High energy physics is one of the areas of study in physics, which forms with the basic theories of most of the subatomic physical phenomena occurring in nature. Considering its importance, we include this first course of high energy physics for students of this programme with the following objectives:

1. Introduce to the students the elementary particles and their interactions.
2. Explain to the students the physics of relativistic wave equations.
3. To acquaint the students with the formulation of quantum field theory.
4. Apply the concepts of quantum field theory to quantum electrodynamics by students.

Course Outcomes (COs): The students will able to

CO1: Explain the basics of elementary particle physics.

- **LO1.1:** Recognize the historical perspectives of elementary particle physics.
- **LO1.2:** Classify the elementary particles.
- **LO1.3:** Understand the symmetry properties of elementary particles.
- **LO1.4:** Describe the fundamental interactions.

CO2: Understand the necessity of relativistic wave equations, their formulations and roles.

- **LO2.1:** Describe the natural units and four vector notations.
- **LO2.2:** Explain the importance of wave equations, their formulations and solutions.
- **LO2.3:** Illustrate positive and negative energy states.

LO2.4: Interpret the particles, antiparticles and basis of zero mass particles (neutrinos).

CO3: Apply the quantum field theory in quantum electrodynamics.

LO3.1: Understand the elementary particle interactions in terms of quantum field theories of scalar, vector and spinor fields.

LO3.2: Develop the particle scattering formalism using the Feynman diagram.

LO3.3: Utilize the scattering formalism to calculate amplitudes of different scattering processes.

CO4: Analyze any contributing topologically distinct electromagnetic interaction.

LO4.1: Examine the significant topologically distinct Feynman diagram from a set of Feynman diagrams.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual	LO1.1 LO1.2 LO2.1 CO1	LO1.3 LO1.4				
Conceptual		LO2.2 LO2.3 LO2.4 CO2	LO3.1 LO3.2 CO3			
Procedural			LO3.3	LO4.1 CO4		
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S	M		S			M
CO2	S	S	S	S	M		S			M
CO3	S	S	S	S	M		S			M
CO4	S	S	S	S	M		S			M

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: Introduction to Elementary Particles

Historical introduction and classification of elementary particles, intrinsic properties of elementary particles: baryon number, lepton number, isospin, strangeness etc.; behavior of elementary particles under: charge conjugation (C), parity (P), time reversal (T) and G-parity; Gell-Mann-Nakano-Nishijima law, eightfold way (Gell-Mann and Ne'eman classification).

Fundamental interactions (electromagnetic, weak and strong) and their characteristics, conservation laws and decay modes. **(L 12, H 12, M 12)**

Unit II: Relativistic Wave Equations
Natural units, Lorentz covariance and four vector notation; Klein-Gordon equation; Dirac equation and its covariant form, Dirac gamma matrices, adjoint equation and conserved current, solution of the Dirac equation (free particle spinors), negative energy states, antiparticles, normalization of spinor and the completeness relations, Lorentz covariance of Dirac equation, bilinear covariants, Dirac equation for zero mass particles (the two-component neutrino), helicity states.

(L 15, H 15, M 15)

Unit III: Quantum Field theory
Concept of field and quantization, Lagrangian of a field, Schwinger's action principle, Fock space states and their eigenvalues, method of second quantization, canonical quantization of scalar, vector and spinor fields, energy, momentum and charge of the field, vacuum in field theory, propagators. **(L 18, H 18, M 18)**

Unit IV: Quantum Electrodynamics
S-matrix, covariant perturbation theory, Feynman diagram (rules in momentum space), Wick's theorem, propagators, calculation of second order process, vacuum polarization, self-energy of electrons. Electron interaction with electromagnetic field, Compton scattering (Klein-Nishina formula), Bhaba scattering. **(L 15, H 15, M 15)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Suggested Readings:

1. Introduction to Elementary Particles, *D. J. Griffiths,* John Wiley & Sons.
2. Quarks and Leptons, *Francise Halzen, Alan D. Martin,* John Wiley & Sons.
3. Introduction to High Energy Physics, *Donald H. Perkings,* Cambridge University Press.
4. Gauge Theory of Elementary Particle Physics, *T. P. Cheng, L. F. Li,* Oxford University Press.
5. Physics of Elementary Particles, *H. Muirhead,* Pergamon Press.
6. Field Quantization, *W. Greiner, J. Reinhardt*, Springer.
7. A First Book of Quantum Field Theory, *A. Lahiri, P.B. Pal*, Narosa.

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Course title: Astrophysics and Cosmology I
Course code: PHY-DSE-IIIC
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This is the first advanced-level course on astrophysics and cosmology offered to the students of this programme. From this course, students will learn about stars, energy transport in the stellar mediums, stellar evolution, galaxy and distance measurements. The unit for stars is designed to learn about various properties of stars and the corresponding theories, spectral classification, H-R diagram, variable stars and star clusters. From the energy transport unit, the students will learn about various mechanisms of energy transport in stars with the associated parameters and derivation of the equation of radiative transfer. The stellar evolution unit will provide an opportunity to study star formation with the related Jeans criteria, different stages of stellar evolution and compact objects like white dwarfs, neutron stars and black holes. The last unit is designed to learn about the galaxies and their classification, active galactic nuclei, supermassive black holes, gravitational lensing and different methods of cosmic distance measurements.

Course Objectives: Astrophysics and cosmology are subjects that deal with mankind's never-ending curiosities about our Universe and its constituents. Currently, these are very active and emerging fields of research in physics. Therefore, the study of these fields at the postgraduate level is very important to understand our Universe as a whole and to gather the working knowledge for the future research careers of physics students. Taking into account the importance, this first course of astrophysics and cosmology is included in this programme with the following objectives:

1. To understand various properties of stars by students.
2. To understand the mechanism of energy transport, formation and evolution of stars by students.
3. Provide an idea to students about the galaxies and the methods of large-scale distance measurements.

Course Outcomes (COs): The students will able to

CO1: Describe the properties of stars, related mechanisms and laws.

- **LO1.1:** Explain the basic properties of stars.
- **LO1.2:** Understand the stellar structure and different related equations in hydrostatic equilibrium.
- **LO1.3:** Illustrate Saha's ionization theory, spectral classification, H-R diagram, variable stars and star clusters.

CO2: Understand the energy transport, stellar evolution, formation of galaxies and methods of large-scale distance measurements.

- **LO2.1:** Explain the various mechanisms of energy transport in stars and related parameters.
- **LO2.2:** Describe the processes of stellar evolution and formation of different compact stars, such as white dwarfs, neutron stars and black holes.
- **LO2.3:** Illustrate the galaxies, their classifications, active galactic nuclei, supermassive black holes, quasars etc. and methods of distance measurements with related

relations.

CO3: Apply the energy transport process, Jeans criteria and gravity to different astrophysical processes.

LO3.1: Explain the radiative processes in astrophysics.

LO3.2: Use Jeans criteria to verify the stability of a stellar model.

LO3.3: Utilize the gravitational law to explain the supernovae and gravitational lensing.

CO4: Analyze the astrophysical data.

LO4.1: Examine the theoretical finding of the rotational velocity of stars with the observational data using the Tully-Fisher relation.

LO4.2: Analyze different theoretical calculations related to stellar structures and different galactic phenomena using the corresponding relations with the observational data.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual	LO1.1	LO1.2 CO1				
Conceptual		LO1.3 LO2.1 LO2.2 LO2.3 CO2	LO3.1			
Procedural			LO3.2 LO3.3 CO3	LO4.1 LO4.2 CO4		
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S	M		S			M
CO2	S	S	S	S	M		S			M
CO3	S	S	S	S	M		S			M
CO4	S	S	S	S	M		S			M

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: Stars

Properties of stars: luminosity, surface temperature, mass and their correlations; stellar structures: structure equations, Newtonian theory of equilibrium, polytropic gas spheres, Lane-Emden equation; mean molecular weight, Saha's ionization theory, spectral classification, Hertzsprung-Russel diagram; variable stars, star clusters. **(L 20, H 20, M 20)**

Unit II: Energy Transport
Various mechanisms of energy transport in stars, stellar opacity, Rosseland mean opacity, equation of radiative transfer, thermodynamics of radiation; radiative processes in astrophysics. **(L 10, H 10, M 10)**

Unit III: Stellar Evolution
Star formation, Jeans criteria, various stages of nuclear burning; compact objects: white dwarfs, neutron stars (pulsars) and black holes. **(L 10, H 10, M 10)**

Unit IV: Galaxies and Distance Measurement
Hubble's classification, active galaxies: starburst galaxies, Seyfert galaxies, active galactic nuclei, supermassive black holes, quasars, blazars; cosmic distance ladder: trigonometric parallax, Cepheid variables, mean sequence fitting, Tully-Fisher relation, supernovae and gravitational lensing. **(L 20, H 20, M 20)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Suggested Readings:

1. An Introduction to the Study of Stellar Structure, *S. Chandrasekhar*, Dover Publication.
2. General Relativity and Cosmology, *Banerji and Banerjee*, Elsevier.
3. An Introduction to Cosmology, *J. V. Narlikar*, Cambridge University Press.
4. An Introduction to Astrophysics, *B. Basu*, Prentice-Hall of India.
5. Astrophysics: Stars and Galaxies, *K. D. Abhyankar*, Orient Longman.
6. Stars and Galaxies, *Michael A. Seeds*, Thomson Learning.
7. Cosmic Perspective, *Bennettt, Donahue, Schneider and Voit*, Pearson Addision Wesley.

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Course title: Condensed Matter Physics I
Course code: PHY-DSE-IIID
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: The course deals primarily with different electron models, polarization and dielectric properties, quantum mechanical treatment of Magnetic Properties and Superconductivity.

Course Objectives: At the completion of this course, a student will be able to
1. Understand the chronology in the Development of the Electron theory in Metals.
2. Understand the importance of Polarisation and Di-electric behavior of material and their primary applications.
3. Understand and appreciate the exchange interaction responsible for co-operative magnetic behavior.
4. Understand the electron phonon interaction in superconductivity and behavior related to the

cooper pair.

5. Understand the Optical properties of materials in terms of electronic band transitions and optical constants.

Prerequisites: Basic Quantum Mechanics, Basic Condensed Matter Physics.

Course Outcomes (COs): After completion of the course, the students will able to

CO1: Understand the electron models, importance of polarization mechanism, origin of magnetic and superconducting behavior of solids.

- **LO 1.1:** Compare the difference among different electron models based on their basic assumptions.
- **LO 1.2:** Illustrate the effect of frequency of electric field on dielectric behavior of solids.
- **LO 1.3:** Demonstrate the role of magnetic interactions in the co-operative magnetic behavior.
- **LO 1.4:** Interpret the role of lattice vibrations in the origin of superconducting behavior

CO2: Apply basic quantum mechanics to explain the co-operative magnetic behavior and the superconductivity.

- **LO 2.1:** Identify the primary reason of ferromagnetic and other co-operative magnetic phenomena.
- **LO 2.2:** Explain diverge concepts of superconductivity viz. Flux quantization, Josephson effect, SQUIDS etc.

CO3: Analyze the difference among various electron models with their advantages and limitations, importance of polarization mechanism on dielectric and ferroelectric behavior, electron-electron interaction in magnetic behavior and electron-ion interaction in superconductivity.

- **LO 3.1:** Inspect the relationship between the assumptions of different electron models with their advantages and limitations.
- **LO 3.2:** Examine the role of polarization in determining the electrical behavior of solids.
- **LO 3.3:** Compare Hartree and Hartree Fock approximations analyzing the importance of Hartree Fock approximation.
- **LO 3.4:** Analyze the significance of cooper pair in the explanation of superconducting behavior.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	**Remember**	**Understand**	**Apply**	**Analyze**	**Evaluate**	**Create**
Factual		LO 1.1	LO 2.1	LO 3.1		
Conceptual		LO 1.2 LO 1.3 LO 1.4 CO1	LO 2.2 CO2	LO 3.2 LO 3.3 LO 3.4 CO3		
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	S	M	M	S			M
CO2	S	S	M	S	M	M	S			M
CO3	S	S	M	S	S	M	S			M

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: Electron Theory

Free electron theory, Drude Model, Electrical and thermal conductivity of metals, Wiedemann Franz law, Free Electron Fermi Gas, Sommerfeld theory, Energy levels and density of states, Fermi energy, Boltzmann equation, relaxation time, Tight binding approximation method. **(L 16, H 16, M 16)**

Unit II: Dielectric and Ferroelectric Properties

Polarization, Langevin's theory, Clausius-Mossotti relation, Static dielectric constant of solids, Complex dielectric constant & dielectric loss, Dielectric relaxation, Debye equation. Ferroelectric effect, dipole theory of ferroelectricity, Piezoelectric effect, Pyroelectric effect, Electrostrictive effect, anti-ferroelectricity. **(L 16, H 16, M 16)**

Unit III: Magnetic Properties of a System

Magnetic Hamiltonian, Exchange interaction and exchange integral for two-electron system, Heisenberg Hamiltonian, Slater's Criterion, Relationship between exchange energy and molecular field, Hartree and Hartree-Fock approximation, Ferromagnetic spin waves **(L 14, H 14, M 14)**

Unit IV: Superconductivity

Isotope effect, Electron-phonon interaction, Cooper Pair, BCS theory, Flux quantization in a superconducting ring, Superconducting tunneling, Josephson Effect, SQUIDS. **(L 14, H 14, M 14)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Suggested Readings:

1. The Theory of transport phenomena in solids, *J. M. Ziman*, Oxford University Press.
2. Solid State Physics, *N. W. Ashcroft and N. D. Mermin*, Brooks/Cole
3. Intermediate Quantum Theory of Crystalline Solids, *A. O. E. Animallu*, Prentice Hall.
4. Quantum Theory of Solids, *C. Kittel*, John Wiley International.
5. Elements of Solid State Physics, *J. P. Srivastava*, Prentice Hall India.
6. Introduction to Solid State Theory, *O. Madelung*, Springer-Verlag.
7. Quantum Theory of Solid State, *J Callaway*, Academic Press.
8. 8. Theoretical Solid State Physics, *A. Huang*, Elsevier.

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Course title: Communication Electronics
Course code: PHY-DSE-IIIE
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: The course on Communication Electronics begins with a discussion on Communication theory and Digital data transmission techniques. It describes the different types of digital modulation techniques and multiplexing techniques which are of utmost importance in any modern-day communication system. The course also covers the concept of Antennas, RADAR, Cellular communication, Satellite communication and Microwave communication. This course is designed for introducing the students with the various technologies involved in modern communication systems so that they can apply the knowledge in the field of communication electronics.

Course Objectives: At the completion of this course, a student will be able to

1. Understand the basic techniques of electronic communication like modulation, multiplexing etc.
2. Apply the knowledge to understand the current generation communication technologies.
3. Get familiarized with microwave communication.
4. Lear about cellular and satellite communication.

Prerequisites: Knowledge of analog and digital signal, Knowledge about analog communication, Basic Electromagnetic Theory, Digital electronics.

Course Outcomes (COs): The students will able to

CO1: Understand the basic principle and methods used in communication systems.

- **LO1.1:** Define key terms in information theory, such as entropy, source encoding, and Channel.
- **LO1.2:** Compare the fundamental concepts of spread spectrum techniques and multiple access methods like CDMA, TDMA, and FDMA.
- **LO1.3:** Illustrate the key components and operation principles of radar systems.
- **LO1.4:** Define key concepts in cellular communication, such as cell splitting and frequency reuse.

CO2: Explain the basic principle and methods used in communication systems.

- **LO2.1:** Describe the process and importance of Huffman coding and Shannon-Fano coding.
- **LO2.2:** Explain the principles behind various modulation techniques, including ASK, FSK, BPSK, QPSK, 8PSK, 16PSK, and QAM.
- **LO2.3:** Describe the architecture of cellular mobile communication networks.

CO3. Apply suitable techniques for a good communication system.

- **LO3.1:** Apply different modulation techniques to transmit digital data.
- **LO3.2:** Utilize scattering parameters and vector network analyzers to measure antenna performance.

CO4. Analyze different techniques used in communication system

- **LO4.1:** Compare different multiple access methods in terms of their advantages and disadvantages.

LO4.2: Analyze the impact of pulse repetition frequency on radar performance.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual		LO1.1 LO2.3		LO4.1		
Conceptual		LO1.2 LO1.3 LO1.4 LO2.1 LO2.2	LO3.1 LO3.2	LO4.2		
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	M	M	M	S	M	M	S
CO2	S	S	M	S	M	M	M	M	M	M
CO3	M	S	M	S	M	M	S	M	M	S
CO4	S	S	M	M	M	M	S	M	M	S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: Information Theory
Information Theory**:** Measure of Information, Source Encoding, Entropy, Channel capacity, Shannon-Hartley Theorem, Error Correcting codes: Hamming code, linear block codes, cyclic codes, Huffman coding, Shannon-Fano coding, code tree & Trellis diagram.
(L 6, H 6, M 6)

Unit II: Digital Data Transmission and Modulation Techniques
Sampling theorem, quantization, Dynamic range, Companding, Pulse code modulation (PCM), Delta modulation, granular noise, slope overloading, adaptive delta modulation, differential PCM, Concept of bit rate, baud, bandwidth, ASK, FSK, BPSK, QPSK, 8PSK, 16PSK, QAM, probability of error and bit error. **(L 12, H 12, M 12)**

Unit III: Spread Spectrum and Multiple Accessing
Frequency hopping, DSSS.CDMA, TDMA, FDMA. **(L 6, H 6, M 6)**

Unit IV: Microwave Communication
Loss in free space, microwave frequencies and bands, propagation of microwaves, effective height of antenna in LOS communication, field strength of tropospheric waves, atmospheric effects on propagation, Fresnel zone problem, ground reflection, fading sources.
(L 10, H 10, M 10)

Unit V: Antennas
Basic antenna theory, beam-width, directivity, antenna efficiency, gain, Hertzian dipole, dipole arrays, folded dipole, log-periodic antenna, UHF and microwave antennas, microstrip antenna, scattering parameters and their measurements, vector network analyzer.
(L 7, H 7, M 7)

Unit VI: Radar Systems
Radar block diagram and operation, radar frequencies, pulse considerations, radar range equation and derivation, pulsed and CW radar, minimum detectable signal, pulse repetition frequency. **(L 5, H 5, M 5)**

Unit VII: Cellular Communication
Cell splitting, frequency reuse, roaming and hands off, architecture of cellular mobile communication network, AMPS, IS, GSM system of communication, GPRS, EDGE, 3G and 4G systems. Frequency bands in cellular Communication. **(L 7, H 7, M 7)**

Unit VIII: Satellite Communication
Satellite orbits, geostationary satellites, antenna look angles, frequency allocations, satellite system link models, up link, down link, cross link, transponders, satellite system parameters, satellite system link equation. **(L 7, H 7, M 7)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Suggested Readings:

1. Advanced Electronic Communication Systems, *W. Tomasi*, Pearson Education India.
2. Principles of electronic communication systems, *L. E. Frenzel*, McGraw Hill Education.
3. Electronic Communication Systems, *G. Kennedy, Davis, Prasanna*, McGraw Hill Education.
4. Microwave Devices and Circuits, *S Y Liau*, Pearson Education India.
5. Introduction to RADAR Systems, *M Skolnik*, Tata McGraw Hill Education.
6. Data and Computer Communications, *W. Stallings*, Pearson Education India.
7. Antenna and Wave Propagation, *J D Kraus, R.J. Marhefka*, McGraw Hill Education.
8. Microwave and RADAR engineering, *M. Kulkarni*, Umesh Publication.
9. Modern Digital and Analog Communication Systems, *Lathi, Ding*, Oxford University Press.

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Course title: Space Physics
Course code: PHY-DSE-IIIF
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description and Objectives: Space physics is a broad discipline covering from cosmology to solar physics. The near earth space is extensively studied and used to provide practical solutions to many societal problems. It's an applied discipline of physics where understanding of the physics related to upper atmospheric layers, the Sun and space weather is combined with satellite and ground measurements. Space technology is an offshoot of space physics and India's strong presence in space technology is increasingly being leveraged for economic gains and to provide employability. Therefore, this course aims to introduce students to the earth's outer environments where satellites orbit the Earth in presence of solar influences. Methods of probing these environments and implication of space weather are discussed. A brief glimpse of radio astronomy is provided.

Course Outcomes (COs): Student will able to

CO1: Explain the different stratification of the upper atmosphere and their implication for humans.

- **LO1.1:** Explain and differentiate the atmospheric stratifications
- **LO1.2:** Describe Chapman's hypothesis and the processes involved in ion production and loss in the ionosphere.
- **LO1.3:** Explain the formation and characteristics of D, E, and F1/F2 layers in different latitudes.
- **LO1.4:** Evaluate the morphological features of equatorial, low, middle latitude ionospheres, considering local time, seasonal, and solar cycle variations.

CO2: Explain the phenomenon of space weather and apply the fundamental knowledge to analyze the impact of space weather.

- **LO2.1:** Describe the structure of the Sun and the solar cycle.
- **LO2.2:** Explain the formation of the solar wind in the corona and its interaction with Earth's magnetosphere.
- **LO2.3:** Analyze the formation and characteristics of Earth's magnetosphere.
- **LO2.4:** Evaluate the effects of solar phenomena such as solar flares and Coronal Mass Ejections (CMEs) on geomagnetic activity.

CO3: Explain and evaluate different techniques of probing space environments

- **LO3.1:** Compare and contrast in situ and remote measurement techniques used in ionospheric and space weather studies.
- **LO 3.2:** Describe the principles and applications of instruments such as Langmuir probes, ionosondes, radar systems, and radio occultations.
- **LO 3.3:** Explain the use of energetic particle detectors, coronographs, and magnetometers in space environment studies.

CO4: Evaluate satellite missions and models for applicability to space weather study.

- **LO4.1:** Define orbital terms and coordinate systems used in satellite missions.
- **LO4.2:** Analyze the atmospheric effects on satellite communications and navigation systems like GPS/GNSS/IRNSS.
- **LO4.3:** Evaluate the accuracy and limitations of ionospheric and space weather models

such as IRI and SAMI2.

CO 5: Demonstrate the understanding of the principles and techniques used in radio astronomy.

LO5.1: Differentiate between radio astronomy and optical astronomy, describing the unique properties of radio waves.

LO5.2: Explain the discovery and characteristics of cosmic microwave background radiation.

LO5.3: Define and calculate radio astronomy terms such as flux density and spectral power.

LO5.4: Describe the principles of radio telescopes and interferometry in radio astronomy.

LO5.5: Analyze the capabilities and contributions of major radio telescopes and arrays like the GMRT and Event Horizon Telescope.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual	LO1.1 LO 5.2 LO 5.3	LO2.1 LO 5.2	LO 3.1			
Conceptual		LO1.3 LO2.2 LO 3.2 LO3.3 LO 4.1 LO 5.3 LO 5.4 CO1 CO 5	LO2.3 LO4.2 LO 5.1 CO2	LO2.3 LO 5.5	LO 1.4 LO 2.4 LO 4.3 CO 3 CO4	
Procedural		LO1.2				
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	M	M	M	S	S	M	S
CO2	S	S	M	S	M	M	M	M	M	M
CO3	M	S	M	S	M	M	S	S	M	S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: Physics of the Ionosphere

Introduction to atmospheric stratifications, Discovery of ionospheric layers, principle of formation, Chapman’s hypothesis of ion production, ionization by EUV and energetic particles, Loss process: chemical recombination, alpha and beta Chapman, vertical transport and diffusion, Formation of D, E, and F1 and F2 layers, morphological features of equatorial/low and middle latitude ionosphere, local time, seasonal and solar cycle variations, brief idea of planetary ionospheres. **(L 18, H 18, M 18)**

Unit II: Physics of the Space Weather

Structure of the Sun, solar cycle, solar wind, solar wind formation in the corona, formation of magnetosphere, magnetosphere of earth-size, characteristics, currents, solar wind interaction with the magnetosphere, solar flares, CME, Geomagnetic effects, study of solar phenomena from L1 point. **(L 15, H 15, M 15)**

Unit III: Measurement Techniques

In situ and remote measurement techniques-Langmuir probe, ionosonde, radar systems, radio occultations, energetic particle detectors: Electrostatic analyzer, Channel multiplier; Coronagraph, magnetometer, ellipse geometry and definition of orbit terms/elements, coordinate systems, different orbits: Keplerian orbits, polar, sun synchronous, geosynchronous, and geostationary, Molniya orbits, LEO, MEO, GEO etc. atmospheric effect on satellite, satellite navigation and positioning, GPS/GNSS/IRNSS systems. Models of the ionosphere: IRI, SAMI2 etc. **(L 15, H 15, M 15)**

Unit IV: Radio Astronomy

Introduction to Radio Astronomy and comparison with optical astronomy, Cosmic microwave background: discovery, power, spectral power, brightness, discrete radio sources, flux density, radio sky, galactic radio noise, radio sources, Fundamentals of radio telescopes, breakdown of a radio telescope, interferometry, Array telescopes: Giant Metre-wave Radio Telescope (GMRT), Event Horizon Telescope. **(L 12, H 12, M 12)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Suggested Readings:

1. Earth's Ionosphere, Plasma Physics and Electrodynamics, *M. C. Kelley*, Academic Press.
2. The Solar Terrestrial Environment, *J. K. Hargreaves*, Cambridge University Press.
3. Introduction to Ionospheric Physics, *Henry Rishbeth and Owen K. Garriott*, Academic Press.
4. Space Plasma Physics, *A. C. Das*, Narosa Publishing House.
5. Radio Astronomy, *J. D. Kraus*, McGraw Hill.

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SEMESTER X

Group IV (Compulsory)
(Any one from this group to be chosen)

Course title: High Energy Physics II
Course code: PHY-DSE-IVA
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This is the second and last course of high energy physics in this programme. This course is designed for students who have already taken the first course, High Energy Physics I in their previous semester. From this present course, they will learn about how group theory can be used to construct the quark model, i.e. the theoretical basis of the quark model. Then they will learn about the theory of weak interaction along with some associated mechanisms and laws or theorems. They will also learn about the gauge theories, which are the backbones of different quantum field theories of high energy physics, and the mechanisms of symmetry breaking in different gauge theories. The mechanisms of symmetry breaking in gauge theories lead to the generation of masses to the quanta or particles of a field via the Higgs mechanism, which is the basis of the standard electroweak theory. Hence, they will learn about the formalism of the standard electroweak theory. Here students will also learn about Higgs bosons and its discovery. Finally, students will be able to learn the shortcomings of the standard model of high energy physics and subsequently will learn the elementary ideas of physics beyond the standard model.

Course Objectives: High energy physics is one of the areas of study in physics, which forms with the basic theories of most of the subatomic physical phenomena occurring in nature. Considering its importance, we included this second course of high energy physics for students of this programme with the following objectives:

1. Introduce to the students the formulation of group theory used in high energy physics.
2. Understand the application of group theory in the quark model and different interactions by students.
3. Understand the mechanisms and theory of weak interaction by students.
4. Introduce to the students the basics of gauge theories.
5. Understand the concept of spontaneous symmetry breaking in gauge theories by students.
6. Introduce to the students the development of new physics beyond the standard model.

Course Outcomes (COs): The students will able to
CO1: Describe the quark model in terms of group theory.
LO1.1: Explain the symmetry groups in physics.
LO1.2: Understand the group theoretical formalisms.
LO1.3: Illustrate the quark model from the group theoretical approach.

CO2: Understand the theory of weak interaction.

LO2.1: Define CP violation and CPT theorem.

LO2.2: Explain different weak decay modes.

LO2.3: Describe the V-A theory of weak interaction.

LO2.4: Illustrate the role of flavour mixing mechanisms in weak interactions.

CO3: Apply the group theory in gauge symmetries and these symmetry breakings.

LO3.1: Define Noether's theorem, gauge symmetries, Spontaneous symmetry breaking and Goldstone boson.

LO3.2: Understand the Abelian and non-Abelian gauge theories, and Higgs mechanism.

LO3.3: Utilize the spontaneous local gauge symmetry breaking and Higgs mechanism to develop the electroweak theory.

CO4: Analyze the success and drawbacks of the standard model.

LO4.1: Understand the importance of physics beyond the standard model.

LO4.2: Describe the basics of different theories beyond the standard model.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual	LO1.1 LO2.1 LO3.1	LO1.2				
Conceptual		LO1.3 LO2.2 CO1	LO2.3 LO2.4 CO2			
Procedural			LO3.2 LO3.3 CO3	LO4.1 LO4.2 CO4		
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S	M		S			M
CO2	S	S	S	S	M		S			M
CO3	S	S	S	S	M		S			M
CO4	S	M	S	S	M		S			M

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: Group Theory and The Quark Model

Symmetries in physics, Lie groups, unitary and special unitary groups (U(1), SU(2) and SU(3)), tensor method in SU(N), Young tableaux, isospin symmetry the quark model, quark-mass formulas, Zweig rule, quark color, hadron wave functions, quark model predictions: magnetic moment, hadron masses. **(L 16, H 16, M 16)**

Unit II: Weak Interactions
Decays of muon, neutron and charged pions, charged current weak interactions, neutral current weak interactions, V-A theory of weak interaction, Cabibbo angle, weak mixing angle (GIM mechanism), CP violation, CPT theorem. **(L 6, H 6, M 6)**

Unit III: Gauge Theories
Noether's theorem, gauge symmetries (global and local), gauge principle, U(1) Abelian gauge theory of electromagnetic interaction, non-Abelian gauge theories (Yang-Mills field theory). **(L 10, H 10, M 10)**

Unit IV: Symmetry Breaking in Gauge Theories
Spontaneous symmetry breaking, Goldstone theorem and Goldstone bosons, Higgs mechanism and Higgs boson, standard electro-weak theory (Glashow-Weinberg-Salam theory), Large Hadron Collider and Discovery of Higgs boson. **(L 22, H 22, M 22)**

Unit V: Elementary Ideas of Physics Beyond the Standard Model
Particle physics cosmology interface, grand unified theories (GUTs) and proton decay possibilities, supersymmetry and minimal supersymmetric standard model (MSSM), neutrino oscillation and neutrino mass, magnetic monopoles, solitons, instantons, string and superstring theories, extra dimensions. **(L 6, H 6, M 6)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Suggested Readings:

1. Introduction to Elementary Particles, *D. J. Griffiths*, John Wiley & Sons.
2. Quarks and Leptons, *Francise Halzen, Alan D. Martin*, John Wiley & Sons.
3. Introduction to High Energy Physics, *Donald H. Parkings*, Cambridge University Press.
4. Gauge Theory of Elementary Particle Physics, *T. P. Cheng, L.F. Li*, Oxford University Press.
5. Physics of Elementary Particles, *H. Muirhead*, Pergamon Press.
6. Quantum Field Theory, *Lewis H. Ryder*, Cambridge University Press.
7. An Introduction to Quantum Field Theory, *M. E. Paskin, D.V. Scroeder*, Levant Books.
8. Field Quantization, *W. Greiner, J. Reinhardt*, Springer.
9. A First Book of Quantum Field Theory, *A. Lahiri, P.B. Pal*, Narosa.
10. QFT Lecture Notes I and II, *David Tong*, Cambridge University.

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Course title: Astrophysics and Cosmology II
Course code: PHY-DSE-IVB
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This is the second and last course on astrophysics and cosmology offered to the students of this programme. From this course, students will learn about the general theory of relativity (GTR), predictions and applications of GTR, cosmology and the early Universe. From the GTR unit students will learn about the formulation of Einstein's field equations of GTR along with various principles on which it is based as well as the relation between the mass and the curvature of spacetime. They will also learn about the Newtonian approximation of Einstein's field equations, Schwarzschild solution in different coordinates, Schwarzschild black holes and Kerr black holes. From the next unit, the students will learn about various predictions of GTR including, perihelion precession of Mercury, banding of light, gravitational redshift, gravitational lensing and gravitational waves. Also, they can learn some astrophysical applications, such as to derive TOV equations and to get the solutions of neutron stars. The cosmological unit will provide an opportunity to study the Universe from wide perspectives from the theoretical point to observational consequences. It covers Einstein's steady-state Universe to FRW expanding Universe to accelerating Universe, dark energy, dark matter models to alternative theories of gravity. The last unit is designed to learn about the introductory ideas of the early Universe covering the energy scale of this Universe, the Big Bang, inflation, the problem of baryon asymmetry, topological defects etc.

Course Objectives: Astrophysics and cosmology are subjects that deal with mankind's never-ending curiosities about our Universe and its constituents. Currently, these are very active and emerging fields of research in physics. Therefore, the study of these fields at the postgraduate level is very important to understand our Universe as a whole and to gather the working knowledge for the future research careers of physics students. Taking into account the importance, this second course of astrophysics and cosmology is included in this programme with the following objectives:

At the completion of this course, a student will be able to

1. Understand clearly the GTR and its range of applications.
2. Apply the concept of GTR to solve problems of astrophysics and cosmology.
3. Get a clear view on the present and early states of the universe, and related unsolved issues.
4. Understand the basics and necessities of the modified theories gravity.

Course Outcomes (COs): The students will able to

CO1: Understand the General Theory of Relativity (GTR), its predictions and applications.

- **LO1.1:** Explain the principle of equivalence, general covariance and spacetime curvature.
- **LO1.2:** Describe Einstein field equations and Newtonian approximation.
- **LO1.3:** Illustrate Schwarzschild solution, its forms in different coordinate systems and different forms of black holes.
- **LO1.4:** Discuss various predictions of GTR and its wide range of applications

CO2: Discuss cosmology, its parameters, current state and the early state of the Universe with its components.

- **LO2.1:** Explain the various cosmological models.

LO2.2: Describe different cosmological observations and their implications and laws.
LO2.3: Illustrate the dark matter and dark energy from different scalar field models.
LO2.4: Interpret the current accelerating phase of the Universe from the perspectives of alternative theories of gravity.
LO2.5: Recognize the limitations of classical cosmology to apply in the early Universe.

CO3: Apply GTR and alternative theory of gravity.
LO3.1: Calculate different black hole solutions from GTR.
LO3.2: Develop different models of black hole solutions from alternative theories of gravity.
LO3.3: Utilize the black hole solutions from GTR and alternative theories of gravity to study different modes of gravitational waves.

CO4: Analyze the compact stars' solutions obtained from GTR and alternative theories of gravity.
LO4.1: Distinguish neutron star and black hole solutions from GTR and alternative theories of gravity in terms of observable characteristics.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual	LO1.1	LO1.2 LO1.3 LO1.4 CO1				
Conceptual	LO2.1	LO2.2 CO2	LO3.1			
Procedural		LO2.3 LO2.4 LO2.5	LO3.2 LO3.3 CO3	LO4.1 CO4		
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S	M		S			M
CO2	S	S	S	S	M		S			M
CO3	S	S	S	S	M		S			M
CO4	S	S	S	S	M		S			M

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: General Theory of Relativity (GTR)
Principle of equivalence, general covariance, spacetime metric, geodesic equation, gravity as curvature of spacetime, Bianchi identities, energy momentum tensor, Einstein's field equations, Newtonian approximation, Schwarzschild solution, Birkhoff's theorem, Kruskal-Szekeres coordinates, Kerr metric and rotating black holes. **(L 20, H 20, M 20)**

Unit II: Predictions and Applications of GTR

Bending of light, gravitational red-shift, precession of perihelion of Mercury; gravitational lensing, gravitational waves; astrophysical application: neutron stars, Oppenheimer-Volkov equation. **(L 12, H 12, M 12)**

Unit III: Cosmology

Einstein's universe, de Sitter solution, expanding universe, cosmological principles, Robertson-Walker (RW) metric, kinematics of RW metric, Hubble's law, luminosity distance, Friedmann equations, Hot Big Bang model, radiation era, matter-radiation decoupling, CMBR, steady state theory, quasi steady state cosmology (introductory discussion only), dark matter, accelerating universe, dark energy (cosmological constant, quintessence, phantom field), alternative theories of gravity. **(L 20, H 20, M 20)**

Unit IV: Early Universe

Limits of classical cosmology, Planck era, inflation, scalar fields, baryon asymmetry, big-bang nucleosynthesis, topological defects. **(L 8, H 8, M 8)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Suggested Readings:

1. An Introduction to Cosmology, *J. V. Narlikar*, Cambridge University Press.
2. Gravitation and Cosmology, *S. Weinberg*, John Wiley & Sons.
3. General Relativity and Cosmology, *S. Banerji and A. Banerjee*, Elsevier.
4. General Relativity and Cosmology, *S. K. Srivastava*, Prentice-Hall of India.
5. Astrophysics: A Modern Perspective, *K. S. Krishna Swamy*, New Age International Publisher.
6. Gravity: An Introduction to Einstein General Relativity, *James B. Hartle*, Pearson Education.
7. General Theory of Relativity, *P. A. M. Dirac*, Prentice-Hall of India.
8. Principles of Cosmology and Gravitation, *M. V. Berry*, Overseas press.
9. Cosmology, *S. Weinberg*, Oxford University Press.
10. Modern Cosmology, *Scott Dodelson*, Academic press.

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Course title: Physics of Black Holes
Course code: PHY-DSE-IVC
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This is an introductory level course on the theories associated with black holes. Starting with introductory ideas about black hole, the syllabus covers a wide range of topics that include the physics of Schwarzschild black hole, Reissner-Nordstrom black hole, Kerr black hole, uniqueness theorems, energy conditions finally culminating in a discussion of black hole thermodynamics.

Course Objectives: The aim of this course is to

1. To introduce the learners with the fascinating world of black holes.
2. To enable the learners in developing ideas about the theory of black holes.
3. To update the learners about recent developments in black hole physics.
4. To motivate students to pursue research in black holes.

Prerequisites: Theory of Relativity.

Course Outcomes (COs): At the completion of this course, a learner will be able to

CO1: Understand the basic concepts and ideas in black hole physics.

- **LO1.1:** Define key terms in black hole physics.
- **LO1.2:** Explain the rules governing black hole physics.
- **LO1.3:** Describe a black hole in terms of its properties.

CO2: Apply the concepts learnt to different black hole systems.

- **LO2.1:** Use the concepts learnt to solve problems associated with black holes.
- **LO2.2:** Interpret the thermodynamic phase structure of black holes.

CO3: Analyze a problem in black hole thermodynamics.

- **LO3.1:** Examine the thermodynamic behavior of any black hole system.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual	LO1.1	LO1.2 LO1.3 CO1	LO2.1 LO2.2 CO2	LO3.1 CO3		
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S			S	S		S
CO2	S	S	S	S			S	S		S
CO3	S	S	S	S			S	S		S

Course Contents:

Unit I: Introduction and Motivation
Gravitational collapse, The Chandrasekhar limit, Neutron stars, Black holes in Newtonian gravity, Black holes in General Theory of Relativity, Significance of studying black holes. **(L 5, H 5, M 5)**

Unit II: The Schwarzschild Black Hole
Test particles: geodesics and affine parametrization. Symmetries and killing vectors, spherically symmetric pressure free collapse, Carter-Penrose diagrams, the event horizon, black holes vs. naked singularities. **(L 20, H 20, M 20)**

Unit III: Charged and Rotating Black Holes
Charged black holes: Reissner-Nordstrom, Cauchy horizons, Isotropic coordinates for RN.
Rotating black holes: Uniqueness theorem, The Kerr solution, angular velocity of the horizon, the Ergosphere, The Penrose process: Limits to energy extraction, Super radiance.
Energy and angular momentum: Covariant formulation of charge integral, ADM energy, Komar integrals, Energy conditions. **(L 20, H 20, M 20)**

Unit IV: Black Hole Mechanics
Laws of black hole mechanics: Zeroth law, Smarr's formula, First law, Second law, Hawking radiation, black hole thermodynamics. **(L 15, H 15, M 15)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Lecture Notes on Black Holes, *P.K. Townsend,* arxiv:gr-qc/9707012.
2. Gravitation and Cosmology, *S. Weinberg,* Wiley Publications.
3. Lecture Notes on General Relativity, *David Tong,* Cambridge University Press.
4. Lecture Notes on Cosmology, *David Tong*, Cambridge University Press.

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Course title: Condensed Matter Physics II
Course code: PHY-DSE-IVD
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This is a continuation of Condensed Matter Physics I course covering a number of advanced topics on the subject. These topics include: lattice vibrations, thin films, semiconductors and their optical properties.

Course Objectives: The aim of this course is to

1. Acquaint a learner with a few advanced and important topics in condensed matter physics.
2. Provide a learner an in-depth account of thin films, semiconductors and their optical properties.

Prerequisites: Condensed Matter Physics (Core) I and II, Condensed Matter Physics I (DSE).

Course Outcomes (COs): At the completion of this course, a learner will be able to

CO1: Understand a few advanced topics in condensed matter physics.

LO1.1: Define key terms and operations related to lattice vibrations, thin films and semiconductors.

LO1.2: Explain the physics of thin films and semiconductors.

LO1.3: Describe the preparation methods of thin films and semiconductors.

CO2: Apply the basic concepts learnt to build further knowledge.

LO2.1: Solve advanced level physics problems based on the key concepts learned.

LO2.2: Interpret ongoing research work in the field with the concepts learned.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual	LO1.1	LO1.2 LO1.3 CO1	LO2.1 LO2.2 CO2			
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S			M	M		S
CO2	S	S	S	S			M	M		S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: Lattice Vibrations

Harmonic approximation, monatomic and diatomic linear lattices, dispersion relations, normal modes, Phonons, infrared absorption in ionic crystals, lattice dynamics in three dimensions (harmonic & adiabatic approximation), Normal modes of a monatomic 3-dimensional Bravais lattice.

Quantum theory of harmonic crystal, lattice specific heat, anharmonic effects, thermal expansion, the Gruneisen parameter, normal and umklapp processes. **(L 15, H 15, M 15)**

Unit II: Thin Films
Introductory concepts, methods of preparation of thin films (vacuum evaporation, chemical vapour deposition, sputtering), thickness determination, conductivity of thin films, effect of thickness on transport properties, Thomson's theory and Fuch's theory, elementary concepts of surface crystallography, surface structure analysis of thin films (SEM, TEM and AFM).
(L 20, H 20, M 20)

Unit III: Semiconductors
Introductory Concepts, Rectifying properties of barriers, Schottky theory of M.S contact, surface states, p-n junction rectifiers.

Photovoltaic device principles, solar cell, temperature effect, solar cell materials, efficiency.
(L 10, H 10, M 10)

Unit IV: Optical Properties
Optical and high frequency effects in semiconductors, optical constants, free carrier absorption, fundamental absorption, direct and indirect transitions.

Electronic interband and intraband transitions, relation between optical properties and band structure, optical constants, luminescence. **(L 15, H 15, M 15)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Suggested Readings:

1. Introduction to Solid State Theory, *O. Madelung*, Springer-Verlag.
2. Quantum Theory of Solid State, *J. Callaway,* Academic Press.
3. Theoretical Solid State Physics, *A. Huang,* Elsevier.
4. Handbook of Thin Film Technology, *Michelle and Glang*, McGraw Hills.
5. Semiconductors, *R. A. Smith,* Cambridge university Press.
6. Thin Film Fundamentals, *A. Goswami,* New Age International.
7. Physics of Semiconductor Devices, *S. M. Sze,* Wiley.

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Course title: Digital and Optical Electronics
Course code: PHY-DSE-IVE
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Objectives: Digital electronic Signals and signal processing is one of the most important domains of modern electronics science. Signal processing systems or processors have revolutionized the way enhanced hardware performance can lead to new applications and products. Similarly optical electronics and communication systems based on optical fibers have ushered the era of infinite bandwidth leading to the concept of communication super highways. This has enabled the growth of globalization as distances are shortened drastically by the speed of light communication. Therefore, this course aims to briefly introduce ideas of digital signals and processing methods before providing in-depth coverage of optical communication systems.

Prerequisites: Idea of electronic signals, Differential Equations, Fourier and Laplace transforms, Electromagnetic theory, Communication basics.

Course Outcomes (COs): At the completion of this course, a learner will be able to

CO1: Understand Digital Signal Processing (DSP).

- **LO1.1:** Define discrete-time signals and classify them based on energy and power.
- **LO1.2:** Explain the fundamental operations in DSP such as convolution, Fourier transform, and Z-transform.
- **LO1.3:** Analyze the stability of systems using pole-zero analysis.

CO2. Understand Optical Fiber Fundamentals.

- **LO2.1:** Describe the characteristics of optical fibers and their advantages over traditional electronic systems.
- **LO2.2:** Explain the propagation of electromagnetic waves in optical fibers, including reflection, refraction, and dispersion.
- **LO2.3:** Classify optical fibers based on construction and material, and
- **LO2.4:** Analyze fiber losses and dispersion effects.

CO3. Evaluate Optical Components and Systems.

- **LO3.1:** Identify and explain the operation of optical sources (LEDs, diode lasers), detectors (photodiodes, PIN, APDs), and amplifiers (SOA, EDFA, Raman).
- **LO3.2:** Understand modulation techniques and their applications in optical communication systems.
- **LO3.3:** Analyze optical components like couplers, filters, and multiplexers in the context of optical communication systems.

CO4: Design Optical Fiber Links.

- **LO4.1:** Design optical communication systems considering power budget, multiplexing techniques (e.g., WDM), and dispersion management.
- **LO4.2:** Evaluate the performance and limitations of optical fiber systems.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual	LO1.1 LO 2.1	LO 2.3				
Conceptual		LO1.2 LO2.1 LO 2.2 LO 3.2 CO1 CO2	LO1.3 LO 3.1	LO 1.3 LO 2.4 LO 3.3	LO3.1 LO 4.2 CO3	LO 4.1 CO 4
Procedural						LO 4.1
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	W	S	S	M	W	W	M	S	W	S
CO2	S	S	S	M	W	W	M	M	W	M
CO3	S	S	M	S	M	W	S	M	W	S
CO4	M	S	M	S	M	W	S	S	W	S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: Introduction to Digital Signal Processing

Introduction to digital signals-discrete time signals, classification: power and energy signals, deterministic and random signals etc. Digital processing systems, Introduction to Discrete Time Linear Invariant signals, Impulse response and convolution, Digital Fourier Transform- FFT, Z-transform, pole zero analysis for stability, implication of poles and zeros location, Finite duration and infinite duration impulses, FIR and IIR filters. **(L 15, H 15, M 15)**

Unit II: Optical Fiber

The optical regime in electro-magnetic spectrum: characteristics, advantages/disadvantages. Advantage over electronic systems: faster, higher bandwidth, economic, security etc. Ray picture and wave picture. Maxwells' equations and propagation of electro-magnetic waves in dielectric medium, reflection and refraction at interfaces, phase and group velocity, concept of coherence, spatial and temporal coherence.

Total internal reflection, evanescent waves and scattering of light in an attenuating medium. Light propagation in plane and circular waveguides, Numerical Aperture, Optical fiber classification, material and construction, modes of propagation, Step index and communication grade fibers, graded index fibers, losses in fibers, different loss processes, loss windows, properties, attenuation, dispersion- modal, chromatic and waveguide dispersion, dispersion compensation, DCF, idea of solitons, new fiber designs and Plastic fibers. **(L 20, H 20, M 20)**

Unit III: Optical Sources, Amplifiers and Detectors

Semiconductor optoelectronic materials, Source: LED, LASER, Diode as lasing medium, LASER basics, semiconductor LASER diode, device structure (hetero junction), materials and characteristics, longitudinal modes of the cavity, DFB and DBR. Photo detectors, semiconductor detectors, Photo diode, P-I-N photodiode, Avalanche photodiode (APD) and photo transistor, Single, Noise in photo-detection; detector performance characteristics.

Optical Amplifiers & Modulators: Semiconductor optical amplifiers (SOA), EDFA and RAMAN amplifier, characteristics and applications, idea of electro-optic and acoustic modulators.

(L 15, H 15, M 15)

Unit IV: Optical Communication System

Basic architecture of an optical communication link, power budget, multiplexing techniques, Wavelength Division Multiplexing (WDM), components of the system: Optical couplers, Tunable sources and filters, optical MUX/DEMUX, Fiber grating, optical add drop multiplexer (OADM), optical circulators, optical cross connects, coherent detection. **(L 10, H 10, M 10)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Suggested Readings:

1. Digital Signal Processing, *J.G. Proakis and D. G. Manolakis*, Printice-Hall International Inc.
2. Optical Electronics, *Ghatak and Thyagarajan*, Cambridge University Press.
3. Fiber Optics, *Ghatak and Thyagarajan*,Cambridge University Press.
4. Optical communications: Components and Systems, *J. H. Franz and V. K. Jain*, Narosa Publications.
5. Optoelectronics An Introduction, *J.Wilson and J.F.B Hawkes* Prentice-Hall of India Pvt.Ltd.
6. Fundamentals of Fibre Optics in telecommunications and Sensor Systems, *Editor:Bishnu Pal,* New Age International Publishers.

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Course title: Physics of Planetary Atmospheres
Course code: PHY-DSE-IVF
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This course provides a comprehensive introduction to the atmospheric sciences of the solar system, focusing on the physical properties and dynamics of planetary atmospheres. It includes the differences between Terrestrial and Jovian planets, including gas and ice giants, and examines the impact of meteorites, asteroids, and space explorations by ISRO, ESA, and NASA. Key topics include the principles of radiative transfer, atmospheric dynamics, and thermodynamics, with applications in remote sensing. Detailed studies of terrestrial planets, including their atmospheric chemistry, climate change impacts, and special phenomena like Martian dust devils and Venusian lightning, are included. The course also covers the unique features of the atmospheres of Jovian planets, their weather patterns, volcanic activities, and significant events like the Great Red Spot.

Course Objectives: The objective of this course is to

1. Introduce the atmospheres of the earth and the other solar system planets.
2. Introduce the physics and chemistry of the planetary atmospheres.
3. Give an introduction to the physical processes in the atmosphere like dynamics, thermodynamics, radiation etc.
4. Understand the atmospheric composition and their impact on the climate.

Course Outcomes (COs): At the completion of this course, a learner will be able to

CO1: Understand the Planetary Atmosphere.

- **LO1.1:** Identify and compare the physical properties of terrestrial and Jovian planets.
- **LO1.2:** Classify between gas giants and ice giants based on their composition and characteristics.
- **LO1.3:** Compare the atmospheric properties and weather phenomena of different solar system planets.

CO2: Assess the importance of Terrestrial and Jovian Planets.

- **LO2.1:** Discuss the evolution and chemical processes of Earth's atmosphere, including ozone chemistry.
- **LO2.2:** Understand the processes driving Martian dust devils and Venusian lightning and volcanism.
- **LO2.3:** Examine the significance of tidal heating and volcanic activities on Jovian planets and their satellites.

CO3: Knowledge in Atmospheric Dynamics and Thermodynamics.

- **LO3.1:** Describe the vertical structure and density distribution of planetary atmospheres.
- **LO3.2:** State laws of conservation and Navier-Stokes equations to atmospheric dynamics.
- **LO3.3:** Apply the concept of Brunt-Väisälä frequency to determine atmospheric stability.

CO4: Evaluate the concept of Earth's Climate and Atmospheric Radiation.

- **LO4.1:** Analyze the impact of radiation processes on the energy balance of planetary atmospheres.
- **LO4.2:** Apply the radiative transfer equation and Beer-Lambert law to atmospheric studies.
- **LO4.3:** Identify the principles of radiative transfer and its application in interpreting remote sensing data to study atmospheric properties.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	**Remember**	**Understand**	**Apply**	**Analyze**	**Evaluate**	**Create**
Factual	LO1.2 LO3.2 LO4.3 CO3					
Conceptual		LO1.1 LO2.1 LO2.2 LO3.1 CO1	LO3.3 LO4.2	LO1.3 LO2.3 CO2	LO4.1 CO4	
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	S	M	S	S	M	M	M	M	M	M
CO2	S	M	S	S	S	M	S	M	M	S
CO3	S	S	M	M	M	M	M	S	M	S

CO4	S	S	M	S	M	M	S	S	S	S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: Introduction

Introduction to other solar system planets and their satellites, Physical properties and chemical composition, similarities and differences among terrestrial planets, difference between Terrestrial and Jovian planets, difference between gas and ice giants, density, mass, shape and size, rotational and revolution parameters differences, Meteorites & Asteroids, Space explorations by ISRO, ESA and NASA.

Atmospheric composition: gases in the atmosphere, Evolution of the Earth's atmosphere, Chemistry of the Earth's atmosphere- stratospheric ozone chemistry- Chapman cycle, limitations of Chapman model, ozone photolysis, ozone distribution, heterogeneous reaction, HOx, NOx, CLOx cycles, ozone hole, tropospheric ozone chemistry.

Atmospheric aerosols-sources, composition, formation mechanism in terrestrial planets, role of trace gases and aerosols in climate change, direct and indirect effects of aerosols on climate, natural versus anthropogenic causes of climate change, introduction to a climate model.

(L 18, H 18, M 18)

Unit II: Radiation and Interaction with the Atmosphere

Absorption and scattering of solar radiation in the Atmosphere- Rayleigh scattering by gas molecules and Mie scattering by particulates, thermal infrared radiation and the greenhouse effect.

Principles of radiative transfer in Planetary Atmospheres- Introduction to radiative transfer, radiative transfer equation, Beer-Bougher- Lambert law, Schwarzschild's equation and solution, equation of radiative transfer for plane-parallel atmosphere and for 3D inhomogeneous media, Application of Radiative transfer knowledge in remote sensing. **(L 10, H 10, M 10)**

Unit III: Atmospheric Thermodynamics

Vertical thermal structure of the atmosphere, Environmental lapse rate, Ideal gas law for the atmosphere, Dalton's law of partial pressure-mean molecular weight of dry and moist air, equation of state for the atmosphere, the first law of thermodynamics and applications- isothermal, isochoric, isobaric transformation, adiabatic transformation, entropy and potential temperature, parcel concept, atmospheric stability, Brunt Vaisala frequency, Humidity, Saturation, Dew point temperature. Adiabatic Cooling, air lifting processes, atmospheric stability, forms of condensation. **(L 12, H 12, M 12)**

Unit IV: Atmospheric Dynamics and Clouds

Atmospheric pressure and density, Hydrostatic equation, density structure of the atmosphere, conservation laws-momentum, mass, energy, Navier-Stokes theorem, Primitive equations, tropospheric dynamics, atmospheric waves and oscillations, moisture in the atmosphere- latent heat, Clausius-Clapeyron's relation, lifting condensation level, cloud formation and dynamics: Raoult's Law, Kelvin's formula, Ways to attain saturation, Formation, Classification, Nucleation of liquid drop, Cloud condensation nuclei, Growth of droplet: Collision coalescence process, Bergeron Process.

Dynamics of other terrestrial planets: Martian dust devils' formation and their effect on the atmosphere, Lightning and volcanism in the Venus atmosphere. **(L 12, H 12, M 12)**

Unit V: Atmosphere of other Solar System Planets

Jovian planets: Physical properties and chemical composition, difference between gas and ice giants, rings in Jovian planets, weather and volcanic activities on Jovian planets, tidal heating, satellite missions.

Special cases like hexagonal storm, dust storms- red spot etc. **(L 8, H 8, M 8)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Suggested Readings:

1. Meteorology for Scientists and Engineers, *R. Stull, Brooks/Cole*, Thomson Learning.
2. Atmospheric Chemistry and Physics, *J. H. Seinfeld and S. N. Pandis*, John Wiley and Sons.
3. Introduction to Atmospheric Physics, *D. G. Andrews*, Cambridge University Press.
4. Fundamentals of Atmospheric Modeling, *M. Z. Jacobson*, Cambridge University Press.
5. An Introduction to Atmospheric Radiation, *K. N. Liou*, Academic Press.
6. Stratosphere-Troposphere Interaction, *K. Mohankumar*, Springer.
7. The Atmosphere: An Introduction to Meteorology, *F. K. Lutgens and E. J. Tarbuck,* Prentice Hall.
8. The Atmosphere and Climate of Mars, *Haberle, R., Clancy, R., Forget, F., Smith, M., & Zurek, R. (Eds.).,* Cambridge: Cambridge University Press.
9. MARS: An Introduction to its interior, surface and Atmosphere, *Nadine Barlow*, Cambridge University Press.
10. Planetary Atmospheres, *F. W. Taylor,* Wiley.
11. Atmospheric Evolution on Inhabited and Lifeless Worlds, Cambridge University Press, ISBN-9781139020558.
12. NASA, ESA and ISRO websites for updated information.

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Group V (In lieu of Dissertation)
(Any one from this group to be chosen)

Course title: String Theory
Course code: PHY-DSE-VA
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This is an introductory level course on string theory. Starting with introductory ideas about relativistic string, the syllabus covers a wide range of topics that include quantum string, open strings and D-brane, superstring theory finally culminating in a discussion of AdS-CFT correspondence.

Course Objectives: The aim of this course is to
1. To introduce the learners with the fascinating world of string theory.
2. To enable the learners in developing ideas about quantum theories of gravity.
3. To update the learners about recent developments beyond the standard model physics.
4. To motivate students to pursue research in string theory.

Prerequisites: Theory of relativity, Quantum Mechanics I and II, Mathematical Physics I, II and III, Classical Mechanics, Statistical Mechanics.

Course Outcomes (COs): At the completion of this course, a learner will be able to
CO1: Understand the basic concepts and ideas in string theory.
  LO1.1: Define key terms in string theory.
  LO1.2: Describe the beyond the standard model physics.
  LO1.3: Explain the rules governing string theory.
CO2: Apply the concepts learnt to different physical systems.
  LO2.1: Use AdS-CFT correspondence to solve problems associated with different physical systems.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual	LO1.1	LO1.2 LO1.3 CO1	LO2.1 CO2			
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S			S	S		S
CO2	S	S	S	S			S	S		S

CO3	S	S	S	S			S	S		S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: Introduction to Relativistic String
Introduction to string theory and its significance, the relativistic point particle: quantization, Einbein. The Nambu-Goto action: symmetries of Nambu Goto action, equations of motion. The Polyakov action: Symmetries of the Polyakov action, Fixing a gauge, mode expansions.
(L 15, H 15, M 15)

Unit II: The Quantum String
Covariant quantization: ghosts, constraints. Light Cone quantization: Light Cone gauge, quantization. The string spectrum: the tachyon, the first excited states, higher excited states. Lorentz invariance. A node to the superstring. **(L 20, H 20, M 20)**

Unit III: Open Strings and D-Branes
Quantization: the ground state, first excited states: a world of light, higher excited states and Regge trajectories, another node to the superstring. Brane dynamics: The Dirac action. Multiple branes: a world of glue. **(L 15, H 15, M 15)**

Unit IV: Introducing AdS-CFT Correspondence
Basics of AdS space and conformal field theory, The correspondence and its dictionary, Large N Gauge theory, Maldacena duality, ABJM duality, Applications of AdS-CFT: hydrodynamics, holographic superconductors, AdS-CMT, SYK Model. **(L 10, H 10, M 10)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Suggested Readings:

1. Lecture Notes on String Theory, *David Tong,* Cambridge University Press.
2. String Theory, *J. Polchinski,* Cambridge University Press.
3. Superstring Theory, *M. Green, J. Schwarz and E. Witten,* Cambridge University Press.
4. A First Course in String Theory, *B. Zwiebach,* Cambridge University Press.
5. Introduction to AdS-CFT, *L. Nastase,* arxiv:hep-th/0712.0689.
6. Lecture Notes on Holographic Methods for Condensed Matter Physics, *S. A. Hartnoll,* arxiv:hep-th/0903.3246.

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Course title: Quantum Field Theory in Solids
Course code: PHY-DSE-VB
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This course provides a comprehensive exploration of theoretical and practical aspects in condensed matter physics and quantum materials. Starting with foundational concepts such as second quantization and field operators, it progresses through advanced topics like mean-field theories, Feynman diagrams, and the physics of strongly correlated systems. The course covers key concepts like electron-electron and electron-phonon coupling mechanisms, progressing to an in-depth study of superconductivity, including BCS theory and magnetic Josephson junctions. In addition, students will learn advanced topics like topological insulators, Majorana fermions and the Quantum Hall Effect etc. The final unit introduces cutting-edge research on two-dimensional materials and exotic quasiparticles, offering insights into recent developments in quantum materials.

Course Objectives: At the completion of this course, a student will be able to

1. Master the principles of quantum field theory with a focus on its applications in Solid State Physics.
2. Apply theoretical frameworks and techniques to describe the quantum properties of materials.
3. Understand the behavior of quasiparticles, electronic structures and collective excitations.

Prerequisites: Fundamentals of Quantum Mechanics, Basic knowledge of Solid-State Physics, Mathematical Physics.

Course Outcomes (COs): The students will be able to

CO1: Understand the foundations of Quantum Field Theory and apply it to solve many body systems.

- **LO1.1:** Explain the concepts of second quantization, the creation and annihilation operators in quantum field theory.
- **LO1.2:** Solve many-body systems using various approximation techniques.
- **LO1.3:** Utilize Feynman diagrams to calculate physical quantities in quantum field theory.

CO2: Understand and analyze Interactions and Collective Phenomena.

- **LO2.1:** Describe the effects of electron-electron and electron-phonon interactions.
- **LO2.2:** Solve the Bogliubov-de Gennes (BdG) equations for homogeneous systems and tight-binding models.
- **LO2.3:** Examine the principles of superconductivity and related phenomena.

CO3: Explain Topological and Low-Dimensional systems.

- **LO3.1:** Understand the fundamental concepts of topological insulators.
- **LO3.2:** Examine the quantum Hall effects and their implications.
- **LO3.3:** Assess strongly correlated systems and advanced quantum materials.

CO4: Investigate Advanced Topics and Current Research in Quantum Materials.

- **LO4.1:** Understand the properties and applications of graphene and other two-dimensional materials.

LO4.2: Compare the nature of exotic quasiparticles such as anyons and Weyl fermions.
LO4.3: Assess recent developments in quantum materials and their importance in technological applications.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual	LO1.1					
Conceptual	LO2.1	LO3.1 LO4.1 LO4.2	LO1.2			
Procedural			LO1.3 CO1 LO2.2	LO2.3 CO2 LO3.2	LO3.3 CO3 LO4.3	CO4
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S	M	M	S	M		S
CO2	S	S	S	S	M	M	S	M		S
CO3	S	S	S	S	M	M	S	M		S
CO4	S	S	S	S	M	M	S	M		S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: Fundamentals of Quantum Field Theory
Introduction to Quantum Field Theory, second quantization, Creation and annihilation operators, Review of Fermi and Bose gases, Field operators and commutation relations in bosonic and fermionic fields.

Many body systems, Hartree - Fock approximation, Mean-field theory and exchange interaction, Ground state properties, Elementary excitations, Time-ordered products and propagators, Dyson series, Feynman diagrams, Calculation of spectral functions and density of states.

(L 8, H 8, M 8)

Unit II: Interactions and Collective Phenomena
Electron-Electron Interactions: Screening effects in metals, Thomas-Fermi and Debye screening, Linear response theory and collective excitations, Plasmons, Dispersion relations and dielectric function. **(L 5, H 5, M 5)**

Electron-Phonon Interactions: Phonon quantization and lattice vibrations, Electron-phonon coupling mechanisms, Frohlich and Holstein models. **(L 5, H 5, M 5)**

Superconductivity: Review of BCS theory: Cooper pairs and energy gap, Bogliubov – de Gennes (BdG) equations, Solution to the BdG equations in homogeneous systems, Abrikosov – Gor’kov

Equations, BdG equations in Tight binding model, Unconventional superconductivity, Josephson junctions and bound states, Formation of Yu – Shiba - Rusinov and Andreev bound states. **(L 12 H 12 M 12)**

Unit III: Topological and Low-Dimensional Systems

Introduction to topological insulators: Time reversal symmetry, Anti-Unitary operation, and Kramers' theorem, Broken time-reversal symmetry, Chiral and helical Edge States. Majorana fermions: theory and potential applications, Topological superconductivity.

Integer Quantum Hall Effect (IQHE), Landau levels and quantized Hall conductance, Fractional Quantum Hall Effect (FQHE), Composite fermions and Laughlin wave function.

Strongly Correlated Systems: Introduction to Mott insulators, Metal-insulator transitions and Hubbard model, theory and applications, Quantum magnetism and spin liquids, Heisenberg model and frustrated magnets, Kondo effect: theory and implications. **(L 17, H 17, M 17)**

Unit IV: Advanced Topics and Current Research

Graphene and other two-dimensional materials, Exotic quasiparticles: Anyons and Weyl fermions, Magnetism in 2D materials: Magnons, Bimerons and Skyrmions. Recent developments in quantum materials and their applications. **(L 5 H 5 M 5)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Quantum Field Theory, *Lewis H. Ryder*, Cambridge University Press.
2. An Introduction to Quantum Field Theory, *M. E. Peskin and D. V. Scroeder,* Levant Books.
3. A First Book of Quantum Field Theory, *A. Lahiri and P. B. Pal*, Narosa.
4. Quantum Field Theory in Condensed Matter Physics, *Alexander Altland and Ben Simons*, Cambridge University Press.
5. Quantum Many-Particle Systems, *John W. Negele and Henri Orland*, CRC Press.
6. Topological Insulators, *Grigory Tkachov*, Taylor & Francis Group.
7. Bogoliubov de Gennes Methods and Its Applications, *Jian – Xin Zhu*, Springer Books.

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Course title: Electronics Laboratory
Course code: PHY-DSE-VC
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Objectives:

1. To allow students to learn the electronic principles using hands-on philosophy.
2. To allow students to design small analog circuit systems like small signal amplifiers, filter comparators etc.
3. To allow students to apply their knowledge for assembly language programming. to do arithmetic operations and make small data processing software.
4. To introduce students to use microprocessors and microcontrollers to interface peripheral devices.
5. To introduce students to the radiation pattern of antennas through measurement.
6. To introduce students to optical electronics components and measurements.

Prerequisites: Electronics-1**,** Optical and Digital Electronics.

Course Outcomes (COs): By the end of this lab course, students will be able to

CO1: Demonstrate an understanding of advanced transistor amplifier configurations and techniques for improving input impedance.

- **LO1.1:** Analyze the effect of bootstrapping on the input impedance of a transistor amplifier.
- **LO1.2:** Design and implement a Darlington pair circuit to achieve a desired input impedance.
- **LO1.3:** Evaluate the performance of the amplifier in terms of input impedance improvement.

CO2: Knowledge and skills in the design and analysis of Yagi antenna arrays with different configurations of director and reflector elements.

- **LO2.1:** Measure and analyze the radiation pattern of each antenna configuration using appropriate instrumentation.
- **LO2.2:** Compare the directional properties and gain of different Yagi antennas.
- **LO2.3:** Interpret the impact of spacing between transmitter and receiver on antenna performance.

CO3: Make use of the 8051microcontroller kit for performing various arithmetic operations and implementing additional computational tasks.

- **LO 3.1:** Utilize the 8051microcontroller kit to perform addition, subtraction, multiplication, and division operations.
- **LO 3.2:** Implement factorial calculation on the 8051microcontroller.
- **LO 3.3:** Develop algorithms and code for sorting a set of numbers in ascending and descending order.
- **LO 3.4:** Create and utilize lookup tables for efficient data retrieval and processing.

CO 4: Understand of the characteristics and applications of single-mode and multi-mode optical fibers.

LO 4.1: Differentiate between single-mode and multi-mode optical fibers based on their construction and transmission properties.

LO 4.2: Measure and compare the attenuation characteristics of single-mode and multi-mode fibers.

CO 5: Experiment with optical fibers for measuring and interpreting the numerical aperture of optical fiber.

LO 5.1: Define numerical aperture and understand its significance in optical fiber performance.

LO 5.2: Design and set up an experimental setup to measure the numerical aperture of an optical fiber.

LO 5.3: Calculate numerical aperture from experimental data using appropriate formulas.

LO 5.4: Compare measured numerical aperture values with theoretical predictions and industry standards.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	**Remember**	**Understand**	**Apply**	**Analyze**	**Evaluate**	**Create**
Factual		LO5.3 CO2				
Conceptual			LO2.3 LO5.4	LO1.1		
Procedural	LO2.1 LO4.1 LO5.1	LO2.2 LO4.2 CO4 CO2	LO3.1 LO3.2 LO3.3, CO3 CO5			LO1.2 LO1.3 LO5.2
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**
CO1	S	M	W	W	S	S	M	M	W	S
CO2	S	M	W	M	S	S	S	W	M	S
CO3	S	S	W	S	S	S	S	W	M	S
CO4	S	S	S	S	M	S	S	M	S	S
CO5	S	S	M	S	S	S	S	M	M	S

(S: Strong, M: Medium, W: Weak)

List of Experiments:

Guidelines: 80% experiments need to be performed for claiming 4 credits. All analog experiments except the antenna radiation pattern are to be assembled by the students in either breadboard or PCB (No-Kit allowed for analog experiments). Each student will use Simulation software like Simulink for designing the analog circuits. The design parameter for each student would be decided by the course teacher and the students final circuit needs to perform as per the design specification. Microprocessor/microcontroller experiments can be conducted using pre-assembled kits but each student is required to write one unique program for passing the course.

1. Darlington pair/bootstrapping to improve input impedance of transistor amplifier.
2. To study the radiation pattern of various types of Yagi antenna elements using a different number of director and reflector elements at different distances between transmitter and receiver.
3. To use 8051 kit for arithmetic operations like addition, subtraction, division, multiplication, factoring etc. One additional experiment to be given to each students to judge his learning like (a) Calculation of factorial (b) Sorting of 5 numbers in ascending and descending order (c) Look-up table creation etc.
4. Study and characterization of single mode and multi-mode of optical fiber.
5. Measurement of optical fiber numerical aperture.

(Total Classes 60, Total Contact Hours 120, Total Marks 60)

Suggested Readings:

1. Microelectronics, *J.Millman and A Grabel*, Mc Graw Hill.
2. Optical Electronics*, A Ghatak and K Thyagarajan*, Cambridge University Press.

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Course title: Space Physics Lab
Course code: PHY-DSE-VD
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Objective: To provide hands-on experience in utilizing different measurement techniques and data sources for studying ionospheric physics and space weather phenomena. Primary aim is to enhance experimental data analysis and interpretation skills related to space weather forecasting applications.

Equipment and Materials required:

1. Desktop computer with internet connection.
2. Ionosonde/GNSS data acquisition system (provided by the laboratory).
3. Data analysis software (e.g., MS Excel, MATLAB, or Python).

Prerequisites:

1. Idea of different **i**onospheric layers (D, E, F1, F2) and their formation.
2. Knowledge of ionosonde operation and the parameters it measures (e.g., electron density profiles, critical frequencies).

3. Knowledge of GNSS operation and TEC.
4. Idea of radio occultation and operational RO missions.

Course Outcomes (COs): By the end of this lab course, students will be able to

CO1: Explain the operation and working principle of measuring instrument like Ionosonde, GNSS TEC estimation.

LO1.1: Understand the working of Ionosonde.

LO1.2: Understand the working of GNSS and estimation of VTEC from time delay.

LO1.3: Understand about virtual and real height and use of POLAN.

LO1.4: Understand about radio occultation geometry.

CO2: Apply the knowledge to extract ionospheric parameters.

LO2.1: Extract parameters such as foF2 (critical frequency of the F2 layer), hmF2 (height of maximum electron density of the F2 layer).

LO2.2: Estimate the Vertical Total Electron Content from GNSS measurements and the vertical density profile.

LO2.3: Identify signatures of ESF, ES, and TID on ionograms.

CO3: Analyze the data to understand.

LO3.1: Analyze temporal and spatial variation of ionospheric parameters.

LO3.2: Analyze the spatio-temporal variation of the altitudinal profile.

CO4: Interpret results in terms of the variability and ionospheric response.

LO4.1: Discuss the variability of the ionospheric parameters due to different drivers.

CO5: Design new experimental scheme using all the available dataset.

LO5.1: Apply the different techniques or data sets to investigate a particular Space weather event.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual		LO2.1, CO2				
Conceptual			LO2.3			
Procedural	LO1.1, LO1.2, CO1		CO2	LO3.1, LO3.2, LO 3.3, CO3	LO4.1, CO4	LO5.1, CO5
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	M	W	W	S	S	M	M	W	S
CO2	S	M	W	M	S	S	S	W	M	S
CO3	S	S	W	S	S	S	S	W	M	S
CO4	S	S	S	S	M	S	S	M	S	S
CO5	S	S	M	S	S	S	S	M	M	S

(S: Strong, M: Medium, W: Weak)

Lists of Experiments:

1. Use ionograms from digital Ionosonde to scale various parameters like foF2, hmF2, foF1, foE and analyze them to find the diurnal and seasonal variations.
2. Use ionograms to identify ESF, ES and TID.
3. Use GNSS data to calculate Total Electron Content and estimate the TEC variability.
4. Use radio occultation data to plot the vertical density profile.
5. Use POLAN to invert the ionograms to real height variation.

(Total Classes 60, Total Contact Hours 120, Total Marks 60)

Suggested Readings:

1. Introduction to Space Physics, *M. G. Kivelson and C. T. Russe*l, Cambridge University Press.
2. Space Plasma Physics: *An introduction, A C Das*, Narosa Publications.

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Group VI (In lieu of Dissertation)
(choose any one from this group)

Course title: Advanced Mathematical Physics
Course code: PHY-DSE-VIA
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This is an advanced level course covering Nonlinear Dynamics, Topology, and Differential Geometry. These three topics have been instrumental in shaping modern theoretical physics.

Course Objectives: The aim of this course is to

1. Develop a basic understanding of nonlinear dynamics, topology and differential geometry.
2. Acquaint a learner with application of these mathematical tools and methods in physics.
3. Develop an adequate amount of mathematical skill among the learners to navigate through advanced concepts in theoretical physics.

Prerequisites: Mathematical Physics-I, Mathematical Physics-II, Mathematical Physics-III.

Course Outcomes (COs): At the completion of this course, a learner will be able to
CO1: Understand a few mathematical concepts and their importance in physics.
- **LO1.1:** Define key terms and operations in nonlinear dynamics, topology and differential geometry.
- **LO1.2:** Explain the rules governing nonlinear dynamics, topology and differential geometry.
- **LO1.3:** Describe a problem in physics in terms of nonlinear dynamics, topology and differential geometry.

CO2: Apply the above mathematical concepts to solve problems.
- **LO2.1:** Solve advanced level mathematical problems based on the key concepts in nonlinear dynamics, topology and differential geometry.
- **LO2.2:** Use the concepts in nonlinear dynamics, topology and differential geometry to solve problems in different areas of theoretical physics.

CO3: Analyze a problem in physics by relating it with the above mathematical concepts.
- **LO3.1:** Relate the learnt mathematical concepts with problems in physics.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual	LO1.1	LO1.2 LO1.3 CO1	LO2.1 LO2.2 CO2	LO3.1 CO3		
Procedural						

Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S			S	S		M
CO2	S	S	S	S			S	S		M
CO3	S	S	S	S			S	S		M

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: Nonlinear Dynamics

Overview: Significance of nonlinearity; one-dimensional flows: flows on the line and the circle, fixed points and stability, existence and uniqueness, impossibility of oscillation, potentials; bifurcations: saddle-node bifurcation, transcritical bifurcation, pitchfork bifurcation, imperfect bifurcations and catastrophes, ghosts and bottlenecks, applications to physical problems; two-dimensional flows: linear systems, classification of linear system; phase plane: phase portraits, fixed points and linearization; chaos: strange attractors, chaos on a strange attractor, Lorentz map, Logistic map, Henon map, Liapunov exponent; Fractals: countable and uncountable sets, self-similarity, dimension of self-similar fractals, applications to physical problems.

(L 20, T 5, M 20)

Unit II: Topology

Overview: topology and geometry in physics, maps, linear maps, images and kernels, dual vector space; topological spaces: definition and types, compactness, connectedness; homeomorphisms and topological invariants; Nielsen-Olensen vortex, topological excitations; homology and homotopy groups; fibre, vector and principal bundles; anomaly, abelian and non-abelian anomaly; some examples and applications. **(L 18, T 5, M 18)**

Unit III: Differential Geometry

Manifolds: Definition, calculus of manifolds; Killing vectors: definition, Killing vector fields, conformal Killing vector fields; non-coordinate bases, differential forms, duality transformation; submanifolds; complex manifolds: definition, calculus on complex manifolds, complexifications, complex differential forms; Hermitian manifolds: definition, Hermitian differential geometry, Kahler form, torsion and curvature; Kahler manifolds: definition, Kahler geometry, Kahler differential geometry; moduli space; matter fields and covariant derivatives; some examples and applications. **(L 22, T 5, M 22)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Suggested Readings:

1. Nonlinear Dynamics and Chaos, *S. H. Strogatz,* Perseus Books Publishing.

2. Stability, Instability and Chaos: An Introduction to the Theory of Nonlinear Differential Equations, *P. Glendinning*, Cambridge University Press.
3. Introduction to Applied Nonlinear Dynamical System and Chaos, *Stephen Wiggins*, Springer.
4. Geometry, Topology and Physics, *M. Nakahara*, IOP Publishing.
5. Calculus on Manifolds, *M. Spivak*, Addison-Wesley Publishing.
6. Topology, Geometry and Gauge Fields, *G. L. Naber*, Springer.
7. Topology and Geometry in Physics, *E. Bick and F. D. Steffen (Eds.)*, Springer.

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Course title: Advanced Quantum Mechanics
Course code: PHY-DSE-VIB
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This is an advanced level course on quantum physics covering scattering theory, relativistic quantum mechanics, path integral formalism and quantum entanglement.

Course Objectives: The aim of this course is to

1. Develop a basic understanding of scattering theory, relativistic quantum mechanics, path integral formalism and quantum entanglement.
2. Acquaint a learner with application of these quantum concepts in different areas of physics.
3. Develop an adequate amount of quantum mechanical skill among the learners to navigate through advanced concepts in physics.

Prerequisites: Mathematical Physics-I, Mathematical Physics-II, Mathematical Physics-III, Quantum Mechanics-I and II.

Course Outcomes (COs): At the completion of this course, a learner will be able to

CO1: Understand a few advanced quantum mechanical concepts and their importance in physics.

- **LO1.1:** Define key terms and operations in scattering theory, relativistic quantum mechanics, path integral formalism and quantum entanglement.
- **LO1.2:** Explain the rules governing scattering theory, relativistic quantum mechanics, path integral formalism and quantum entanglement.
- **LO1.3:** Describe a problem in physics in terms of scattering theory, relativistic quantum mechanics, path integral formalism and quantum entanglement.

CO2: Apply the above quantum mechanical concepts to solve problems.

- **LO2.1:** Solve advanced level problems based on the key concepts in scattering theory, relativistic quantum mechanics, path integral formalism and quantum entanglement.
- **LO2.2:** Use the concepts in scattering theory, relativistic quantum mechanics, path integral formalism and quantum entanglement to solve problems in different areas of

theoretical physics.

CO3: Analyze a problem in physics by relating it with the above concepts.

LO3.1: Relate the learnt quantum mechanical concepts with problems in physics.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual	LO1.1	LO1.2 LO1.3 CO1	LO2.1 LO2.2 CO2	LO3.1 CO3		
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S			S	S		M
CO2	S	S	S	S			S	S		M
CO3	S	S	S	S			S	S		M

(S: Strong, M: Medium, W: Weak)

Course Content:

Unit I: Scattering Theory

The Lipmann-Schwinger Equation, the Born Approximation, Optical Theorem, Eikonel Approximation, Free Particle States: Plane versus Spherical waves, Method of partial waves, Low-energy scattering and Bound states, Resonance scattering, Identical Particles and Scattering.

(L 15, H 15 M 15)

Unit II: Path Integral Quantization

Quantum mechanical law of motion: Classical Action, quantum mechanical amplitude, the sum over paths, examples: the free particle, diffraction through a slit. Path integral as a functional, evaluation of path integrals, perturbation method in quantum mechanics, transition elements.

(L 15, H 15 M 15)

Unit III: Relativistic Quantum Mechanics

Klein Gordon Equation and its solution, Dirac Equation and its solution, Spin angular momentum, Dirac matrices, covariant form of Dirac equation, Fields and its quantization, Quantization of Klein Gordon and Dirac fields. **(L 15, H 15 M 15)**

Unit IV: Quantum Entanglement

Definition, EPR Paradox, Bell's theorem and inequalities, Experimental realizations, Quantum Computing, Quantum Cryptography, Quantum Teleportation. **(L 15, H 15 M 15)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Suggested Readings:

1. Modern Quantum Mechanics, *J. J. Sakurai,* Addison Wesley.
2. Quantum Mechanics, *L. I. Schiff,* McGraw Hill.
3. Quantum Mechanics, *Bransden and Joachain*, Pearson Education.
4. Quantum Mechanics, *Powell and Craseman*, Narosa Publishing House.
5. Quantum Mechanics, *R. Shankar*, Kluwer Academic.
6. Quantum Mechanics, *D. J. Griffiths*, Pearson Education.
7. Quantum Mechanics, *Mathews and Venkatesan*, McGraw Hill.
8. Quantum Mechanics, *Richard L. Liboff*, Pearson Education.

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Course title: Laser and Spectroscopy
Course code: PHY-DSE-VIC
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: Embark on a comprehensive exploration of lasers and spectroscopy in this advanced course. Begin by mastering the fundamental elements of lasers, including the principles of light amplification, laser rate equations for three- and four-level systems, and the crucial role of resonant cavities. Throughout the course, blend theoretical insights with practical applications, preparing students for careers in research, technology development, and advanced spectroscopic methodologies across diverse scientific disciplines.

Course Objectives: The objective of this course is to

1. Acquaint with basic principle and working of lasers.
2. Familiarize with modern trends in spectroscopy.

Course Outcomes (COs): The students will able to

CO1: Understand the fundamentals of laser.

- **LO1.1:** Understand the fundamental principles of lasers.
- **LO1.2:** Analyze the role of resonant cavities and optical modes.
- **LO1.3:** Evaluate diverse types and applications of lasers.

CO2: Apply spectroscopic methods to complex analytical challenges.

- **LO2.1:** Understand the principles and methods of visible and ultraviolet spectroscopy.
- **LO2.2:** State the advantages of lasers in spectroscopy.
- **LO2.3:** Analyze absorption spectroscopy.

CO3: Apply laser spectroscopic methods to cutting-edge research and applications.

- **LO3.1:** Apply optical pumping techniques.
- **LO3.2:** Evaluate laser cooling and trapping techniques.
- **LO3.3:** Design and analyze experiments using optical traps.

CO4: Understanding of linear and nonlinear optical phenomena.

- **LO4.1:** State the principles of linear and nonlinear absorption

LO4.2: Describe and analyze nonlinear interactions.
LO4.3: Evaluate nonlinear optical mixing techniques.
LO4.4: Explain advanced nonlinear Raman effects.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual	LO2.2 LO4.1					
Conceptual		LO1.1 LO2.1 LO4.4 CO1 CO4	LO3.1 CO2 CO3	LO1.2 LO2.3 LO4.2	LO1.3 LO3.2 LO4.3	
Procedural						LO3.3
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	M	M	M	S	S	M	M
CO2	S	S	M	S	S	M	S	S	M	S
CO3	S	M	M	S	M	M	S	S	M	S
CO4	S	S	S	S	M	M	S	S	S	S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: Laser
Basic elements of lasers, laser rate equation for three and four level systems, role of resonant cavity, longitudinal and transverse mode, Stability criterion, Q-switching and mode locking in lasers. Types of lasers: solid state lasers, gas lasers, free electron lasers, fiber lasers, molecular lasers, Dye laser, semiconductor lasers, application of lasers, Holography, Optical communication, pollution monitoring. **(L 15, H15, M 15)**

Unit II: High Resolution Spectroscopy
Visible and ultraviolet spectroscopy, absorption spectroscopy, microwave and radiofrequency spectroscopy, magnetic resonance spectroscopy.

Advantages of Lasers in spectroscopy, Saturation spectroscopy, burning and detection of hole, two photon and multi photon spectroscopy, photo-acoustic spectroscopy, Rosencwaig-Gersho theory, thermally thin and thick samples, depth profiling study. **(L 15, H 15, M 15)**

Unit III: Non-linear Optics
Linear and nonlinear absorption, Description of nonlinear interactions, the coupled wave equations for sum frequency generation and different frequency generation, second harmonic

generation, nonlinear optical –mixing techniques, phase matching consideration, optical parametric oscillator, Phase conjugation: four wave mixing, Tunable Raman lasers.

Nonlinear Raman effect: hyper Raman effect, stimulated Raman scattering, coherent Raman scattering and inverse Raman scattering. **(L 15, H 15, M 15)**

Unit IV: Modern Trends in Spectroscopy
Introduction, Double Resonance Spectroscopy, laser-induced atomic spectroscopy, laser induced breakdown spectroscopy, laser Abalation Molecular Isotopic spectrometry, Laser cooling and trapping of atoms: variation of atomic absorption in an electromagnetic field, polarization gradient of counter propagating laser beams, optical pumping. **(L 15, H 15, M 15)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Suggested Readings:

1. Molecular Spectra and Molecular Structure, *G. Herzberg*, McGraw Hill.
2. Principles of Fluorescence Spectroscopy, *J. R. Lakowicz*, Springer.
3. High Resolution Spectroscopy, *J. M. Hollas*, John Wiley and Sons.
4. Fundamental of Molecular Spectroscopy, *Banwell and McCash*, Tata McGraw Hill.
5. Vibrational Spectroscopy *D. N. Sathyanarayana*, New age international publishers.
6. Introduction to IR and Raman Spectroscopy, *N. B. Colthup*, Science Direct.
7. Laser Spectroscopy, *W. Demtrider*, Springer.
8. Atomic Spectra, Structure and Modern Spectroscopy D. K. Rai and S. N. Thakur Vaivaswat Publication, Varanasi.
9. The Physics and engineering of solid state Lasers, PHI learning, New Delhi.
10. Nonlinear Optics, *R.W. Boyd*, Elsevier, New Delhi.
11. Optoelectronics, *J. Wilson and J. F. B. Hawks*, Prentice Hall India.
12. Physics of Atoms and molecules, B. H. Brasden and C. J. Joachain, Longman.

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Course title: Condensed Matter Physics Lab
Course code: PHY-DSE-VID
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This course is a collection of a number of important condensed matter physics experiments.

Course Objectives: The aim of this course is to

1. Equip a student with different experimental techniques used for determination of various properties of solids.
2. Enhance the laboratory skill of a student which will help a student to experimental research work in the area.
3. Enable a student to understand the subject in some more detail.

Prerequisites:
1. Condensed Matter Physics (Core) I and II.
2. Condensed Matter Physics I and II (DSE).

Course Outcomes (COs): At the completion of this course, a learner will be able to

CO1: Understand the basic concepts in hands-on mode through the basic solid state physics experiments.

LO1.1 Identify key components of the experimental set ups used.

LO1.2: Explain the physics behind the experimental observations.

LO1.3: Describe the steps involved in the experiment with minute details about the procedure.

CO2: Apply the hands on knowledge to further enhance their command over condensed matter Physics.

LO2.1: Relate the experimental findings with the corresponding theory.

LO2.2: Operate the experimental set-ups used.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual	LO1.1	LO1.2 LO1.3 CO1	LO2.1 LO2.2 CO2			
Procedural	LO1.1	LO1.2 LO1.3 CO1	LO2.1 LO2.2 CO2			
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S			M	M		S
CO2	S	S	S	S			M	M		S

(S: Strong, M: Medium, W: Weak)

List of Experiments:
1. To determine the Lange g-factor by Electron Spin Resonance Method.

2. To determine the Curie temperature of phase transition for (a) ferroelectric materials and (b) for ferrites.
3. To determine the Boltzmann Constant.
4. To determine Stefan's Constant.
5. To determine the Neel temperature of an anti-ferromagnetic material by Gouy's method.
6. To prepare and measure the thickness of a thin film.
7. To study the thermo-luminescence of an F-center.
8. To study X-ray diffraction using powder photography.
9. To study the Hall Effect and determine the different parameters.

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Suggested Readings:

1. Introduction to Solid State Physics, *C. Kittel,* John Wiley & Sons.
2. Solid State Physics, *A. J. Dekker*, Macmillan India Ltd.
3. Thin Film fundamentals, *Pallav Chowdhury*, New Age International.
4. Semiconductors, *R. A. Smith*, Cambridge University Press.

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Course title: Atmospheric Physics Lab
Course code: PHY-DSE-VIE
Nature of the course: DSE
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This course offers an in-depth study of atmospheric aerosols and trace gases, emphasizing their measurement, analysis, and impact on environmental and human health. Students will learn to use various advanced instruments and satellite data to assess aerosol optical thickness, column ozone, and black carbon mass concentration.

Course Objectives:

1. Analyze different atmospheric parameters obtained from ground based instruments.
2. Acquainted with handling atmospheric data for various planets from NASA web portal like GIOVANNI, planetary data system etc.
3. Apply programming tools to analyze satellite and reanalysis data sets in cloud platform like google earth engine.

Course Outcomes (COs): After the completion of this course the students will be able to
CO1: Analyze Atmospheric Data from different sources for understanding aerosol types and properties.

LO1.1: Use Multi Wavelength Solar Radiometer (MWR) and Aethalometer for measuring Aerosol Optical Thickness (AOT) and Aerosol Black Carbon (BC) mass concentration.
LO1.2: Interpret the AOT and BC mass concentration values measured from MWR and Aethalometer respectively.
LO1.3: Compare the values of AOT and BC measured from MWR and Aethalometer with the values from NASA Giovanni Web Interface.
LO1.4: Assess the Particle Number Size Distribution from Scanning Mobility Particle Sizer.

CO2: Understand Air Quality and Health Impacts.
LO2.1: Perform elemental characterization and source apportionment of aerosols using spectroscopic techniques.
LO2.2: Analyze PM10 concentrations using aerosol spectrometer and/or reanalysis data set from GIOVANNI portal.
LO2.3: Identify biological aerosols through microscopic analysis using Burkard Pollen Sampler.

CO3: Estimation of Ozone and different trace Gas Levels.
LO3.1: Calculate surface level mass mixing ratio of SO_2, $NO_x(NO+NO_2)$, O_3 and CO using respective gas analyzers and/or TROPOMI onboard Sentinel 5P from google earth engine or OMI/AIRS from Giovanni portal.
LO3.2: Analyze the measured values of surface level mass mixing ratio of SO_2, $NO_x(NO+NO_2)$, O_3 and CO.
LO3.3: Develop Simple Models of the Atmosphere.

CO4: Calculation of Aerosol Optical Depth (AOD) and Dust Layer Height Using Multispectral Camera and Mars Climate Sounder data for Mars.
LO4.1: Explain the concepts of AOD and dust layer height, and their significance in atmospheric studies and climate research.
LO4.2: Apply image processing techniques to analyze images from multispectral cameras (VMC and MCC) for AOD estimation.
LO4.3: Identify dust layers in the atmosphere and estimate their heights using Mars Climate Sounder data.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual		LO2.3 LO4.1 LO4.3 CO2	LO1.1 LO1.2 CO3 CO4	LO1.3 LO2.2 LO3.2 CO1	LO1.4	
Procedural			LO2.1 LO3.1 LO4.2			LO3.3
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	M	S	M	S	S	M	M
CO2	S	S	M	S	S	M	S	S	M	S
CO3	S	M	M	S	S	M	S	S	M	S
CO4	S	S	S	S	S	M	S	S	M	S

(S: Strong, M: Medium, W: Weak)

Lists of Experiments:

1. Study of Aerosol Optical Thickness using a Multi Wavelength solar Radiometer and/or MODIS satellite sensors.
2. Estimation of column ozone using satellite data over an area of interest.
3. Estimation of Aerosol Black Carbon mass concentration using an Aethalometer and/or reanalysis product available in NASA Giovanni web interface.
4. Study of atmospheric boundary layer using ceilometer lidar.
5. Study of cloud base heights using ceilometer lidar.
6. Calculate the Particle Number Size Distribution (PNSD) with different size regime using Scanning Mobility Particle Sizer (SMPS).
7. Estimation of surface level mass mixing ratio of SO2 using SO2 analyzer, and/or TROPOMI onboard Sentinel 5P from google earth engine or OMI/AIRS from Giovanni portel.
8. Estimation of surface level mass mixing ratio of NOx (NO2+NO) using NOx analyzer, and/or TROPOMI onboard Sentinel 5P from google earth engine or OMI from Giovanni portal.
9. Estimation of surface level mass mixing ratio of CO using CO analyzer, and/or TROPOMI onboard Sentinel 5P from google earth engine or AIRS from Giovanni portal.
10. Estimation of surface level mass mixing ratio of O3 using O3 analyzer, and/or TROPOMI onboard Sentinel 5P from google earth engine or OMI from Giovanni portal.
11. Estimation of Aerosol Black Carbon using an Aethalometer and/or reanalysis product available in NASA Giovanni web interface.
12. Estimation of AOD using image captured by various color cameras like VMC and MCC (NASA.gov.in, https://www.issdc.gov.in/).
13. Estimation of the height of dust layer using sounder data from sounder like MCS (https://pds.nasa.gov/)
14. Understand the elemental characterization of different types of aerosols and it's source apportionment through spectroscopic techniques.
15. Estimation of the PM10 concentration using aerosol spectrometer, and/or reanalysis data set from GIOVANNI portal.
16. Identification of different types of biological aerosols through microscopic analysis using Burkard pollen sampler.

(Total Classes 60, Total Contact Hours 120, Total Marks 60)

At least 60% of the experiments must be performed from each unit.

Suggested Readings:

1. Introduction to Space Physics, *M. G. Kivelson and C. T. Russel*, Cambridge University Press.
2. Space Plasma Physics: An introduction, *A. C. Das*, Narosa Publications.

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DETAILED SYLLABUS OF SKILL ENHANCEMENT COURSES

SEMESTER I

Course title: Electrical Circuits and Network Skills
Course code: PHY-SEC-IA
Nature of the course: Skill Enhancement Course
Total credits: 3
Distribution of credits: Theory -1, Practical -2
Distribution of marks: 60 (End sem) + **40** (In-sem)

Course Description: Electrical Circuits and Network Skills is a skill-oriented course which focuses on fundamental concepts of electrical components, symbols, devices etc. It also provides fundamental skills necessary for designing, analyzing, troubleshooting electrical circuits and appliances through hands-on mode. It also enables the students to apply theoretical concepts in real-world scenarios.

Course Objectives:

1. Enable the students to design and troubleshoot the electrical circuits, networks and appliances through hands on mode.
2. Build the basic foundation for learning electrical wiring and repairing other household equipment.
3. Study of various devices.

Course Outcomes (COs): The students will be able to

CO1: Demonstrate proficiency in circuit analysis and apply fundamental concepts of electrical circuits.

- **LO1.1:** Identify basic circuit elements.
- **LO1.2:** Explain the effects of electric current.
- **LO1.3:** Solve DC circuits using Ohm's law and Kirchhoff's laws.
- **LO1.4:** Explain the working and principles of generators and motors.

CO2: Develop and Implement Electrical circuits.

- **LO2.1:** Build dc circuits using elements.
- **LO2.2:** Utilize breadboarding techniques to construct and troubleshoot simple electrical circuits.

CO3: Develop Proficiency in Electrical Safety and Protection.

- **LO3.1** Explain the concept and purpose of earthing, along with different types of earthing methods and their procedures.
- **LO3.2** Draw earthing system and build safety protocols and precautions for electrical installations.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual	LO1.1					

Conceptual	LO3.1	LO1.2 LO 1.4 LO 3.1	CO1 LO1.3			
Procedural		CO3 LO3.2	CO2 LO2.1 LO2.2			
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	M	S	S	M	M	M	M
CO2	S	S	M	M	S	S	M	M	M	S
CO3	S	S	M	M	S	S	M	M	M	S

(S: Strong, M: Medium, W: Weak)

Course Contents:

1-credit Theory

Unit 1: Basic Electricity Principles
Voltage, Current, Resistance, and Power. Ohm's law. Series, parallel, and series-parallel combinations. AC Electricity and DC, Electricity. Familiarization with multimeter, voltmeter and ammeter.
(L 2, H 2, M 3)

Unit 2: Understanding Electrical Circuits
Main electric circuit elements and their combination. Rules to analyze DC sourced electrical circuits. Current and voltage drop across the DC circuit elements. Single-phase and three-phase alternating current sources. Rules to analyze AC sourced electrical circuits. Real, imaginary and complex power components of AC source. Power factor. Saving energy and money. **(L 2, H 2, M 4)**

Unit 3: Electrical Drawing and Symbols
Drawing symbols. Blueprints. Reading Schematics. Ladder diagrams. Electrical Schematics. Power circuits. Control circuits. Reading of circuit schematics. Tracking the connections of elements and identifying current flow and voltage drop. **(L 2, H 2, M 4)**

Unit 4: Generators and Motors
DC Power sources. AC/DC generators. Inductance, capacitance, and impedance. Operation of transformers, Single-phase, three-phase & DC motors. Basic design. Interfacing DC or AC sources to control heater and motors, speed and power of ac motor. **(L 3, H 3, M 6)**

Unit 5: Solid State Devices
Resistors, inductors and capacitors, Diode and rectifiers, Components in series or in shunt, Response of Inductors and capacitors with AC or DC sources. **(L 1, H 1, M 3)**

Unit 6: Electrical Protections

Relays, fuses and disconnect switches, Circuit breakers, Overload devices. Ground-fault protection. Grounding and isolating. Phase reversal. Surge protection. Interfacing DC or AC sources to control elements (relay protection device). **(L 2, H 2, M 5)**

Unit 7: Electrical Wiring

Different types of conductors and cables. Basics of wiring-Star and delta connection. Voltage drops and losses across cables and conductors. Instruments to measure current, voltage, power in DC and AC circuits. Insulation. Solid and stranded cable. Conduit. Cable trays. Splices: wire nuts, crimps, terminal blocks, split bolts, and solder. Preparation of the extension board. **(L 3, H 3, M 5)**

(Total Lectures 15, Total Contact Hours 15, Total Marks 30)

2-credits Practical

Demonstration and Laboratory:

1. Identify different electrical components: Resistor, Capacitor, variable resistor, Rheostat, dc voltage sources: battery, battery eliminator, power supply.
2. Use ammeter and voltmeter in a circuit and measure current and voltage.
3. Use a Multimeter for measuring (a) Resistances, (b) AC and DC Voltages, (c) DC Current, (d) Capacitances, and Checking electrical continuity and fuses.
4. Connect resistances in series and parallel and measure the equivalent resistance using a multimeter.
5. Build a dc circuit using elements like battery, resistances and switch and measure current flow and voltage drop across the components.
6. Demonstration of dc motor and ac motor (like motor of a fan) and identify the differences between them.
7. Identify the electronic components like rectifying diodes, Zener diodes, transistor, carbon resistance, capacitors, and test them with a multimeter.
8. Read electrical diagrams and draw an electrical diagram of the room with proper symbols.
9. To study & find the specifications of various types of wires and cables.
10. Demonstrate different types of Splices (knot) and joints and practice.
11. Demonstration of different types of connectors used in electrical circuits: split bolts connector, Terminal blocks etc.
12. Identify the different types of Protection Devices: that prevent electrical damages: Fuse, Circuit Breaker, MCB, Lighting Arrester.
13. Demonstrate a distribution box with connections.
14. Preparation of extension board with switches, sockets and indicator.

(Total Practical Classes 30, Total Contact Hours 60, Total Marks 30)

Recommended Readings:

1. A textbook in Electrical Technology, *B. L. Theraja,* S Chand & Co.
2. A textbook of Electrical Technology, *A. K. Theraja,* S Chand & Co.

3. Performance and design of AC machines, *M. G. Say,* ELBS Edition.

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Course title: Electrical Wiring and Maintenance
Course code: PHY-SEC-IB
Nature of the course: Skill Enhancement Course
Credit assigned: 3
Distribution of credits: Theory – 1, Practical -2
Distribution of marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This course provides a comprehensive understanding of the fundamentals of electrical circuits, wiring, and safety. It covers essential concepts such as electric current, conductors, insulators, resistance, potential difference, and various voltage sources (AC and DC). Students will learn about Ohm's law, the heating effect of current, Joule's law, electric power, and energy, as well as the analysis of DC circuits using Kirchhoff's laws. The course delves into series, parallel, and combination circuits, and introduces AC currents, single-phase and three-phase sources, transformers, and power transmission. It also explores different types of lighting sources, switches, and domestic electrical appliances. Students will learn about different types of wiring techniques including casing-capping, PVC conduit, and concealed along with the selection and design of wiring schemes, wire joints, and protective devices such as MCBs and ELCBs. Students will become proficient in reading and creating electrical schematics and symbols, designing wiring diagrams, and estimating materials for domestic installations.

Course Objectives: The basic objectives of this course are to

1. Develop the skills of domestic wiring and troubleshooting the electrical circuits especially electrical wiring and common household appliances through hands-on mode.
2. Prepare a working diagram of electrical wiring for a house/ building and install and commission electrical wiring and maintenance in domestic applications.

Course Outcomes (COs): After completion of the course the students will be able to:

CO1: Understand and Apply Fundamental Concepts of Electrical Circuits.

- **LO1.1:** Identify basic circuit elements.
- **LO1.2:** Explain the effects of electric current.
- **LO1.3:** Solve DC circuits using Ohm's law and Kirchhoff's laws.

CO2: Design and Implement Wiring Systems.

- **LO2.1:** Distinguish between types of wiring and accessories.
- **LO2.2:** Design a wiring scheme for a domestic installation.

CO3: Develop Proficiency in Electrical Safety and Protection.

- **LO3.1:** Describe the concept and purpose of earthing, along with different types of earthing methods and their procedures.
- **LO3.2:** Draw earthing system and build safety protocols and precautions for electrical installations.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual	LO1.1					
Conceptual	LO3.1	LO1.2	LO1.3 CO1	LO2.1		
Procedural						CO2 LO3.2 CO3
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	M	S	S	M	S	S	M	M	S
CO2	S	S	S	S	M	S	S	S	M	S
CO3	S	S	S	S	M	S	S	S	M	S

(S: Strong, M: Medium, W: Weak)

Course Contents:

1 credit Theory

Unit 1: Basics of Electrical Circuits

Introductory concepts and basic circuit elements: Concept of Electric current and its unit, Conductors, Insulators, Resistance, potential and potential difference-units-different voltage sources (AC and DC)- Effects of current- - Ohm's law, heating effect of current, Joule's law of heating, electric power, electric energy, Analysis of DC circuits; Kirchhoff's laws: KCL, KVL, Current and voltage drop across the DC circuit elements. Series circuit, parallel circuit, combination circuit. AC current and voltage, single-phase and three-phase alternating current sources, Transformers, transmission of AC Unit of power and energy, kWh, KVA. Different types of light sources like filament bulb, tube (fluorescent) light, CFL, LED and Neon light, Different types of switches, two-way, three-way, four-way switches, fan regulators, dimmer, different types of domestic electrical appliances and their power.

(L 4, H 4, M 7)

Unit 2: Types of wiring

Various types of tools and wiring accessories, Basics of wiring: casing-capping, PVC conduit wiring, concealed wiring (PVC/MS), comparison of different wire joint (flat and straight), types of wiring systems; selection and design of wiring schemes for particular situation (domestic), selection of wire, cables, wiring accessories and use of protective devices i.e., MCB, ELCB etc.; rating and current carrying capacity of wires, cables, fuse, switches, socket, MCBs, ELCBs and other electrical accessories. **(L 2, H 2, M 7)**

Unit 3: Electrical Drawing and Symbols

Different types of electrical symbols used in domestic installation and power systems as per BIS code. Electrical Schematics. Power circuits and control circuits. Reading of circuit schematics. Understanding the connections of elements and identifying current flow and voltage drop. Wiring diagram of light, fan, bell and alarm circuit, staircase wiring, schematic diagram of lighting system of small room, hall and conference room, circuit breakers, inverter connections, Design and drawing of panels, distribution board using MCB, ELCB, main switches and change over switches for domestic installations, Estimation of electrical materials for domestic wiring. **(L 4, H 4, M 8)**

Unit 4: Electrical Protection and Safety

Earthing: Concept and purpose of earthing, different types and procedure of earthing, drawing of plate and pipe earthing, test material and costing and estimating. Safety precautions: Effect of electric shock on human body, first aid for electric shock-rules and standards in house wiring, Introduction to Lightning Arresters – Types - Necessity and Advantages - Layout and Installation, Electrical Hazards and its effects - Basic safety introduction - Personal protection and PPE - Basic injury prevention - Basic first aid - Hazard identification and avoidance. **(L 5, H 5, M 8)**

(Total Lectures 15, Total Contact Hours 15, Total Marks 30)

2-credits Practical

Demonstration and Laboratory:

1. Safety use in electricity, shock treatment methods, safety precautions.
2. To study & find the specifications of various types of wires and cables.
3. To measure the gauge of a given wire with the help of a wire gauge.
4. Prepare a chart of wattage of different electrical items/ appliances like CFL bulb, LED bulb, Tube light, Ceiling Fan, Table Fan, Gyger, Mixer-grinder, Refrigerator, Water pump, Iron, Xerox Machine, Inverter, TV, Hanging/ pendant Light, Microwave oven etc.
5. Measurements of ac voltage with multimeter.
6. To connect the wires with different electrical accessories.
7. Skinning the cable and joint practice on single and multi-strand wire.
8. To make a main switch board for house wiring
9. Installation of common electrical accessories such as switch, holder, plug on board
10. Installation and wiring connection of ceiling fan, exhaust fan, geyser, and water purifier
11. Preparation of extension board with switches, sockets and indicator.
12. Demonstrate electrical circuit diagrams related to electrical household appliances.
13. Carry out the earthing of the installed electrical circuit as per standard practice
14. Practice on different types of House Wiring installation and testing
15. House wiring circuits using fuse, switches, sockets, ceiling fan etc. in P.V.C. casing-capping.
16. Prepare one estimate of materials required for CTS wiring for small domestic installation of one room and one verandah within 25 m^2 with given light, fan & plug points.

(Total Practical Classes 30, Total Contact Hours 60, Total Marks 30)

Recommended Readings:

1. Elementary Electrical Engineering, *M. L. Gupta*, New Heights.
2. Electrical Installation and Estimating, *S. Singh*, Dhanpatrai and sons.
3. A course in Electrical Installation, Estimating and costing, *J. B. Gupta, S K Kataria* and Sons.

4. A textbook in Electrical Technology, *B. L. Theraja*, S Chand & Co.
5. A textbook of Electrical Technology, *A. K. Theraja*, S Chand & Co.

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SEMESTER II

Course Title: Basic Instrumentation Skills
Course Code: PHY-SEC-II
Nature of the Course: Skill Enhancement Course
Credit assigned: 3
Distribution of credits: Theory – 1, Practical -2
Distribution of marks: 60 (End-sem) **+ 40** (In-sem)

Course Description: The course on Basic Instrumentation Skills is an introductory course on basic tools and equipment used in laboratories. It describes the different types of analog and digital voltmeter and ammeters used in measurements. The course also covers the concept of CRO, Function generator and bridges and the techniques to use them in laboratory measurements. The course also includes laboratory sessions so that the students learn the basic experimental techniques.

Course Objectives: This course aims to

1. Provide exposure to various aspects of instruments.
2. Provide hands-on experience of handling instruments.
3. Teach various debugging techniques for the instruments.

Course Outcomes (COs): The students will able to

CO1: Understand the basic principle and techniques required to carry out laboratory measurements

- **LO1.1:** Define terms related to measurement such as accuracy, precision, sensitivity, and resolution.
- **LO1.2:** Explain the construction and operation principles of CRT, including electron gun and electrostatic focusing.
- **LO1.3:** Explain the block diagram and working principle of digital voltmeters.

CO2: Explain the working of multimeter, CRO, etc.

- **LO2.1:** Explain the block diagram and working principle of digital voltmeters.
- **LO2.2:** Explain the time base operation and synchronization in CROs.

CO3: Apply CRO, Multimeters, Bridges for different measurements.

- **LO3.1:** Make use of CRO to measure voltage (DC and AC), frequency, and time period.
- **LO3.2:** Utilize signal generators and frequency counters in practical measurement scenarios.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual		LO1.1 LO1.2 LO1.3 LO2.1				
Conceptual		LO2.2	LO3.1 LO3.2			

Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	M	M	M	S	M	M	S
CO2	S	S	M	S	M	M	M	M	M	M
CO3	M	S	M	S	M	M	S	M	M	S

(S: Strong, M: Medium, W: Weak)

Course Contents:

1 credit Theory

Unit 1: Basic of Measurement
Instruments accuracy, precision, sensitivity, resolution range etc. Errors in measurements and loading effects. Ideal Voltage and Current source. **(L 2, H 2, M 5)**

Unit 2: Voltmeter and Multimeter
Principles of measurement of dc voltage and dc current, ac voltage, ac current and resistance. Specifications of a multimeter and their significance. Principles of voltage measurement (block diagram only). Specifications of an electronic Voltmeter/ Multimeter and their significance. Digital Voltmeter, Block diagram and working of a digital Voltmeter. **(L 4, H 4, M 7)**

Unit 3: Cathode Ray Oscilloscope
Block diagram of basic CRO. Construction of CRT, Electron gun, electrostatic focusing and acceleration (Explanation only– no mathematical treatment), Time base operation, synchronization. Front panel controls. Specifications of a CRO and their significance.
Use of CRO for the measurement of voltage (dc and ac frequency, time period. Digital storage Oscilloscope. **(L 4, H 4, M 7)**

Unit 4: Signal Generators and Analysis Instruments
Block diagram, explanation and specifications of low frequency signal generators. pulse generator, and function generator. Working principle of time interval, frequency and period measurement using universal counter/ frequency counter, time- base stability, accuracy and resolution. **(L 3, H 3, M 6)**

Unit 5: Impedance Bridges & Q-Meters
Working principles of basic (balancing type) RLC bridge. Specifications of RLC bridge. Kelvins Bridge **(L 2, H 2, M 5)**

(Total Lectures 15, Total Contact Hours 15, Total Marks 30)

2-credits Practical

Demonstration and Laboratory:

The test of lab skills will be of the following test items:

1. Use of an oscilloscope.
2. CRO as a versatile measuring device.
3. Circuit tracing of Laboratory electronic equipment.
4. Use of Digital multimeter / VTVM for measuring voltages.
5. Circuit tracing of Laboratory electronic equipment.
6. Winding a coil / transformer.
7. Study the layout of a receiver circuit.
8. Troubleshooting a circuit.
9. Balancing of bridges.

Laboratory Exercises:

1. To observe the loading effect of a multimeter while measuring voltage across a low resistance and high resistance.
2. To observe the limitations of a multimeter for measuring high frequency voltage and currents.
3. Measurement of voltage, frequency, time period and phase angle using CRO.
4. Measurement of time period, frequency, average period using universal counter/ frequency counter.
5. Measurement of rise, fall and delay times using a CRO.
6. Measurement of R, L and C using a LCR bridge / universal bridge.

Open Ended Experiments:

1. Using a Dual Trace Oscilloscope.
2. Converting the range of a given measuring instrument (voltmeter, ammeter).

(Total Practical Classes 30, Total Contact Hours 60, Total Marks 30)

Recommended Readings:

1. Modern Electronic Instrumentation & Measurement Techniques, *A. D. Helfrick, W.D. Cooper*, Pearson India.
2. A textbook in Electrical Technology, *B. L. Theraja, A.K. Theraja*, S Chand and Co.
3. Electronic Measurements and Instrumentation, *R.S. Sedha*, S Chand and Co.

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SEMESTER III

Course Title: Computational Physics Skills
Course Code: PHY-SEC-IIIA
Nature of the Course: Skill Enhancement Course
Credit assigned: 3
Distribution of credits: Theory – 1, Practical -2
Distribution of marks: 60 (End sem) **+ 40** (In-sem)

Course Description: The Computational Physics Skills course includes the basics of computer programming and scientific writing to emphasize their role in dealing with problems in Physics.

Course Objectives:

1. To introduce the use of computer language and computer programming in solving physics problems.
2. To familiarize the learners about scientific writing and analysis tools useful for interpretation and presentation of results obtained.

Course Outcomes (COs): After successful completion of the course, the student will be able to
CO1: Apply computer programming language to solve physics problems.
LO1.1: List the syntax of computer programming.
LO1.2: Solve physics problems using computer programming.
CO2: Utilize scientific writing and analysis tools.
LO2.1: Construct standard scientific documentation using scientific writing tool.
LO2.2: Show the outcomes of graphical analysis using visualization tool.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual	LO1.1	LO2.2	LO2.1 CO2			
Conceptual			LO1.2 CO1			
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S	S	S	S	S	S	S
CO2	S	S	S	M	S	S	S	S	S	S

(S: Strong, M: Medium, W: Weak)

Course Contents:

1 credit Theory

Unit 1: Introduction

Importance of computers in Physics, paradigm for solving physics problems for solution**.** Usage of linux as an Editor.

Algorithms and Flowcharts: Algorithm: Definition, properties and development. Flowchart: Concept of flowchart, symbols, guidelines, types with examples. **(L 3, H 3 M 6)**

Unit 2: Scientific Programming

Some fundamental Linux Commands (Internal and External commands). Development of FORTRAN, Basic elements of FORTRAN: Character Set, Constants and their types, Variables and their types, Keywords, Variable Declaration and concept of instruction and program. Operators, Relational, Logical, Character and Assignment Expressions. Fortran Statement. **(L 3, H 3 M 6)**

Unit 3: Control Statements

Types of Logic, Branching Statements, Looping Statements, Jumping Statements, Subscripted Variables, Functions and Subroutines, open a file, writing in a file, reading from a file.

(L 3, H 3 M 6)

Unit 4: Scientific Word Processing: Introduction to LaTeX

TeX/LaTeX word processor, preparing a basic LaTeX file, Document classes, preparing an input file for LaTeX, Compiling LaTeX File, LaTeX tags for creating different environments, Defining LaTeX commands and environments, Changing the type style, Symbols from other languages.

Equation representation: Formulae and equations, figures and other floating bodies, lining in columns-Tabbing and tabular environment, generating table of contents, bibliography and citation, making an index and glossary, List making environments, Fonts, Picture environment and colors, errors.

(L 3, H 3 M 6)

Unit 5: Visualization

Introduction to graphical analysis and its limitations. Introduction to Gnuplot. importance of visualization of computational and computational data, basic Gnuplot commands: simple plots, plotting data from a file, saving and exporting, multiple data sets per file, physics with Gnuplot (equations, building functions, user defined variables and functions), Understanding data with Gnuplot. **(L 3, H 3 M 6)**

(Total Lectures 15, Total Contact Hours 15, Total Marks 30)

2-credits Practical

Programming:

1. Exercises on syntax on usage of FORTRAN Usage of GUI Windows, Linux Commands, familiarity with DOS commands and working in an editor to write source codes in FORTRAN.
2. To print out all natural even/ odd numbers between given limits.
3. To find maximum, minimum and range of a given set of numbers.
4. Calculating Euler number using exp(x) series evaluated at x = 1.

Hands on Exercises:

1. To compile a frequency distribution and evaluate mean, standard deviation etc.
2. To evaluate the sum of a finite series and the area under a curve.
3. To find the product of two matrices.
4. To find a set of prime numbers and Fibonacci series.
5. To write a program to open a file and generate data for plotting using Gnuplot.
6. Plotting trajectory of a projectile projected horizontally.
7. Plotting trajectory of a projectile projected making an angle with the horizontal.
8. Creating an input Gnuplot file for plotting data and saving the output for seeing on the screen. Saving it as an eps file and as a pdf file.
9. To find the roots of a quadratic equation.
10. Motion of a projectile using simulation and plot the output for visualization.
11. Numerical solution of equation of motion of simple harmonic oscillator and plot the outputs for visualization.
12. Motion of a particle in a central force field and plot the output for visualization.

(Total Practical Classes 30, Total Contact Hours 60, Total Marks 30)

Recommended Readings:

1. Introduction to Numerical Analysis, *S. S. Sastry*, PHI Learning Pvt. Ltd.
2. Computer Programming in Fortran 77, *V. Rajaraman,* PHI Learning Pvt. Ltd.
3. LaTeX–A Document Preparation System, *L. Lamport*, Addison-Wesley.
4. Gnuplot in action: understanding data with graphs, *P. K. Janert*, Manning.
5. Schaum's Outline of Theory and Problems of Programming with Fortran, *S. Lipsdutz and A. Poe*, Mc-Graw Hill.
6. Computational Physics: An Introduction, *R. C. Verma et al.* New Age International Publishers.
7. A first course in Numerical Methods, *U. M. Ascher and C. Greif,* PHI Learning Pvt. Ltd.
8. Elementary Numerical Analysis, *K. E. Atkinson*, Wiley India Edition.

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Course title: Renewable Energy and Energy Harvesting
Course code: PHY-SEC-IIIB
Nature of the course: Skill Enhancement Course
Total credits: 3
Distribution of credits: Theory – 2, Practical - 1
Distribution of marks: 60 (End-sem) **+ 40** (In-sem)

Course Description: This course explores a wide range of energy sources, beginning with fossil fuels and nuclear energy, highlighting their limitations and the necessity for renewable energy alternatives. It provides an in-depth examination of various renewable energy technologies, including solar, wind, ocean, geothermal, and hydro energy, along with their applications and environmental impacts. The course also covers advanced topics in energy harvesting, such as piezoelectric and electromagnetic energy, focusing on their principles, technologies, and sustainable applications. Through this comprehensive study, students will gain a thorough understanding of both conventional and innovative energy sources, preparing them to contribute to the development of sustainable energy solutions.

Course Objectives: The aim of this course is

1. Examine the limitations and environmental impacts of fossil fuels and nuclear energy as well as the necessity of renewable energy and their practical applications.
2. Gain knowledge of solar, wind, ocean, geothermal, and hydro energy sources, including their applications and environmental benefits.
3. Study advanced energy harvesting methods, such as piezoelectric and electromagnetic energy, and their sustainable applications
4. Understand the integration of both conventional and innovative energy sources for a comprehensive approach to energy sustainability.

Course Outcomes (COs):

CO1: Core knowledge of Renewable Energy Technologies.

- **LO1.1:** Describe the characteristics, advantages, and limitations of fossil fuels and nuclear energy.
- **LO1.2:** State the need for and benefits of transitioning to renewable energy sources.
- **LO1.3:** Explain the fundamental principles and applications of various renewable energy technologies, including solar, wind, ocean, geothermal, and hydro energy.

CO2: Understanding practical Skills in Designing and Implementing Renewable Energy Systems.

- **LO2.1:** Design and implement solar energy systems, such as solar water heaters, photovoltaic systems, and solar greenhouses.
- **LO2.2:** Assess and evaluate wind energy systems, including wind turbines and their power electronic interfaces.
- **LO2.3:** Analyze the efficiency and practical applications of solar and wind energy technologies in real-world scenarios.

CO3: Discuss Advanced Energy Harvesting and Sustainability Practices.

- **LO3.1:** Explain the principles and applications of piezoelectric and electromagnetic energy harvesting technologies.
- **LO3.2:** State the environmental impact and sustainability of various energy sources and harvesting techniques.
- **LO3.3:** Assess knowledge of renewable energy systems to propose sustainable solutions for reducing carbon footprint and enhancing energy efficiency.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual	LO1.2 LO3.2 CO1					
Conceptual		LO1.1 LO1.3 LO3.1 CO2		LO2.3 LO1.4 LO3.3	LO2.2	

		CO3				
Procedural						LO2.1
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	M	S	M	S	S	M	M
CO2	S	S	M	S	S	M	S	S	M	S
CO3	S	M	M	S	S	M	S	S	M	S

(S: Strong, M: Medium, W: Weak)

Course Contents:

2-credits Theory

Unit 1: Fossil Fuels and Alternative 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. **(L 5, H 5, M 5)**

Unit 2: 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. **(L 5, H 4, M 5)**

Unit 3: Wind Energy Harvesting

Fundamentals of Wind energy, Wind Turbines and different electrical machines in wind turbines, Power electronic interfaces, and grid interconnection topologies. **(L 4, H 4, M 4)**

Unit 4: 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 Biomass. **(L 4, H 4, M 4)**

Unit 5: Geothermal Energy

Geothermal Resources, Geothermal Technologies. **(L 2, H 2, M 2)**

Unit 6: Hydro Energy

Hydropower resources, hydropower technologies, environmental impact of hydro power sources. **(L 2, H 2, M 2)**

Unit 7: Piezoelectric Energy harvesting
Introduction, Physics and characteristics of piezoelectric effect, materials and mathematical description of piezoelectricity, Piezoelectric parameters and modeling piezoelectric generators, Piezoelectric energy harvesting applications, Human power. **(L 3, H 3, M 3)**

Unit 8: 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. **(L 5, H 5, M 5)**

(Total Lectures 30, Total Contact Hours 30, Total Marks 30)

1-credit Practical

Demonstrations and Experiments/ Project

1. Demonstration of Training modules on Solar energy, wind energy, etc.
2. Conversion of vibration to voltage using piezoelectric materials.
3. Conversion of thermal energy into voltage using thermoelectric modules.

OR

Project Preparation.

(Total Practical Classes 15, Total Contact Hours 30, Total Marks 30)

Recommended Readings:

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, *S. P. Sukhative*, Tata McGraw, Hill Publishing Company Ltd.
4. Renewable Energy: Power for a sustainable future, *G. Boyle*, Oxford University Press.
5. Solar Energy: Resource Assessment Handbook, *P. Jayakumar*.
6. Photovoltaics, *M. Shaw and S. Jarosek*, Lawrence J Goodrich (USA).

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DETAILED SYLLABUS OF GENERIC ELECTIVE COURSES

SEMESTER I

Course title: Evolution of Science
Course code: PHY-GEC-IA
Nature of the course: Generic Elective Course
Total credits: 3
Distribution of marks: 60 (End-sem) **+ 40** (In-sem)

Course Description: This generic elective course is designed for general students of this programme at the beginning level and students will be able to learn about the development of science as a whole starting from the very early stage to its modern state. From the early stage part of this course, students will know the invention of the wheel as the beginning of science up to the very famous Newton's Universal law of gravitation. From the middle stage part, which includes the development of science in the nineteenth century, students will learn about the development of electricity and magnetism, works of Maxwell to Thomas Alva Edison. These developments are indeed the beginning of modern science. The last part of this course covers almost all major modern developments of science, in which students will learn about the developments of special relativity, quantum mechanics to electronics and optical evolution. In addition, students will also know the Indian contributions to contemporary science developments.

Course Objectives: This course aims to provide students with a comprehensive understanding of the evolution of science, its impact on society, and the role that science will play in shaping the future. So, the course is designed with the following specific objectives:

1. To provide students with an understanding of the historical development of scientific knowledge, including key figures and their contributions.
2. To examine the interdisciplinary nature of science and its impact on various fields and industries.
3. To explore the ethical and social implications of scientific advancements, and to promote critical thinking about their consequences.
4. To foster an appreciation for the scientific method and the role of experimentation and observation in advancing scientific knowledge.

Course Outcomes (COs): The students will able to

CO1: Understand the historical development of scientific knowledge with key figures and their contributions.

- **LO1.1:** Explain the invention of the wheel as the beginning of science to the industrial revolution.
- **LO1.2:** Describe the contributions of Aristotle to Darwin, Kepler etc.
- **LO1.3:** Discuss the contributions of Sir Isaac Newton and his famous laws.
- **LO1.4:** Illustrate nineteenth century science such as developments of electricity and magnetism with contributions of Thomas Alva Edison and Maxwell. These developments led to the beginning of modern science.
- **LO1.5:** Outline the developments of modern science from quantum mechanics, special theory. of relativity, field quantization, electronics, computer to Laser and optical evolution.

LO1.6: Explain contemporary science and India's contributions.

CO2: Describe the interdisciplinary nature of science and its impact on various fields and industries.

LO2.1: Explain the impacts of Darwin's, Newton's and Einstein's works and quantum mechanics on various branches of sciences.

LO2.2: Understand the impacts of Edison's, Maxwell's, Newton's etc. works and quantum evolutions on the industrial revolutions, technological developments and space science and technology etc. developments.

CO3: Relate the ethical and social implications of scientific advancements, and promote critical thinking about their consequences.

LO3.1: Understand the devotion, patience, ethical value and social responsibility of scientists in the development of their scientific works and achieving the goals.

CO4: Recognize the roles of scientific methods of experimentation and observation in advancing scientific knowledge.

LO4.1: Understand the necessity of dedicated experiments and observations in achieving scientific results and advancing scientific knowledge.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual	LO1.1 LO1.2 LO1.3 LO1.4 LO1.5 LO1.6 CO1	LO2.1 LO2.2 CO2				
Conceptual		LO3.1 LO4.1 CO3 CO4				
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	M	M	S	M	M		M	M	M	
CO2	M	M	S	M	M		M	M	M	
CO3	M	M	S	S	M		M	M	M	
CO4	M	M	S	S	M		M	M	M	

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: Early Stage
Invention of wheel and beginning of science, science for progress, science in ancient world, medieval science; Renaissance and industrial revolution: Rise of western science, contributions of Aristotle, Galileo Galilei, Robert Hooke, Darwin, Kepler etc., contributions of Sir Isaac Newton: Laws of motion, universal law of gravitation. **(L 14, H 14, M 20)**

Unit II: Middle Stage
Nineteenth century and beginning of modern science: Developments of electricity and magnetism, Maxwell's contributions, contributions of Thomas A. Edison. **(L 13, H 13, M 16)**

Unit III: Modern Stage
Einstein and special theory of relativity; The paradigm shift: quantum theory, general theory of relativity, quantum generation; The second quantization: development of concept of field quantization, ups and downs; Nuclear era: space science and technology; Electronic age and birth of computers; Laser and optical evolution; Contemporary science and India's contribution. **(L 18, H 18, M 24)**

(Total Lectures 45, Total Contact Hours 45, Total Marks 60)

Recommended Readings:

1. The Scientific Revolution, *Steven Shapin*, University of Chicago Press.
2. A History of Physics in its Elementary Branches: Including the Evolution of Physical Laboratories, *Florian Cajori*, Macmillan.
3. A Brief History of Physics, *Paul F. Kisak*, CreateSpace Independent Publishing Platform.

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Course title: Introduction to Communication Technology
Course code: PHY-GEC-IB
Nature of the course: Generic Elective Course
Total credits: 3
Distribution of marks: 60 (End sem) **+ 40** (In-sem)

Course Description: The course on Introduction to Communication Technology begins with a discussion on what is communication, what are the techniques used in communication systems. It describes the different types of modulation and multiplexing techniques which are of utmost importance in any modern-day communication system. The course also covers the introductory idea of Antennas, RADAR, and microwave communication. A brief discussion about optical communication systems has also been included in the course.

Course Objectives:

1. To introduce the students with the technologies used in modern communication systems.
2. To make the students familiar with antennas.
3. To discuss the basic idea behind cellular communication, satellite communication etc.

Course Outcomes (COs): The students will able to

CO1. Understand the basic blocks of a communication system.

LO1.1: Define the key components of a communication system and the concept of modulation.
LO1.2: Explain the block diagram of Pulse Code Modulation.
LO1.3: Explain how antennas work.
LO1.4: Define microwave communication, cellular communication and optical fiber communication.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual		LO1.4				
Conceptual		LO1.1 LO1.2 LO1.3				
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	M	M	M	S	M	M	S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: Basics of Communication Systems

What is a communication system, Block diagram of a communication system, Need of modulation, basic idea of Amplitude Modulation its advantages, disadvantages and application, Frequency modulation, advantages, disadvantages and its application, electromagnetic Spectrum.

Multiplexing in communication systems, Frequency Division Multiplexing and Time division multiplexing. **(L 15, H 15, M 18)**

Unit II: Digital Communication Processes

Digital communication, Block diagram of Pulse code modulation and its applications, digital modulation, advantages and disadvantages of digital modulation. **(L 5, H 5, M 9)**

Unit III: Transmission Systems

Basic idea of Transmission line, What is an antenna, Dipole antenna, Yagi antenna, different parameters used in antenna, Introduction to RADAR, RADAR block diagram, Pulse Repetition Frequency. **(L 5, H 5, M 9)**

Unit IV: Microwave and Optical Communications
Introduction to microwave, Microwave communication system, advantages and disadvantages. Cellular communication, basic idea of spectrum and technologies used in cellular communication, generations of cellular communications. Introduction to satellite communication, antenna look angles, satellite communication block diagrams and frequency ranges used, Basic principle of GPS.
Historical development of optical communication, general system, advantages, disadvantages, and applications of optical fiber communication, cylindrical fiber, single mode fiber, cutoff wavelength. Optical Fiber materials. **(L 20, H 20, M 24)**

(Total Lectures 45, Total Contact Hours 45, Total Marks 60)

Recommended Readings:

1. Electronic Communications System: Fundamentals Through Advanced, *W. Tomasi,* Pearson Education.
2. Kennedy's Electronic Communication Systems (SIE), *I. G. Kennedy, Davis, Prasanna*, McGraw Hill Education.
3. Principles of electronic communication systems, *L. E. Frenzel*, McGraw Hill Education.
4. Optical Fiber Communications, *G. Keiser,* Tata McGraw Hill Education.

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SEMESTER II

Course title: Materials Today
Course code: PHY-GEC-IIA
Nature of the course: Generic Elective Course
Total credits: 3
Distribution of marks: 60 (End sem) **+ 40** (In-sem)

Course Description: The course on Materials Today defines different forms of matter and also introduces history and evolution of materials over ages. Classification of engineering materials and the trend of advanced materials are also included in this course.

Course Objectives:
1. To introduce different forms of matter along with the history and development of materials.
2. To familiarize the learners about various types of materials, their composition and properties.

Course Outcomes (COs): After successful completion of the course, the student will be able to
CO1: Classify different types of materials.
  LO1.1: List forms of matter and match the development of materials in different ages
  LO1.2: Summarize engineering materials.
CO2: Identify properties and application of nanomaterials.
  LO2.1: List properties and application of nanomaterials.
  LO2.2: Apply unique features of nanomaterials for a variety of applications.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual	LO1.1 LO2.1	LO1.2 CO1				
Conceptual			LO2.2 CO2			
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	M	S	M	S	S	S	S	S	S
CO2	S	M	S	M	S	S	S	S	S	S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: Introduction to Matter
Overview of the different states of matter: Solid, Liquid, Gas, Plasma, Atomic structure and Bonding.
(L 7, H 7, M 10)

Unit II: History and Evolution of Materials
Materials: Drivers of human civilization. Development of materials: Stone age, Copper age, Bronze age, Iron age. Explanation with examples to mark this development. **(L 10, H 10, M 15)**

Unit III: Classification of Engineering Materials
Metals & Alloys, Non-Metals, Ceramics, Polymers, Composites etc. with examples and applications. Uses, Performance, Composition & Structure; Physical and Chemical properties; Processing & Synthesis of various classes of materials. **(L 15, H 15, M 20)**

Unit IV: Trends in Advanced Materials
Breakthroughs in Materials Development. Overview of Advanced Materials: Semiconductors, Biomaterials, Smart Materials (Materials of the Future), Nano-structured Materials.
(L 13, H 13, M 15)

(Total Lectures 45, Total Contact Hours 45, Total Marks 60)

Recommended Readings:

1. Materials Science and Engineering: An introduction, *William D. Callister, Jr. and David G. Rethwisch,* John Wiley & Sons, Inc.
2. Understanding Materials Science: History, Properties, Applications, *Rolf E. Hummel*, Springer-Verlag, New York.
3. Essentials of Materials Science and Engineering, *Donald R. Askeland and Pradeep P. Fulay*, Cengage learning, Canada.

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Course title: Digital and Space Technologies
Course code: PHY-GEC-IIB
Nature of the course: Generic Elective Course
Total credits: 3
Distribution of marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This course comprises topics of digital and space technologies available in current time.

Course Objectives: To equip students with a comprehensive understanding of modern technologies, their societal implications, and their applications across various domains including communication, digital infrastructure, and space technology. To foster critical thinking and problem-solving skills essential for navigating the evolving technological landscape.

Course Outcomes (COs): A students will able to

CO1: Explain the Interdependence of Technology and Society.

LO1.1: Understand the impact of technology on societal development, emphasizing dependencies and vulnerabilities.

LO1.2: Understand the role of digital infrastructure in economic growth and global competitiveness.

CO2: Explain currently used Communication Systems in general terms.

LO2.1: Acquire Knowledge of various communication technologies and their applications.

LO2.2: Understand the issues in information security and optimize data uses.

CO3: Assess Emerging Technologies and Automation**.**

LO 3.1: Understand the societal and ethical implications of different technologies.

LO3.2: Discuss strategies to address technological disparities and enhance digital literacy

CO4: Analyse the applicability of Digital Technology/Software.

LO4.1: Apply knowledge of semiconductor devices, digital systems, and software development in practical scenarios.

LO4.2: Assess the feasibility and risk of technology/ software platforms for diverse applications related to societal problems.

CO5: Explain Space Technology and its Impact on Society.

LO5.1: Understand the impact of space-based technologies on communication, navigation, and disaster management.

LO5.2: Assess the tools of space technology for societal use.

LO5.3: Understand the importance of space technology for national development.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual	LO1.1 LO1.2 LO5.1 LO 5.3 CO1	LO2.1 CO2				
Conceptual		LO2.2 LO3.1 CO2	LO4.1 LO3.2 CO5	LO3.3 CO4	LO 4.2 LO 5.2 CO3	
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	W	M	M	S	M	W	W	S	W	M
CO2	W	M	S	S	S	W	W	S	M	M
CO3	W	M	M	S	M	W	W	S	M	M

CO4	W	M	M	S	M	W	W	S	M	M
CO5	W	M	M	S	M	W	W	S	W	M

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit 1: Overview of modern technologies in society

Dependency of modern life style on technology, various example technologies like microprocessor/microcontroller, computing devices, programming language-open source and proprietary software , stand alone and connected systems, communication systems-network of systems, client-server systems, GSM/CDMA, VoLTE, internet, security, cryptography, communication medium- optical fiber leading to information age, wireless, satellite communication-radio waves in earth's atmosphere , use of satellites for remote sensing , weather prediction, disaster managements, positioning and navigation (GPS/NAVIC) and military applications, rise of automation using neural networks and AI etc. India specific technological strengths and needs like semiconductor chip manufacturing, digital literacy and A.I. Integration of societal services by digital and software platforms. **(L 7, H 7, M 12)**

Unit 2: Digital technology

Semiconductor, chip, solar cell, LED, IC, processor IC, Boolean algebra, mass production large scale fabrication technology leading to use of binary systems and digital revolution- computer miniaturization, portability by CMOS, microprocessor basics, low power battery operated devices, networks of systems powered by optical fibers, basic of optical and quantum technologies, limitation of electronics processing, Software and advantages. Software and communication driven growth in services and economy. Software development-programming and apps. Integration of services using software and communication platforms like online banking, online education, streaming and virtual meeting, digitization of government services like online application and forms, land dispute resolutions, India's software service/technology industry and its role in the economy and nation building. **(L 20, H 20, M 25)**

Unit 3: Earth's outer environment, Satellite and Space technology

The Earth's atmosphere-composition, stratification and its connection to outer space. The role of the Sun and the Earth's magnetic field in space-based technologies line GPS/IRNSS and ground systems. The SUN's cycles and short scale eruptions like flare, CME. Implication for space weather. The magnetosphere-ionosphere-thermosphere-atmosphere system. Differential response in different time and space configuration, Effect on satellites and their operation, satellite drag, Artificial satellites, types like geostationary, geo synchronous, LEO, MEO, mini/micro satellites etc. Polar, equatorial, Molniya orbits and implications, applications of space technology for society, use in communication-navigation and Earth observation, Brief idea of Indian satellites like INSAT, GSAT, IRS, IRNSS, GAGAN, Chandrayan etc.; launch vehicles like ASLV, PSLV. Application of satellite SAC (ISRO) **(L 18, H 18, M 23)**

(Total Lectures 45, Total Contact Hours 45, Total Marks 60)

Recommended Readings:

1. Digital Principles and Applications, *Donald P. Leach*, McGraw Hill.
2. Human Computer Interaction Handbook: Fundamentals, Evolving Technologies, and Emerging Applications*, Editor: Julie A. Jacko*, CRC Press Inc.
3. Optical electronics, *Ghatak and Thyagarajan*, Combridge University Press
4. Satellite Technology and Its Applications *P.R.K. Chetty*, TAB Books Inc; 2nd edition
5. Computer Networks, *Tanenbaum*, Prentice-Hall, India.
6. Foundations of IT and Computers, *Himadri Barman*, (ISBN - 9789384303068), Mahaveer Publications, Dibrugarh.

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SEMESTER III

Course title: The Universe
Course code: PHY-GEC-IIIA
Nature of the course: Generic Elective Course
Total credits: 3
Distribution of marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This course comprises elementary topics in astronomy and cosmology such as knowledge of our solar system, stars and galaxies, astronomical telescopes etc.

Course Objectives: This course aims to
1. Provide an overview of astronomy and cosmology.
2. Know about and understand the observed properties of physical systems that comprise the known universe, on various scales.

Course Outcomes (COs): At the completion of this course, a student will be able to
CO1: Understand the basics of astronomy and cosmology.
  LO1.1: Define terms and phenomena related to astronomy and cosmology.
  LO1.2: Describe the origin, composition and evolution of the universe.
  LO1.3: Explain various astrophysical and cosmological phenomena.
CO2: Apply the learnt concepts learnt for various purposes.
  LO2.1: Use the acquired knowledge for the purpose of astronomical observations.
  LO2.2: Solve problems based on the basic concepts in astronomy and cosmology.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual	LO1.1	LO1.2 LO1.3 CO1	LO2.1 LO2.2 CO2			
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S			M	M		S
CO2	S	S	S	S			M	M		S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: Solar System
Planets: Formation of Solar System - planet types - planet atmospheres - extrasolar planets
Sun: Solar Parameters, Solar Photosphere, Solar Atmosphere, Chromosphere. Corona, Solar Activity, solar flare. **(L 10, H 10, M 13)**

Unit II: Stars and Galaxies
Stars: Measuring stellar characteristics (temperature, distance, luminosity, mass, size) -stellar evolution; Galaxies: Our Milky Way - Galactic structure - - Galaxy types - Galaxy formation, Hubble's Classification of Galaxies. **(L 9, H 9, M 12)**

Unit III:
Constellation, Bright stars in night sky, constellation -Zodiacs, Orion, ursa major, ursa minor. **(L 6, H 6, M 8)**

Unit IV: Basic Astronomy
Astronomical Distance - light years and parsec, Mass and Time Scales, Stellar mass and temperature, Astronomical Quantities measurement and Astronomical Distances. **(L 8, H 8, M 10)**

Unit V: Basic Cosmology
History of the Universe, Big Bang model, expansion of the Universe, fate of the Universe.
Other stellar objects: White dwarf, Black hole, nebula, supernova, comets and Kuiper belt. **(L 8, H 8, M 10)**

Unit VI:
Astronomical telescope. Hubble telescope, James Webb telescope. **(L 4, H 4, M 7)**

(Total Lectures 45, Total Contact Hours 45, Total Marks 60)

Recommended Readings:

1. Introduction to Astronomy from Darkness to Blazing Glory, *Jeffrey Wright Scott*, Minuteman Press, California.
2. Astronomy for beginners, *Jeff Becan,* For beginner series.
3. Astronomy For Beginners: The Introduction Guide to Space, Cosmos, Galaxies and Celestial Bodies, *Sally r Ball*, Han Global Trading Pvt. Ltd.
4. Stargazing: Beginners Guide to Astronomy, *Radmila Topalovic and Tom Kerss*, Collins publication.
5. Astronomy: The Complete Beginners Guide to Discover Stars and Astronomy, *Nicole Carlisle,* Andrew Zen.

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Course title: Atmosphere of the Earth and Climate Change
Course code: PHY-GEC-IIIB
Nature of the course: Generic Elective Course
Total credits: 3
Distribution of marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This course covers the evolution and composition of Earth's atmosphere, including its layers and altitudinal variations in pressure. It examines atmospheric thermodynamics and radiative processes, such as absorption and scattering of solar radiation, alongside discussions on the Greenhouse Effect and global climatic phenomena like El Niño. Additionally, the course delves into climate change science, exploring past climate variations and distinguishing between natural and anthropogenic influences. It addresses the impacts of climate change on ecosystems, human health, and the strategies for sustainability, resilience, and mitigation, including carbon sequestration and renewable energy technologies.

Course Objectives: The objective of this course is to:

1. Study the historical evolution, thermal and density structure, and altitudinal variations in atmospheric pressure and composition.
2. Explore atmospheric thermodynamics, radiative forcing, and other key processes.
3. Gain basic knowledge of climate change and its impacts on ecosystems, human health, and well-being.
4. Assess strategies for climate change mitigation, sustainability, and resilience.

Course Outcomes (COs): A student will able to

CO1: Understanding the Earth's atmosphere and climate system.

- **LO1.1:** State the historical evolution of Earth's atmosphere, including significant events and changes that have shaped its current composition and structure.
- **LO1.2:** Understand thermal and density structure of the atmosphere.
- **LO1.3:** Underline the composition of the atmosphere by examining the properties and interactions of atmospheric.
- **LO1.4:** Relate the altitudinal variations in temperature and pressure in atmospheric dynamics.

CO2: Apply principles of atmospheric thermodynamics and radiation in dealing with atmospheric processes.

- **LO2.1:** Investigate the role of the First Law of Thermodynamics in atmospheric processes.
- **LO2.2:** Interpret Clausius-Clapeyron equation to predict cloud formation and precipitation patterns.
- **LO2.3:** Explain the absorption and scattering of solar radiation and their impact on Earth's energy balance.
- **LO2.4:** Discuss atmospheric phenomena like the Antarctic ozone hole and El Niño-Southern Oscillation using thermodynamic and radiative principles.

CO3: Evaluate the concept of contemporary climate change.

- **LO3.1:** Explain the differences between weather and climate, and identify climate forcing agents.
- **LO3.2:** Discuss natural and anthropogenic causes of recent climate change.
- **LO3.3:** Analyze the impacts of climate change on ecosystems, human health, and well-being.

CO4: Assess the complexities of climate change.

- **LO4.1:** Explain the interactions between different components of the climate system.

LO4.2: Analyze historical climate data to understand long-term climate patterns and changes.
LO4.3: Propose and discuss strategies for sustainability, resilience to climate change impacts, and mitigation efforts.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual	LO1.1 LO1.3 LO4.1					
Conceptual		LO1.2 LO2.3 LO2.4 LO3.1 CO1	LO2.2 LO3.2 CO2	LO1.4 LO2.1 LO3.3	LO4.2	
Procedural					CO3 CO4	LO4.3
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	M	M	M	S	S	M	M
CO2	S	S	M	S	S	M	S	S	M	S
CO3	S	M	M	S	M	M	S	S	M	S
CO4	S	S	S	S	M	M	S	S	S	S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit 1: Introduction
Evolution of the Earth Atmosphere, layers of the Atmosphere: Troposphere, Stratosphere, Mesosphere, Thermosphere, ionosphere: D, E, and F layers, Hydrostatic Balance, altitudinal variation of pressure. Composition of the atmosphere: Atmospheric gases, aerosols, hydrometeors, chemical reactions in the troposphere and the stratosphere. **(L 12, H 12, M 15)**

Unit 2: Atmospheric Processes
Atmospheric thermodynamics: First law of thermodynamics for atmosphere and its application, Clausius-Clapeyron equation Radiative processes: absorption and scattering of solar. radiation in the atmosphere: Rayleigh and Mie Scattering. Greenhouse effect- natural and enhanced, Antarctic ozone hole, global warming, Indian monsoon, El-nino and southern oscillations, general circulation. **(L 15, H 15, M 20)**

Unit 3: Climate Change, Sustainability and Resilience

The climate system, interaction among the sub-systems, Weather and climate, climate forcing agents- greenhouse gases, aerosols, clouds, land use land cover change, Role of atmosphere in climate change Climates of the past: last hundred, thousands and millions of years; Recent Climate Change: natural versus anthropogenic causes. Climate change impacts: Ecology-freshwater resources, vegetation, marine ecosystem, human health and well being, The role of Intergovernmental Panel on Climate Change (IPCC) .Sustainability and Resilience to Climate Change: SDGs, adaptation to climate change, Carbon sequestration, Mitigation technologies and potential in 2030, Zero carbon future: carbon dioxide removal (CDR), carbon free renewable energy technology- alternative energy, efficient use of energy and its conservation, reduction of global warming by geoengineering, Global Village, climate change preparedness. **(L 18, H 18, M 25)**

(Total Lectures 45, Total Contact Hours 45, Total Marks 60)

Suggested Readings:

1. Meteorology for Scientists and Engineers, *R. Stull*, Brooks/Cole.
2. Atmospheric Chemistry and Physics, *J H Seinfeld and S N Pandis,* John Wiley and Sons.
3. Introduction to Atmospheric Physics, *D G Andrews*, Cambridge University Press.
4. Fundamentals of Atmospheric Modelling, *M Z Jacobson*, Cambridge University Press.

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DETAILED SYLLABUS OF MINOR COURSES

SEMESTER I

Course title: Mechanics
Course code: PHY-MIN-1
Nature of the course: Minor
Total credits: 4
Distribution of marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This course comprises Newtonian mechanics and the fundamental laws of motion. It focuses on important topics in mechanics such as reference frames, work-energy theorems, conservation laws, matter and its properties, types of oscillations, and fundamental ideas about the special theory of relativity for undergraduate students. .It aims to provide students with a deep understanding of the laws governing the motion of objects and the nature of space and time.

Course Objectives: The course aims to impart knowledge of Newtonian mechanics, the properties of matter, oscillations, and rotating frames, as well as their role in relevant areas of physics. It will help the students develop the concepts of the special theory of relativity and help them understand space and time more.

Course Outcomes (COs): After the completion of the course, a student will be able to
CO1: Understand the basic concepts of mechanics, reference frames, and conservation laws.
- **LO1.1:** Define key terms related to mechanics.
- **LO1.2:** Explain linear dynamics and rotational dynamics.
- **LO1.3**: Interpret relative transformations and the invariance of laws of physics.

CO2: Analyze simple harmonic oscillators in detail.
- **LO2.1:** Explain simple harmonic motion in an oscillatory system.
- **LO2.2:** Solve the differential equation of simple harmonic motion.

CO3: Compare special relativity with Newtonian relativity.
- **LO3.1:** Define key terms related to the special theory of relativity.
- **LO3.2:** Contrast the changes in motion that occurred due to relativistic speed and non-relativistic speed.
- **LO3.3:** Interpret equivalence of mass and energy, relativistic transformation of momentum and energy and relativistic effects such as relativistic doppler effect.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual	LO1.1 LO3.1	LO1.2 LO1.3 LO2.1 LO3.2 CO1	LO2.1 LO2.2	CO2		

Procedural		CO3				
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S			M	M		S
CO2	S	S	S	S			M	M		S
CO3	S	S	S	S			M	M		S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit 1: Newtonian Mechanics

Frames of Reference, Inertial Frames, Galilean Transformations, Galilean Invariance; Dynamics of a System of Particles, Centre of Mass, Principle of Conservation of Linear Momentum. **(L 6, H 6, M 6)**

The Work-Energy Theorem, Conservative and Non-conservative Forces, Conservation of Mechanical Energy, Work done by non-conservative forces, Force as gradient of potential energy, Energy Diagram, Stable and Unstable Equilibrium. **(L 8, H 8, M 8)**

Principle of Conservation of Angular Momentum, Rotation about a fixed axis, Moment of Inertia, Calculation of Moment of Inertia for rectangular, cylindrical and spherical bodies, Kinetic Energy of Rotation, Motion involving both translation and rotation. **(L 10, H 10, M 10)**

Unit 2: Properties of Matter

Relation between Elastic constants, Twisting torque on a Cylinder or Wire. **(L 6, H 6, M 6)**

Kinematics of Moving Fluids, Poiseuille's Equation for Flow of a Liquid through a Capillary Tube. **(L 5, H 5, M 5)**

Unit 3: Oscillations

Simple Harmonic Motion (SHM) and Oscillations, Differential Equation of SHM and its solution, Kinetic Energy, Potential Energy, Total energy and their time-average values, Damped oscillation, Forced oscillations, Resonance, Power Dissipation and Quality Factor. **(L 10, H 10, M 10)**

Unit 4: Special Theory of Relativity

Michelson-Morley Experiment and its outcome, Postulates of Special Theory of Relativity, Lorentz Transformations, Simultaneity and order of events, Lorentz contraction, Time dilation. Relativistic addition of Velocities, Variation of Mass with Velocity, Mass-energy Equivalence. **(L 15, H 15, M 15)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. An introduction to Mechanics, *D. Kleppner, R. J. Kolenkow,* McGraw Hill.

2. Mechanics, Berkeley Physics, *C. Kittel, W. Knight, et.al.* Tata McGraw-Hill.
3. Physics, Resnick, *Halliday and Walker* Wiley.
4. Analytical Mechanics, *G. R. Fowles and G. L. Cassiday*, Cengage Learning.
5. Feynman Lectures, *R. P. Feynman, R. B. Leighton, M. Sands,* Pearson Education.
6. Mechanics, *D. S. Mathur*, S. Chand and Company Limited.
7. Introduction to Special Relativity, *R. Resnick*, John Wiley& Sons.
8. University Physics, *R. L. Reese*, Thomson Brooks/Cole.

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SEMESTER II

Course title: Waves and Optics
Course code: PHY-MIN-2
Nature of the course: Minor
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This course provides an introduction to the basic concepts of waves, oscillation, and optics. It aims to provide knowledge about superposition principles, give comprehensive ideas about simple harmonic oscillations, and introduce wave concepts, including group velocities and phase velocities. It depicts the electromagnetic nature of light and enters the domain of optics by providing in depth knowledge of optical phenomena and optical instruments based on these phenomena to undergraduate students.

Course Objectives: This course aims to develop theoretical knowledge of waves, oscillations, and the superposition principle. The course provides fundamental concepts in the study of wave phenomena and the behavior of light, especially in thin films. To acquaint the learner with the principles behind various optical instruments and to build a theoretical knowledge of them.

Course Outcomes (COs): At the completion of the course, a student will be able to

CO1: Analyze the principle of linearity and superposition, concepts of wave motion and standing waves.
- **LO1.1:** Define superposition, plane and spherical waves, and stationary waves.
- **LO1.2:** Explain the superposition of waves, the velocity of longitudinal and transverse waves in different media, and the role of standing waves in different physical systems.
- **LO1.3:** Construct Lissajous figures and develop the differential equation of a wave.

CO2: Connect the knowledge obtained from the wave with the behaviour of light.
- **LO2.1:** Explain the phenomenon of interference in thin films.
- **LO2.2:** Develop theoretical knowledge of various optical instruments.
- **LO2.3:** Illustrate key concepts of diffraction.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual	LO1.1	LO1.2 LO2.1 LO2.3	LO1.3 LO2.2	CO1 CO2		
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S			M	M		S
CO2	S	S	S	S			M	M		S
CO3	S	S	S	S			M	M		S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit 1: Superposition of Harmonic Oscillations

Linearity and Superposition Principle. Superposition of two collinear harmonic oscillations having equal frequencies and different frequencies (Beats). Superposition of N collinear harmonic oscillations with equal phase differences and equal frequency differences. **(L 5, H 5, M 5)**

Graphical and Analytical Methods: Lissajous Figures with equal and unequal frequency and their use. **(L 3, H 3, M 3)**

Unit 2: Wave Motion

Plane and Spherical Waves, Longitudinal and Transverse Waves, Plane Progressive (Travelling) Waves, Wave Equation, Particle and Wave Velocities, Differential Equation of a Wave. **(L 3, H 3, M 3)**

Velocity of transverse vibrations of stretched strings, Velocity of longitudinal waves in a fluid in a pipe, Pressure of a longitudinal wave, Newton's formula for velocity of sound, Laplace's correction, Comparison of velocity of sound in different media: air, liquid, solid. Energy, power transport and intensity of wave. **(L 8, H 8, M 8)**

Unit 3: Standing Waves

Standing (Stationary) Waves, Standing Waves in a String: Fixed and Free ends, Normal Modes of Stretched Strings, Comparison of Standing Wave with Travelling Waves, Displacement and Velocity of a Particle in a Standing Wave, Plucked and Struck Strings, Melde's Experiment, Longitudinal Standing Waves in Open and Closed Pipes, Normal Modes of Longitudinal Waves, Phase and Group Velocities. **(L 7, H 7, M 7)**

Unit 4: Wave optics

Electromagnetic nature of light, definition and properties of wave front, Huygens' principle, Temporal and Spatial coherence. **(L 3, H 3, M 3)**

Unit 5: Interference

Division of amplitude and wavefront, Young's double slit experiment, Phase change on reflection: Stokes' treatment, Lloyd's Mirror and Fresnel's Biprism, Interference in Thin Films: parallel and wedge-shaped films. Newton's Rings: Measurement of wavelength and refractive index **(L 8, H 8, M 8)**

Michelson Interferometer- (i) Idea of form of fringes (No theory required), (ii) Determination of Wavelength, (iii) Wavelength Difference, (iv) Refractive Index and (v) Visibility of Fringes.

Introduction to Fabry-Perot interferometer. **(L 4, H 4, M 4)**

Unit 6: Diffraction

Kirchhoff's Integral Theorem, Fresnel-Kirchhoff's Integral formula (Qualitative discussion only). **(L 2, H 2, M 2)**

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. **(L 7, H 7, M 7)**

Fraunhofer Diffraction: Single slit, Circular aperture. Resolving Power of a telescope, Double slit, Multiple slits. Diffraction grating, Resolving power of grating. **(L 6, H 6, M 6)**

Unit 7: Holography

Principle of Holography, Recording and Reconstruction Method, Theory of Holography as Interference between two Plane Waves, Point Source Holograms. **(L 4, H 4, M 4)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Waves: Berkeley Physics Course, *F. Crawford*, Tata McGraw-Hill.
2. Fundamentals of Optics, *F. A. Jenkins and H. E. White*, McGraw-Hill.
3. Principles of Optics, *M. Born and Emil Wolf*, Pergamon Press.
4. Optics, *A. Ghatak*, Tata McGraw Hill.
5. The Physics of Vibrations and Waves, *H. J. Pain*, John Wiley and Sons.
6. The Physics of Waves and Oscillations, *N. K. Bajaj,* Tata McGraw Hill.
7. Fundamental of Optics, *A. Kumar, H. R. Gulati and D. R. Khanna*, R. Chand Publications.

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SEMESTER III

Course title: Physics Lab 1 (Minor)
Course code: PHY-MIN-3
Nature of the course: Minor
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This course explores fundamental principles of physics through hands-on experiments and precise measurements. It utilizes techniques and optical instruments to study properties like elasticity, viscosity, and optical phenomena. Students analyze experimental data, apply mathematical models, and verify physical laws, enhancing skills in measurement, analysis, and scientific inquiry.

Course Objectives: This course is essential for developing practical skills in experimental physics, vital for understanding fundamental principles and verifying theoretical concepts through hands-on learning. It equips students with the ability to perform precise measurements, analyze data, and apply scientific methods in real-world scenarios. These skills are crucial for future scientists, engineers, and researchers who require a solid foundation in experimental techniques and scientific inquiry.

Course Outcomes (CO): After completion of this course the students will be able to

CO1: Understand and apply measurement techniques.

- **LO1.1:** Explain the sources of errors in measurements and methods to minimize them.
- **LO1.2:** Apply measurement techniques to determine physical quantities like length, diameter, and thickness accurately using vernier calipers and screw gauges.

CO2: Analyze Physical Phenomena.

- **LO2.1:** Demonstrate experiments to investigate properties such as viscosity, elasticity, and optical dispersion.
- **LO2.2:** Examine the accuracy of experimental results and compare them with theoretical predictions.
- **LO2.3:** Analyze experimental data to calculate spring constants, modulus of rigidity, and moments of inertia.

CO3: Use Optical and Interferometric Techniques.

- **LO3.1:** Apply optical techniques to measure refractive indices, wavelength using diffraction grating, and spectral characteristics of light sources.
- **LO3.2:** Utilize interference patterns to determine parameters like dispersive power and resolving power of optical elements.
- **LO3.3:** Construct experiments using interferometric techniques to verify physical laws like the λ^2–T law and study coupled oscillators.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual		CO1 LO1.1	CO1, LO1.2 LO3.1 LO3.2	CO2, LO2.3		
Procedural		LO2.1	CO3, LO3.3	LO2.2		
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	M	M	S	S	S	M	W
CO2	S	S	M	M	M	S	S	S	M	W
CO3	S	S	M	M	M	S	S	S	M	W

(S: Strong, M: Medium, W: Weak)

Course Contents:

List of Experiments:

Unit I: Mechanics

1. Measurements of length (or diameter) using vernier caliper, screw gauge and traveling microscope.
2. To study the random error in observations.
3. To determine the height of a building using a Sextant.
4. To study the Motion of Spring and calculate (a) Spring constant, (b) **g** and (c) Modulus of rigidity.
5. To determine the Moment of Inertia of a Flywheel.
6. To determine **g** and velocity for a freely falling body using Digital Timing Technique.
7. To determine Coefficient of Viscosity of water by Capillary Flow Method (Poiseuille's method).
8. To determine the Young's Modulus of a Wire by Optical Lever Method.
9. To determine the Modulus of Rigidity of a Wire by Maxwell's needle.
10. To determine the elastic Constants of a wire by Searle's method.
11. To determine the value of **g** using Bar Pendulum.

Unit 2: Waves and Optics

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 study Lissajous Figures.
4. To determine the 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 the wavelength of sodium source using Michelson's interferometer.
7. To determine wavelength of sodium light using Fresnel Biprism.
8. To determine wavelength of sodium light using Newton's Rings.
9. To determine the thickness of a thin paper by measuring the width of the interference fringes produced by a wedge-shaped Film.
10. To determine wavelength of (1) Na source and (2) spectral lines of Hg source using plane diffraction grating.
11. To determine dispersive power and resolving power of a plane diffraction grating.

(Total Practical Classes 60, Total Contact Hours 120, Total Marks)

At least 60% of the experiments must be performed from each unit.

Recommended Readings:

1. Advanced Practical Physics for students, *B. L. Flint and H. T. Worsnop*, Asia Publishing House.
2. Advanced level Physics Practicals, *Michael Nelson and Jon M. Ogborn*, Heinemann Educational Publishers.
3. A Text Book of Practical Physics, *I. Prakash and Ramakrishna*, Kitab Mahal.
4. Engineering Practical Physics, *S. Panigrahi and B. Mallick*, Cengage Learning India Pvt. Ltd.
5. Practical Physics, *G. L. Squires*, Cambridge University Press.
6. A Laboratory Manual of Physics for undergraduate classes, *D. P. Khandelwal*, Vani Publication.

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SEMESTER IV

Course title: Electricity and Magnetism
Course code: PHY-MIN-4
Nature of the course: Minor
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This course provides a fundamental understanding of electrostatics, magnetism, electromagnetic induction and Maxwell's equations. It begins with basics of vector calculus essential for physics and engineering. The curriculum covers the concept of electric fields, potential, capacitance, and dielectric effects. It also delves into the dielectric properties of matter, the principles of magnetostatics, and the magnetic properties of materials. The course also examines electromagnetic induction, including Faraday's and Lenz's laws. Finally, Maxwell's equations unify these concepts, leading to the study of electromagnetic wave propagation and energy dynamics in electromagnetic fields. This course is crucial for understanding electric and magnetic phenomena.

Course Objectives: The basic objective of this course is to

1. Introduce learners to the fundamental principles of electromagnetism.
2. Develop a basic understanding of electrostatics, magnetostatics, and electromagnetic induction.
3. Introduce learners to the dielectric properties of matter and the magnetic properties of materials.
4. Develop problem-solving skills and analytical techniques that will be useful in advanced studies.

Course Outcomes (COs): After the completion of the course the students will be able to
CO1: Understand the fundamental laws of electromagnetism and their importance in Physics.
LO1.1: Define the key concepts of electric and magnetic fields.
LO1.2: Explain the basic laws of electrostatics, magnetostatics and electromagnetic induction.
LO1.3: Describe the concept of electromagnetic induction and Maxwell's equations.
CO2: Apply fundamental laws to solve practical problems.
LO2.1: Use Gauss's law to solve problems involving symmetrical charge distributions.
LO2.2: Solve problems involving magnetic fields in different geometries using Maxwell's equations.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual	LO1.1	LO1.2 LO1.3 CO1	LO2.1 LO2.2 CO2			

Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	M	M	S	S	S	M	W
CO2	S	S	M	M	M	S	S	S	M	W
CO3	S	S	M	M	M	S	S	S	M	W

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: 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). **(L 12, H 12, M 12)**

Unit 2: 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 fields. Dielectric medium, polarisation, displacement vector. Gauss's theorem in dielectrics. Parallel plate capacitor completely filled with dielectric. **(L 22, H 22, M 22)**

Unit 3: Magnetism
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. **(L 10, H 10, M 10)**

Unit 4: 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 a magnetic field. **(L 6, H 6, M 6)**

Unit 5: 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. **(L 10, H 10, M 10)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Electricity, Magnetism & Electromagnetic Theory, *S. Mahajan and Choudhury*, Tata McGraw Hill.
2. Electricity and Magnetism, *Edward M. Purcell*, McGraw Hill Education.
3. Introduction to Electrodynamics, *D. J. Griffiths*, Pearson Education.
4. Feynman Lectures Vol.2, *R. P. Feynman, R. B. Leighton, M. Sands*, Pearson Education.
5. Elements of Electromagnetics, *M. N. O. Sadiku*, Oxford University Press.
6. Electricity and Magnetism, *J. H. Fewkes & J. Yarwood*. Oxford University Press.

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SEMESTER V

Course title: Thermal Physics
Course code: PHY-MIN-5
Nature of the course: Minor
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This course covers fundamental thermodynamic principles and kinetic theory of gasses. The course starts with the main laws of Thermodynamics, energy conservation, isothermal and adiabatic processes, and the relationship between specific heats. Heat engines, Carnot cycles, and entropy concepts are also explored thereafter. Thermodynamic potentials like internal energy, enthalpy, and Gibbs free energy are studied, alongside Maxwell's relations and their applications. The kinetic theory section addresses the Maxwell-Boltzmann distribution, molecular collisions, and real gas behaviour. By course end, students will understand and will be able to apply thermodynamic principles to various physical systems.

Course Objectives: Thermal physics is essential as it provides foundational knowledge of energy transformation and conservation principles crucial for various scientific and engineering disciplines. Understanding thermodynamics is crucial for designing and optimizing engineering systems like engines, refrigerators, and power plants. The course is equipped to provide students with analytical and problem-solving skills, enabling them to apply thermodynamic laws to real-world situations. Additionally, thermodynamics intersects with fields like chemistry, biology, and materials science, making it highly relevant for interdisciplinary applications. This course prepares students for advanced studies and careers in science and engineering by equipping them with essential theoretical and practical skills.

Course Outcomes (COs): After the completion of this course the students will be able to
CO1: Understand the fundamental principles of thermodynamics.
- **LO1.1:** Define extensive and intensive thermodynamic variables and their significance.
- **LO1.2:** Explain the Zeroth Law of Thermodynamics and its role in defining temperature.
- **LO1.3:** Interpret the First Law of Thermodynamics to analyze processes and calculate energy changes.

CO2: Experiment with apparatus for practical thermodynamic applications.
- **LO2.1:** Develop explanations for entropy changes in reversible and irreversible processes.
- **LO2.2:** Illustrate the implications of entropy in the context of the Second Law of Thermodynamics.

CO3: Apply thermodynamic potentials and their applications.
- **LO3.1:** Apply thermodynamic potentials such as internal energy, enthalpy, and Gibbs free energy to solve problems.
- **LO3.2:** Construct equations and relations using Clausius-Clapeyron and Ehrenfest equations.
- **LO3.3:** Summarize the performance of various thermodynamic cycles.

CO4: Analyze the behavior of gases and related phenomena.

LO4.1: Describe the Maxwell-Boltzmann distribution and its significance.
LO4.2: Analyze the behavior of real gases using the Van der Waals equation.
LO4.3: Apply the Joule-Thomson effect to analyze gas cooling processes.
LO4.4: Distinguish between reversible and irreversible processes and their implications.
LO4.5: Identify the efficiency of heat engines and refrigerators using the Second Law of Thermodynamics.
LO4.6: Explain the concept of entropy and its role in energy transformations.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual	LO1.1	CO1 LO1.2	LO3.1 LO4.5	LO4.2		
Conceptual		LO1.3, LO2.2, LO3.3, LO4.1	LO2.1 CO3 LO4.3	CO4, LO4.4		
Procedural		LO4.6	CO2, LO3.2			
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	M	W	W	W	W	M	W
CO2	S	S	M	S	M	W	W	W	M	M
CO3	S	S	M	S	M	W	S	M	M	S
CO4	S	S	M	S	M	M	S	M	W	S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Thermodynamics

Unit 1: Zeroth and First Law of Thermodynamics
Extensive and intensive Thermodynamic Variables, Thermodynamic Equilibrium, Zeroth Law of Thermodynamics & Concept of Temperature, Concept of Work & Heat, State Functions, First Law of Thermodynamics and its differential form, Internal Energy, First Law & various processes, Applications of First Law: General Relation between C_p and C_v, Work Done during Isothermal and Adiabatic Processes, Compressibility and Expansion Co-efficient. **(L 8, H 8, M 8)**

Unit 2: Second Law of Thermodynamics
Reversible and Irreversible process with examples. Conversion of Work into Heat and Heat into Work. Carnot's Theorem, Carnot Cycle, Carnot engine & efficiency. Refrigerator & coefficient of

performance, Second Law of Thermodynamics: Kelvin-Planck and Clausius Statements and their Equivalence. **(L 10, H 10, M 10)**

Unit 3: Entropy

Concept of Entropy, Clausius Theorem. Clausius Inequality, Second Law of Thermodynamics in terms of Entropy. Entropy of a perfect gas. Principle of Increase of Entropy. Entropy Changes in Reversible and Irreversible processes with examples. Entropy of the Universe. Temperature–Entropy diagrams for Carnot Cycle. Third Law of Thermodynamics. Unattainability of Absolute Zero.

(L 7, H 7, M 7)

Unit 4: Thermodynamic Potentials

Thermodynamic Potentials: Internal Energy, Enthalpy, Helmholtz Free Energy, Gibbs Free Energy. Magnetic Work, Cooling due to adiabatic demagnetization, First and second order Phase Transitions with examples, Clausius Clapeyron Equation and Ehrenfest equations. **(L 7, H 7, M 7)**

Unit 5: Maxwell's Thermodynamic Relations

Maxwell's Relations, (i) Clausius Clapeyron equation, (ii) Values of C_p-C_v, (iii) TdS Equations, (iv) Joule-Kelvin coefficient for Ideal and Van der Waal Gases, (v) Change of Temperature during Adiabatic Process. **(L 7, H 7, M 7)**

Kinetic Theory of Gases

Unit 6: Distribution of Velocities

Maxwell-Boltzmann Law of Distribution of Velocities in an Ideal Gas. Mean, RMS and Most Probable Speeds. Degrees of Freedom. Law of Equipartition of Energy (No proof required). Specific Heats of Gases. **(L 7, H 7, M 7)**

Unit 7: Molecular Collisions

Mean Free Path. Collision Probability. Transport Phenomenon in Ideal Gases: (i) Viscosity, (ii) Thermal Conductivity and (iii) Diffusion. Brownian Motion and its Significance. **(L 4, H 4, M 4)**

Unit 8: Real Gases

Behavior of Real Gases: Deviations from the Ideal Gas Equation. Andrew's Experiments on CO_2 Gas. Critical Constants. Continuity of Liquid and Gaseous State. Vapour and Gas. Boyle Temperature. Van der Waals Equation of State for Real Gases. Values of Critical Constants. Law of Corresponding States. Comparison with Experimental Curves. P-V Diagrams. Free Adiabatic Expansion of a Perfect Gas. Joule-Thomson Porous Plug Experiment. Joule-Thomson Effect for Real and Van der Waal Gases. Temperature of Inversion. Joule-Thomson Cooling.

(L 10, H 10, M 10)

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Heat and Thermodynamics, *M. W. Zemansky, Richard Dittman*, McGraw-Hill.
2. A Treatise on Heat, *Meghnad Saha, and B.N.Srivastava*, Indian Press.

3. Thermal Physics, *S. Garg, R. Bansal and Ghosh,* Tata McGraw-Hill.
4. Modern Thermodynamics with Statistical Mechanics, *Carl S. Helrich*, Springer.
5. Thermodynamics, Kinetic Theory & Statistical Thermodynamics, *Sears & Salinger*, Narosa.
6. Concepts in Thermal Physics, *S. J. Blundell and K. M. Blundell*, Oxford University Press.
7. Thermal Physics, *A. Kumar and S.P. Taneja*, R. Chand Publications.

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SEMESTER VI

Course Title: Physics Lab II (Minor)
Course code: PHY-MIN-6
Nature of the course: Minor
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: The course on Physics Lab II (Minor) comprises experiments covering Electricity and Magnetism and Thermal Physics.

Course Objectives: This course will enable the students to
1. Understand and appreciate the theory of electricity and magnetism and thermal physics.
2. Develop the ability to relate the theories into everyday applications.

Course Outcomes (COs): At the completion of this course a student will be able to
CO1: Understand the basic concepts in hands-on mode through the basic electricity, magnetism and thermal physics experiments.
- **LO1.1:** Recall the concepts of series and Parallel LCR circuits.
- **LO1.2:** Explain the characteristics of RC circuit, Thevenin and Norton theorem.
- **LO1.3:** Recall the basics of thermal conductivity and thermos emf.
- **LO1.4:** Explain the basics of ballistic galvanometer.

CO2: Experiment with various electrical circuits and thermal apparatus.
- **LO2.1:** Execute the experiment to measure the thermal conductivity.
- **LO2.2:** Conduct the experiment to study series and parallel LCR circuit.

CO3: Analyze different electronic components and circuits to understand its functioning.
- **LO3.1:** Analyze Q factor and bandwidth.
- **LO3.2:** Analyze the frequency response curve to determine impedance and resonance.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual	LO1.1	LO1.1 LO1.2 LO1.3 LO1.4		LO3.1 LO3.2		
Procedural			LO2.1 LO2.2			
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	M	M	M	M	S	M	M	M
CO2	S	S	M	S	M	M	M	M	M	M
CO3	M	S	M	S	M	M	S	M	M	M

(S: Strong, M: Medium, W: Weak)

Course Contents:

List of Experiments:

Unit I: Electricity and Magnetism

1. Use a Multimeter for measuring (a) Resistances, (b) AC and DC Voltages, (c) DC Current, (d) Capacitances, and I Checking electrical fuses.
2. To study the characteristics of a series RC circuit.
3. To determine an unknown Low Resistance using Potentiometer.
4. To determine an unknown Low Resistance using Carey Foster's Bridge.
5. To compare capacitances using De'Sauty's bridge.
6. To verify the Thevenin and Norton theorems.
7. To verify the Superposition, and Maximum power transfer theorems.
8. To determine self-inductance of a coil by Anderson's bridge.
9. To study the 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.
10. To study the response curve of a parallel LCR circuit and determine its (a) Anti-resonant frequency and (b) Quality factor Q.
11. Measurement of charge and current sensitivity and CDR of Ballistic Galvanometer
12. Determine a high resistance by leakage method using Ballistic Galvanometer.

Unit 2: Thermal Physics

1. To determine Mechanical Equivalent of Heat, J, by Callender and Barnes 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 Cu by Angstrom's Method.
4. To determine the Coefficient of Thermal Conductivity of a bad conductor by Lee and Charlton's disc method.
5. To determine the Temperature Coefficient of Resistance by Platinum Resistance Thermometer (PRT).
6. To study the variation of Thermo-Emf of a Thermocouple with Difference of Temperature of its Two Junctions.

(Total Practical Classes 60, Total Contact Hours 120, Total Marks 60)

At least 60% of the experiments must be performed from each unit.

Recommended Readings:

1. Advanced Practical Physics for students, *B. L. Flint and H. T. Worsnop,* Asia Publishing House.
2. A Text Book of Practical Physics, *I. Prakash & Ramakrishna*, Kitab Mahal.
3. Advanced Level Physics Practicals, *Michael Nelson and Jon M. Ogborn*, Heinemann Educational Publishers.
4. A Laboratory Manual of Physics for undergraduate classes, *D.P. Khandelwal*, Vani Publication.

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SEMESTER VII

Course Title: Elements of Modern Physics
Course code: PHY-MIN-7
Nature of the course: Minor
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: This course offers the fundamental principles of Physics from classical to quantum realms beginning by the nature of blackbody radiation, applying Kirchhoff's law, Stefan-Boltzmann law, and understanding the implications of Wien's displacement and distribution laws. It will explore deeper into quantum theory with investigations into the photoelectric effect, Compton scattering, and the wave-particle duality, including the De Broglie wavelength and matter waves. Moreover, to analyze nuclear reactions, energy release mechanisms in fission and fusion, and their applications in nuclear reactors and stellar energy processes will provide a comprehensive overview. Overall, this course integrates theoretical knowledge with practical applications, preparing students for advanced studies in physics and related disciplines.

Course Objectives:
1. To acquaint the learner with the theoretical developments of modern physics.
2. To deliver the key concepts of modern physics.
3. To impart the knowledge of nuclear physics.
4. To introduce the basics of laser physics.

Course Outcomes (COs): At the completion of this course a student will be able to
CO1: Analyze and apply concepts of both thermal radiation and quantum mechanics.
- **LO1.1:** Explain and apply fundamental laws and principles in physics such as Blackbody Radiation, Kirchhoff's law, Stefan-Boltzmann law, and Planck's Quantum Hypothesis.
- **LO1.2**: Analysis of wave properties such as probability, amplitude, and functions.

CO2: Understanding of quantum mechanics principles.
- **LO2.1:** Explain and apply the concept of wave-particle duality.
- **LO2.2:** Apply the uncertainty principle to calculate and estimate the minimum energy of confined particles.

CO3: Knowledge of the fundamental properties of atomic nuclei.
- **LO3:1:** Analyze theoretical models such as the Liquid Drop Model (Semi-empirical Mass Formula) and the Nuclear Shell Model.
- **LO3.2:** Explain the nuclear stability, isotopic trends (N-Z graph), and the role of nuclear forces in atomic nuclei.
- **LO3.3:** State advanced concepts such as mass defect, binding energy, nuclear spin, and magnetic moment.

CO4: Discuss the principles of laser physics.
- **LO4.1:** State concepts such as optical pumping, population inversion, and their role in

achieving and maintaining laser operation.

LO4.2: Describe the operational principles of three-level and four-level lasers.

LO4.3: Analyze the design considerations for different types of lasers and evaluate their suitability for various applications in technology.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual	LO4.1 LO3.3 CO3					
Conceptual		LO1.1 LO2.1 LO3.2 LO4.2 CO2 CO4	LO2.2	LO1.2 LO2.3 LO3.1 LO4.3 CO1		
Procedural						
Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	M	S	S	M	M	M	M	M	M
CO2	S	M	S	S	S	M	S	M	M	S
CO3	S	S	M	M	M	M	M	S	M	S
CO4	S	S	M	S	M	M	S	S	S	S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit 1: Radiation Laws and Quantum Hypothesis

Blackbody Radiation, Kirchhoff's law, Stefan-Boltzmann law, Wien's Displacement law, Wien's Distribution Law, Rayleigh-Jeans Law, Ultraviolet Catastrophe, Planck's Quantum Hypothesis, Planck's Constant. **(L 10, H 10, M 10)**

Unit 2: Quantum theory of Light

Photo-electric Effect and Compton Scattering. De Broglie Wavelength and Matter Waves; Davisson-Germer experiment. Wave-particle duality, Heisenberg uncertainty principle, Wave description of particles by wave packets. Group and Phase Velocities, Wave Amplitude and Wave Functions.

(L 8, H 8, M 8)

Unit 3: Quantum Equations
Schrodinger Equation for Non-relativistic Particles, Physical interpretation of a wave function, Probability and Normalization; Probability Current Density in one dimension, Momentum and Energy operators, Stationary States, One dimensional square well potential. **(L 12, H 12, M 12)**

Unit 4: Properties and Models of Nucleus
Size and Structure of Atomic Nucleus and its relation with atomic weight; Impossibility of an electron being in the nucleus as a consequence of the Uncertainty Principle. Nature of Nuclear Force, N-Z Graph, Liquid Drop Model: Semi-empirical Mass Formula and Binding Energy, Nuclear Shell Model and Magic Numbers. **(L 10, H 10, M 10)**

Unit 5: Radioactivity
Stability of the Nucleus; Law of Radioactive Decay; Mean-life and Half-life; Alpha decay, Beta decay and Energy Spectrum, Energy-Momentum Conservation, Pauli's Neutrino Hypothesis; Gamma Ray Emission, Electron-Positron Pair Creation by Gamma Photons in the vicinity of a nucleus. **(L 8, H 8, M 8)**

Unit 6: Nuclear Reactions
Fission and Fusion, Mass Deficit, Relativity and Generation of Energy; Fission- nature of fragments and emission of neutrons. Nuclear reactor: slow neutrons interacting with Uranium-235; Fusion and Thermonuclear Reactions driving stellar energy (brief qualitative discussions).
(L 6, H 6, M 6)

Unit 7: Basics of Lasers
Einstein's A and B Coefficients, Metastable States, Spontaneous and Stimulated Emissions, Optical Pumping and Population Inversion, Three-Level and Four-Level Lasers, Ruby Laser and He-Ne Laser, Basic lasing. **(L 6, H 6, M 6)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Concepts of Modern Physics, *Arthur Beiser*,McGraw-Hill.
2. Introduction to Modern Physics, *Rich Meyer, Kennard,* Coop, Tata McGraw Hill.
   Introduction to Quantum Mechanics, *David J. Griffith,* Pearson Education.
3. Physics for Scientists and Engineers with Modern Physics, *Jewett and Serway,* Cengage Learning.
4. Modern Physics, *G.Kaur and G.R. Pickrell,* McGraw Hill.
5. Quantum Mechanics: Theory & Applications, *A.K.Ghatak & S.Lokanathan*, Macmillan.

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SEMESTER VIII

Course Title: Solid State Physics
Course code: PHY-MIN-8
Nature of the course: Minor
Total credits: 4
Distribution of Marks: 60 (End sem) **+ 40** (In-sem)

Course Description: The course on Solid State Physics encompasses various aspects of crystal structures, free electron theory, lattice dynamics, magnetic and dielectric properties of materials. The goal of this course is to teach students the fundamentals of condensed matter physics which will enable them to work in both theoretical and experimental facets thereby broadening the educational goals of developing a strong foundation in condensed matter physics.

Course Objectives: The objective of the course is to:

1. Acquire knowledge of crystal structures, electronic band theory, phonons, magnetic properties, superconductivity, dielectric properties, and optical properties.
2. Develop skills to engage with both theoretical and experimental aspects of condensed matter physics.
3. Enhance understanding of theoretical concepts by applying them in practical laboratory settings.

Course Outcomes (COs): After the completion of the course, a learner will be able to

CO1: Understand a few basic topics in condensed matter physics.

- **LO1.1:** Define key terms and phenomena related to crystallography, electron theory elementary lattice dynamics, magnetic properties of materials and dielectric properties of materials.
- **LO1.2:** Explain the physics of crystallography, electron theory elementary lattice dynamics, magnetic properties of materials and dielectric properties of materials.
- **LO1.3:** Describe the physical phenomena related to crystallography, electron theory elementary lattice dynamics, magnetic properties of materials and dielectric properties of materials.

CO2: Apply the basic concepts learnt to solve condensed matter based problems.

- **LO2.1:** Solve physics problems based on the key concepts learnt.
- **LO2.2:** Use the basic condensed matter concepts to interpret the related experimental observations.

Correlations of Learning Outcomes and Course Outcomes with Level of Learning:

Factual Dimension	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual						
Conceptual	LO1.1	LO1.2 LO1.3 CO1	LO2.1 LO2.2 CO2			
Procedural						

Metacognitive						

Mapping of Course Outcomes with Program Outcomes:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10
CO1	S	S	S	S			M	M		S
CO2	S	S	S	S			M	M		S

(S: Strong, M: Medium, W: Weak)

Course Contents:

Unit I: Crystallography
Solids: symmetry elements. Unit Cell. Crystal systems Lattice Translation Vectors. Bravais Lattice, Lattice with a Basis. Miller Indices. Packing Fraction, Crystal Types. Examples of crystal structures: SC, FCC, BCC, HCP, Diamond, NaCl etc.

Reciprocal Lattice, Brillouin Zones. Diffraction of X-Rays by Crystals. Bragg's Law. Atomic Scattering Factor. Structure Factor.

Introduction to Glasses and Liquid crystals. **(L 14, H 14, M 14)**

Unit II: Electron Theory
Free Electron Theory: Basic ideas, Classical Free electron theory – Drude Model, Free electron Fermi Gas-Sommerfeld theory, Boltzmann Transport Equation.

Basic ideas of Electron Energy Bands, Energy Spectra in atoms, molecules and solids, Bloch Theorem, Kronig Penney Model, Metals, Insulators and Semiconductors according to Band Theory. **(L 12, H 12, M 12)**

Unit III: Elementary Lattice Dynamics
Lattice Vibrations and Phonons: Linear Monatomic and Diatomic Lattice. Acoustical and Optical Phonons. Qualitative Description of the Phonon Spectrum in Solids, Einstein and Debye theories of specific heat of solids, Debye's T^3 law. **(L 12, H 12, M 12)**

Unit IV: Magnetic Properties of Materials
Origin of Magnetic Moment, Gyromagnetic Ratio, Lande-g factor, Dia-, Para-, Ferri- and Ferromagnetic Materials. Classical Langevin Theory of dia– and Paramagnetic Domains. Quantum Mechanical Treatment of Paramagnetism. Curie's law, Weiss's Theory of Ferromagnetism, Domains, Hysteresis and Energy Loss. **(L 12, H 12, M 12)**

Unit V: Dielectric Properties of Materials
Polarization. Types of Polarization, Static Dielectric Constant. Local Electric Field at an Atom. Depolarization Field. Electric Susceptibility. Polarizability. Clausius Mossotti Equation. Classical Theory of Electric Polarizability. **(L 10, H 10, M 10)**

(Total Lectures 60, Total Contact Hours 60, Total Marks 60)

Recommended Readings:

1. Introduction to Solid State Physics, *Charles Kittel*, Wiley India Pvt. Ltd.
2. Elements of Solid State Physics, *J. P. Srivastava*, Prentice-Hall of India.
3. Introduction to Solids, *Leonid V. Azaroff*, Tata Mc-Graw Hill.
4. Solid State Physics, *N.W. Ashcroft and N. D. Mermin,* Cengage Learning.
5. Solid-state Physics, *H. Ibach and H. Luth*,Springer.
6. Solid State Physics, *Rita John,* McGraw Hill.
7. Elementary Solid State Physics, *M. Ali Omar,* Pearson India.
8. Solid State Physics, *M.A. Wahab*, Narosa Publications.

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