दिल्ली विश्वविद्यालय
UNIVERSITY OF DELHI

Bachelor of Science (Hons.) Physics
Or
Bachelor of Science (Hons.) Physics
with Research/ Academic Projects/ Entrepreneurship
Or
Bachelor of Science (Hons.) Physics
with Research (Major) and Discipline - 2 (Minor)

Under UGCF - 2022 based on NEP - 2020
(*Effective from Academic Year 2022-23*)

Syllabus as approved by

Academic Council

Date: No:

Executive Council

Date: No:

Syllabus for Semester I and II is complete and finalized

Syllabus for Semester III to VIII is yet to be decided

Table of Contents

S. No.	List of Contents	Page Number

FOREWORD

The syllabus for undergraduate programme in Physics has been drafted in accordance with the recommendations of the Undergraduate Curriculum Framework 2022. The preamble, definitions and abbreviations, features and important aspects of UGCF have been incorporated in this document as mentioned in UGCF 2022. In step with the evolving trends and developments in higher education globally, UGCF 2022 distinctly integrates the objectives and underlying philosophy of National Education Policy (NEP) 2020 in its attributes. The salient features such as holistic development, academic flexibility, rootedness, life-long learning, multidisciplinary education, multilingualism, intra- and inter- university mobility, apprenticeship, research, innovation, entrepreneurship, social outreach, and the like, aim to enrich the learning experience, creativity, innovation, and skill development of the youth of our nation.

- Drafting Committee

UNDERGRADUATE CURRICULUM FRAMEWORK – 2022

PREAMBLE

The Undergraduate Curriculum Framework-2022 underlines the historical perspective, philosophical basis, and contemporary realities of higher education as enshrined in the National Education Policy (NEP) 2020 and endeavours to synchronize these cornerstones while charting the road ahead for the state of higher education.

The University of Delhi, a premier seat of teaching, learning, and research in higher education, acclaimed nationally and internationally, has nurtured the quest for reaching the peak in every sphere of education, in its true sense, in the process of its contribution to the nation-building. Being a central University, mandated to act as the torchbearer in expanding the horizons of human resource development through expansion of higher education, it has always paid adequate premium towards constructive and meaningful innovation as a regular feature in its undergraduate curriculum development over the years.

A reflection of such sustained and continued endeavour is amply exemplified in the successive revision of undergraduate curricular framework over the decades and especially in the last two decades, keeping pace with the emerging trends in higher education in the new millennium globally and its critical importance in enriching the youth of our nation, well equipped with the prevailing priorities of skill development through innovative and practical oriented teaching-learning more than anything else.

To actualize the noble objective, as succinctly brought out in the National Education Policy 2020, the university has endeavoured to explore the possibility of further restructuring and refinement of its undergraduate curriculum framework in line with the objective and underlying philosophy of the NEP 2020 to capture the imagination of the youth of our nation which depicts the contemporary realities of our demographic advantage globally.

The resultant outcome of this comprehensive exercise undertaken by the university is the Undergraduate Curriculum Framework-2022 (UGCF-2022) which not only underlines the heart and soul of the NEP 2020 in letter and spirit but also goes on to create a teaching-learning framework at the undergraduate level to attract the young minds towards research, innovation, apprenticeship, social outreach, entrepreneurship and similar such areas of human knowledge and endeavour while imbibing the truly charged academic environ of the university and its constituent colleges.

The Department of Physics and Astrophysics, University of Delhi took up the task of drafting the framework for Undergraduate Degree Course in Physics according to the UGCF 2022 guidelines of the University of Delhi. The Committee of Courses of the Department formed subject working groups to formulate the content of different sets of courses for the first year (Semester I and Semester II). The subject working groups included teachers from various constituent colleges of the University, who have experience of teaching the respective courses. Faculty members from the Department of Physics and Astrophysics have also contributed to this important task. The inputs of the subject working groups were compiled, and the present document was prepared by a final drafting team.

1. UGCF-2022: Definitions and Abbreviations

(a) Academic Credit: An academic credit is a unit by which the course work is measured. It determines the number of hours of instructions required per week. One credit is equivalent to one hour of teaching (lecture or tutorial) or two hours of practical work/ field work per week.

(b) Courses of Study: Courses of the study indicate pursuance of study in a particular discipline. Every discipline shall offer four categories of courses of study, *viz.* Discipline Specific Core (DSC) courses, Discipline Specific Electives (DSEs), Skill Enhancement Courses (SECs) and Generic Electives (GEs). Besides these four courses, a student will select Ability Enhancement Courses (AECs) and Value-Added Courses (VACs) from the respective pool of courses offered by the University.

(i) Discipline Specific Core (DSC): Discipline Specific Core is a course of study, which should be pursued by a student as a mandatory requirement of his/ her programme of study. In Bachelor of Science (Hons.) Physics programme, DSCs are the core credit courses of Physics which will be appropriately graded and arranged across the semesters of study, being undertaken by the student, with multiple exit options as per NEP 2020. A student will study three DSC courses each in Semesters I to VI; and one DSC course each in semesters VII and VIII.

(ii) Discipline Specific Elective (DSE): The Discipline Specific Electives (DSEs) are a pool of credit courses of Physics from which a student will choose to study based on his/ her interest. A student of Bachelor of Science (Hons.) Physics, gets an option of choosing one DSE of Physics in each of the semesters III to VI, while the student has an option of choosing a maximum of three DSE courses of Physics in semesters VII and VIII.

(iii) Generic Elective (GE): Generic Electives is a pool of courses offered by various disciplines of study (excluding the GEs offered by the parent discipline) which is meant to provide multidisciplinary or interdisciplinary education to students. In case a student opts for DSEs beyond his/ her discipline specific course(s) of study, such DSEs shall be treated as GEs for that student. In semesters I, II, V and VI, a student has to compulsorily study one GE course from a pool of courses offered by the institution. However, in semesters III and IV a student has an option of choosing between a DSE course in Physics and a GE course of another discipline. Similarly, in semester VII and VIII a student can exercise an option of choosing a maximum of two GE courses out of a combination of three DSE and GE courses.

(iv) Ability Enhancement course (AEC), Skill Enhancement Course (SEC) and Value Addition Course (VAC): These three courses are a pool of courses offered by all the Departments in groups of odd and even semesters from which a student can choose. A student who desires to make Academic Project/ Entrepreneurship as Minor has to pick the appropriate combination of courses of GE, SEC, VAC, and Internship/Apprenticeship/ Project/Community Outreach which shall be offered in the form of various modules.

- **AEC courses** are the courses based upon the content that leads to knowledge enhancement through various areas of study. They are Language and Literature and Environmental Science and Sustainable Development which are mandatory for all disciplines. Every student has to study "Environmental Science and Sustainable Development" courses I and II of two credits each in the first year (I/ II semester) and the second year (III/ IV semester), respectively. The AEC pool consists of credit courses in languages listed in the Eighth Schedule of the Constitution of India, as updated from time to time.

- **SECs** are skill-based courses in all disciplines and are aimed at providing hands-on training, competencies, proficiency and skills to students. SEC courses may be chosen from a pool of courses designed to provide skill-based instruction. Some of these courses may be offered to students of Physics while the rest can be open to students of all other disciplines.
  A student will study one Skill Enhancement Course of 2 credits each (following 1T+ 1P/ 0T+2P credit system) in all the semesters from I to VI. It is to be noted that in the semesters III, IV, V and VI; students can choose either one SEC paper or can join any Internship/ Apprenticeship/ Project (following two credit system).

- **VACs** are common pool of courses offered by different disciplines and aimed towards personality building, embedding ethical, cultural and constitutional values; promote critical thinking, Indian knowledge systems, scientific temperament, communication skills, creative writing, presentation skills, sports and physical education and team work which will help in all round development of students.

2. Features of UGCF 2022

The Undergraduate Curriculum Framework 2022 (UGCF 2022) is meant to bring about systemic change in the higher education system in the University and align itself with the NEP 2020. The objectives of the NEP 2020 have been reflected in the following features of UGCF 2022.

a) Holistic Development

Holistic development of the students shall be nurtured through imparting life skills in initial years. These life skill courses shall include courses on 'Environment and Sustainable Development Studies', 'Communication Skills', 'Ethics and Culture', 'Science and Society', 'Computational Skills', 'IT and Data Analytics', and similar such skills which shall make the students better equipped to deal with the life's challenges.

b) Academic Flexibility

Flexibility to the students to determine their learning trajectories and pursuance of programmes of study has been well ingrained in the UGCF. The framework allows students to opt for one, two, or more discipline(s) of study as a core discipline(s) depending on his/her choice. He/she has been provided the option of focusing on studying allied courses of his/her selected discipline(s) (DSEs) or diversifying in other areas of study of other disciplines. Students have also been provided with the flexibility to study SECs or opt for Internships or Apprenticeship or Projects or Research or Community Outreach at an appropriate stage. In the fourth year, students are provided flexibility to opt for writing a dissertation (on major, minor, or combination of the two) or opt for Academic Projects or Entrepreneurship depending upon their choice and their future outlook, post completion of their formal education.

c) Multiple Exits/ Re-entry/ Academic Bank of Credit (ABC)/ Academic Outreach

Given the extent of plurality of the Indian society and the diverse background to which students belong, multiple exits and provision of re-entry have been provided at various stages of the undergraduate programme to accommodate their requirement and facilitate them to complete their studies depending upon their priorities of life. The earning and accumulation of credits in the Academic Bank of Credit (ABC), and the flexibility to redeem the requisite credit for award of appropriate Certificate/Diploma/Degree, as the per the norms laid down by the UGC and the University, shall be made available to the students to provide the opportunity for lifelong learning as well as for availing academic outreach beyond the superstructure of the programme of study in another University/Institution at the national/ international level depending upon individual choice of the student(s).

d) Multidisciplinary Education

UGCF has incorporated multidisciplinary education by embedding within the framework the need to opt for at least four elective papers from any other discipline(s) other than the one opted as core discipline(s). In fact, a student who pursues a single-core discipline programme may obtain minor in a particular discipline, other than the core discipline, if he/she earns at least 28 credits in that particular discipline.

The framework does not maintain/support hierarchy among fields of study/disciplines and silos between different areas of learning. As long as a student fulfils the pre-requisites of a course of study, he/she shall be able to study it. Modules or systems of study shall be meaningfully laid down so as to guide the students in choosing the track/academic paths for the desired outcome.

e) Multilingualism

One of the significant hallmarks of the framework is a provision of pursuing multilingualism while studying any other discipline as core subject(s), which has no bearing with any language and linguistics. I and II semesters of the programme provides an opportunity to the students to study languages which are enshrined under the eighth schedule of the Constitution of India, thereby allowing the students for their holistic development, including the ability to acquire proficiency in a language beyond their mother tongue.

f) Research and Innovation

The framework provides a mandatory programme on research methodologies as one of the discipline specific elective (DSE) courses at the VI and VII semester for students who opt for writing dissertation on major/minor discipline at VII and VIII semesters. Further, provision for internship/apprenticeship/project/community outreach right from the III semester up to VI semester provides ample opportunity to the students to explore areas of knowledge/activity beyond the four walls of the classroom and reach out to the world outside without any dilution of the academic feature of the course of study, he/she is pursuing. This also acts a precursor for the students to take up academic project or entrepreneurship at a later stage in VII and VIII semester. Such an initiative will help in skill development and laying a strong foundation for research and thus contribute towards overall national development through the development of skilled manpower and innovation.

g) Intra- and Inter-University Mobility

Intra and inter University mobility of students is another element of critical importance which has been ingrained in the framework. A student, by virtue of such mobility, will be able to make lateral movement within the University as well as from the University to any other Institution and vice-versa. Such an attribute allows a student maximum flexibility in terms of pursuance of education with special reference to higher education and enables him/ her to achieve goal of life, the way he/she perceived it.

Based on the aforementioned features of UGCF 2022, the University expects maximum involvement of the student fraternity in utilizing the benefits of such a flexible yet rigorous curriculum framework at the undergraduate level and reaping the benefits of it through enrichment of their skills in their area of interest which will eventually help them in gaining employment, entrepreneurship, start-ups and various other ways of a dignified life and living as a global citizen with comparable skills and innovative ideas befitting to the contemporary global demands. The university expects the youthful nation to reap the maximum benefits out of the UGCF 2022 in developing skilled manpower to harness the youthful energy at one hand and expand the permeation of the skilled workforce globally, taking the demographic advantage on the other hand.

Bachelor of Science (Hons.) Physics

Or

Bachelor of Science (Hons.) Physics with Research/ Academic Projects/ Entrepreneurship

or

Bachelor of Science (Hons.) Physics with Research (Major) and Discipline - 2 (Minor)

3. Introduction to Undergraduate Degree course in Physics

As per the recommendations of UGCF 2022, the undergraduate degree course in Physics is a six/ eight semester course spread over three/ four academic years. The teaching – learning process is student-centric and it involves both theory and practical components. It offers a flexibility of programme structure while ensuring that the student gets a strong foundation in the subject and gains in-depth knowledge. Besides the DSCs, a student can opt courses from the syllabus comprising of DSEs, GEs, SECs, AECs and VACs. Thereby, bringing out the multidisciplinary approach and adherence to innovative ways within the curriculum framework. Moreover, it allows a student maximum flexibility in pursuing his/her studies at the undergraduate level to the extent of having the liberty to eventually design the degree with multiple exit options depending upon the needs and aspirations of the student in terms of his/her goals of life, without compromising on the teaching learning, both in qualitative and quantitative terms. This will suit the present day needs of students in terms of securing their paths towards higher studies or employment.

4. Programme Duration and Exit Options

The minimum credit to be earned by a student per semester is 18 credits and the maximum is 26 credits. However, students are advised to earn 22 credits per semester. This provision is meant to provide students the comfort of the flexibility of semester-wise academic load and to learn at his/her own pace. However, the mandatory number of credits which have to be secured for the purpose of award of Undergraduate Certificate/ Undergraduate Diploma/Appropriate Bachelor’s Degree in Physics are listed in Table 1.

Table 1: Qualification Type and Credit Requirements

S. No.	Type of Award	Stage of Exit	Mandatory Credits to be Secured for the Award
1	Undergraduate Certificate in Physics	After successful completion of Semester II	44
2	Undergraduate Diploma in Physics	After successful completion of Semester IV	88
3	Bachelor of Science Physics (Hons.)	After successful completion of Semester VI	132
4	Bachelor of Science Physics (Hons. with Research / Academic Projects/Entrepreneurship)	After successful completion of Semester VIII	176
5	Bachelor of Science Physics (Hons.) with Research in Physics (Major) and Discipline - 2 (Minor)	After successful completion of Semester VIII with minimum 28 GE credits in Discipline - 2 (Minor)	176

Major Discipline (Physics)
A student pursuing four-year undergraduate programme in Physics (Core course) shall be awarded B.Sc. Honours degree with Major in Physics on completion of VIII Semester, if he/she secures in Physics at least 50% of the total credits i.e., at least 88 credits in Physics out of the total of 176 credits. He/she shall study 20 DSCs and at least 2 DSEs of Physics in eight semesters.

Minor Discipline (Discipline - 2)
A student of B.Sc. (Hons.) Physics may be awarded Minor in a discipline, other than Physics, on completion of VIII Semester, if he/she earns minimum 28 credits from seven GE courses of that discipline.

5. Programme Objectives

The undergraduate degree course in Physics aims to provide:

- In-depth knowledge in physics through understanding of key physical concepts, principles, theories and their manifestations.
- Competence and skill in solving both theoretical and applied physics problems.
- A conducive learning environment to ensure cognitive development of students.
- Exposure to the latest advances in physics, allied disciplines and research.
- Critical and analytical thinking, scientific reasoning, problem-solving skills, communication skills and teamwork.
- Moral and ethical awareness, leadership qualities, innovation and life-long learning.
- Multicultural competence and multilinguism.
- Knowledge and skills to undertake higher studies/research in physics and related interdisciplinary areas thereby enabling students' employment/entrepreneurship.
- Sufficient subject matter competence and enable students to prepare for various competitive examinations such as IIT-JAM, GATE, GRE, UGC-CSIR NET/JRF and Civil Services Examinations.

6. Program Outcomes

The learning outcomes of the undergraduate degree course in physics are as follows:

- **In-depth disciplinary knowledge**: The student will acquire comprehensive knowledge and understanding of the fundamental concepts, theoretical principles and processes in the main and allied branches of physics. The core papers will provide in-depth understanding of the subject. A wide choice of elective courses offered to the student will provide specialized understanding rooted in the core and interdisciplinary areas.
- **Hands-on/ Laboratory Skills:** Comprehensive hands-on/ laboratory exercises will impart analytical, computational and instrumentation skills. The students will be able to demonstrate mature skills for the collation, evaluation, analysis and presentation of information, ideas, concepts as well as quantitative and/or qualitative data.
- **Research skills:** The course provides an opportunity to students to hone their research and innovation skills through internship/apprenticeship/ project/community outreach/dissertation/Academic Project/Entrepreneurship. It will enable the students to demonstrate mature skills in literature survey, information management skills, data analysis and research ethics.
- **Role of Physics**: The students will develop awareness and appreciation for the significant role played by physics in current societal and global issues. They will be able to address and contribute to such issues through the skills and knowledge acquired during the programme. They will be able identify/mobilize appropriate resources required for a project, and managing a project through to completion, while observing responsible and ethical scientific conduct, safety and laboratory hygiene regulations and practices.
- **Communication and IT Skills:** Various DSCs, DSEs, SECs, GEs and AECs have been designed to enhance student's ability to write methodical, logical and precise reports. The courses will, in addition, guide the student to communicate effectively through oral/poster presentations, writing laboratory/ project reports and dissertations. Several IT based papers in DSCs, DSEs, SECs and AECs will enable students to develop expertise in general and subject specific computational skills.
- **Critical and Lateral Thinking**: The programme will develop the ability to apply the underlying concepts and principles of physics and allied fields beyond the classrooms to real life applications, innovation and creativity. A student will be able to distinguish between relevant and irrelevant facts and information, discriminate between objective and biased information, apply logic to arrive at definitive conclusions, find out if conclusions are based upon sufficient evidence, derive correct quantitative results, make rational evaluations, and arrive at qualitative judgments according to established rules.

7. Programme Structure

The detailed framework of undergraduate degree programme in Physics is provided in **Table 2.**

Table 2
Structure of Undergraduate Programme in Physics under UGCF – 2022

Semester	Discipline Specific Core (DSC) (4) #	Discipline Specific Elective (DSE) (4) #	Generic Elective (GE) (4) #	Ability Enhancement Course (AEC) (2) #	Skill Enhancement Course (SEC) (2) #	Internship/ Apprenticeship/ Project/Community Outreach (IAPC) (2) #	Value Addition Course (VAC) (2) #	Total Credits
I	DSC 1 (2T+2P)## DSC 2 (3T+1P) DSC 3 (2T+2P)	NA	Choose one from a pool of courses GE 1 to GE 10 (2T+2P)/ (3T+1P)/ (3T+1Tut)	Choose one AEC from a pool of courses	Choose one from a pool of courses SEC 1 to SEC 8 (1T+1P)/ (0T+2P)	NA	Choose one from a pool of courses	**22**
II	DSC 4 (2T+2P) DSC 5 (3T+1P) DSC 6 (2T+2P)	NA	Choose one from a pool of courses GE 11 to GE 20 (2T+2P)/ (3T+1P)/ (3T+1Tut)	Choose one AEC from a pool of courses	Choose one from a pool of courses SEC 9 to SEC 15 (1T+1P)/ (0T+2P)	NA	Choose one from a pool of courses	**22**
Students on exit shall be awarded Undergraduate Certificate in Physics after securing the requisite 44 credits in Semester I and II								**Total = 44**
III	DSC 7 (4T+0P) DSC 8 (3T+1P) DSC 9 (2T+2P)	Choose from a pool of courses DSE 1 (4T+0P)/ DSE 2 (2T+2P) OR GE 1 to GE 10 (2T+2P)/ (3T+1P)/ (3T+1Tut)*		Choose one AEC from a pool of courses	Choose one from a pool of courses SEC 1 to SEC 8 (1T+1P)/ (0T+2P) OR IAPC**		Choose from a pool of courses	**22**
IV	DSC 10 (3T+1P) DSC 11 (3T+1P) DSC 12 (2T+2P)	Choose from a pool of courses DSE 3 (4T+0P)/ DSE 4 (2T+2P)/ DSE 5 (4T+0P) OR GE 11 to GE 20 (2T+2P)/ (3T+1P)/ (3T+1Tut)		Choose one AEC from a pool of courses	Choose one from a pool of courses SEC 9 to SEC 15 (1T+1P)/ (0T+2P) OR IAPC**		Choose from a pool of courses	**22**
Students on exit shall be awarded Undergraduate Diploma in Physics after securing the requisite 88 credits after completion of Semester IV								**Total = 88**

Semester	Discipline Specific Core (DSC) (4) #	Discipline Specific Elective (DSE) (4) #	Generic Elective (GE) (4) #	Ability Enhancement Course (AEC) (2) #	Skill Enhancement Course (SEC) (2) #	Internship/ Apprenticeship/ Project/Community Outreach (IAPC) (2) #	Value Addition Course (VAC) (2) #	Total Credits
V	DSC 13 (4T+0P) DSC 14 (3T+1P) DSC 15 (2T+2P)	Choose one from a pool of courses DSE 6 (4T+0P) DSE 7 (2T+2P) DSE 8 (2T+2P)	Choose one form a pool of courses GE 1 to GE 10 (2T+2P)/ (3T+1P)/ (3T+1Tut)	NA	Choose one from a pool of courses SEC 1 to SEC 8 (1T+1P)/ (0T+2P) OR IAPC**		NA	**22**
VI	DSC 16 (4T+0P) DSC 17 (3T+1P) DSC 18 (2T+2P)	Choose one from a pool of courses DSE 9 (4T+0P) DSE 10 (2T+2P) DSE 11 (4T+0P) ***	Choose one form a pool of courses GE 11 to GE 20 (2T+2P)/ (3T+1P)/ (3T+1Tut)	NA	Choose one from a pool of courses SEC 9 to SEC 15 (1T+1P)/ (0T+2P) OR IAPC**		NA	**22**
Students on exit shall be awarded *Bachelor of Physics (Hons.)* after securing the requisite 132 credits on completion of Semester VI								**Total = 132**
VII	DSC 19 (4T+0P)	From the pool of DSE 12 to DSE 19 and GE 1 to GE10, Choose three DSE courses OR Choose two DSE and one GE courses OR Choose one DSE and two GE courses ****		NA	NA	NA	Dissertation on Major (6) OR Dissertation on Minor (6) OR Academic project/ Entrepreneurship (6)	**22**
VIII	DSC 20 (4T+0P)	From a pool of DSE 20 to DSE 25 and GE 11 to GE 20, Choose three DSE courses OR Choose two DSE and one GE courses OR Choose one DSE and two GE courses ****		NA	NA	NA	Dissertation on Major (6) OR Dissertation on Minor (6) OR Academic project/ Entrepreneurship (6)	**22**
After securing the requisite 176 credits on completion of Semester VIII, students on exit shall be awarded ***Bachelor of Physics (Hons. with Research /Academic Projects/Entrepreneurship)*** ***Or*** ***Bachelor of Physics (Hons.) with Research in Physics* (Major) and Discipline -2 (Minor)***								**Total = 176**

Value inside parenthesis signifies credit of that course.
T stands for theory credits, P stands for practical credits, Tut stands for tutorial credits.
* There shall be choice in Semester III and IV to either choose a DSE (from a pool of Physics DSE courses) or a GE (from a pool of GE courses other than physics or a DSE course from other discipline which will be considered as a GE course).
** There shall be choice in III to VI Semesters to choose either one 'SEC' or in the alternative 'Internship/Apprenticeship/Project/Community Outreach (IAPC)' in each Semester for two credits each.
*** **'Research Methodology'** shall be offered as one of the DSE courses in VI and VII. If a student wishes to pursue four years Honours Degree with research, he/she shall compulsorily opt for a Research Methodology course in either VI Semester or VII Semester.
****The following choices will be available in VII and VIII semesters:

(i) to choose three DSEs of 4 credits each OR
(ii) to choose two DSEs and one GE of 4 credits each OR
(iii) to choose one DSE and two GEs of 4 credits each.

Note:

1) The syllabus for semesters I and II are final.

2) The syllabus for semesters III to VIII is yet to be finalized.

3) The size of the group for practical papers is recommended to be a maximum of 16 students for an honours course.

4) The size of the group for tutorial hours is recommended to be a maximum of 16 students for an honours course.

7.1 Semester-wise Distribution of Discipline Specific Core (DSC) Courses

A student will study three Discipline Specific Core Courses each in Semesters I to VI and one core course each in semesters VII and VIII. The semester wise distribution of DSC courses over eight semesters is listed in **Table 3**.

Table 3
Semester-wise Distribution of Discipline Specific Core (DSC) Courses

DISCIPLINE SPECIFIC CORE COURSES (4 Credits each)			
SEMESTER	**COURSE CODE**	**NAME OF THE COURSE**	**CREDITS** **T = Theory Credits** **P = Practical Credits**
I	**DSC 1**	Mathematical Physics I	T = 2 P = 2
I	**DSC 2**	Mechanics	T = 3 P = 1
I	**DSC 3**	Waves and Oscillation	T = 2 P = 2
II	**DSC 4**	Mathematical Physics II	T = 2 P = 2
II	**DSC 5**	Electricity and Magnetism	T = 3 P = 1
II	**DSC 6**	Electrical Circuit Analysis	T = 2 P = 2
III	**DSC 7**	Mathematical Physics III	T = 4 P = 0
III	**DSC 8**	Thermal Physics	T = 3 P = 1
III	**DSC 9**	Light and Matter	T = 2 P = 2
IV	**DSC 10**	Modern Physics	T = 3 P = 1
IV	**DSC 11**	Solid State Physics	T = 3 P = 1
IV	**DSC 12**	Analog Electronics	T = 2 P = 2
V	**DSC 13**	Atomic, Molecular and Nuclear Physics	T = 4 P = 0

DISCIPLINE SPECIFIC CORE COURSES (4 Credits each)			
SEMESTER	**COURSE CODE**	**NAME OF THE COURSE**	**CREDITS** **T = Theory Credits** **P = Practical Credits**
V	**DSC 14**	Quantum Mechanics – I	T = 3 P = 1
V	**DSC 15**	Digital Electronics	T = 2 P = 2
VI	**DSC 16**	Statistical Mechanics	T = 4 P = 0
VI	**DSC 17**	Electromagnetic Theory	T = 3 P = 1
VI	**DSC 18**	Modelling and Statistical Analysis in Physics	T = 2 P = 2
VII	**DSC 19**	Classical Mechanics	T = 4 P = 0
VIII	**DSC 20**	Quantum Mechanics II	T = 4 P = 0

7.2 Details of Discipline Specific Elective (DSE) Courses

The Discipline Specific Electives (DSEs) are a pool of credit courses of Physics from which a student will choose to study based on his/ her interest. A student of Bachelor of Science (Hons.) Physics gets an option of choosing one DSE of Physics in each of the semesters III to VI, while the student has an option of choosing a maximum of three DSE courses of Physics in semesters VII and VIII. The semester wise distribution of DSE courses over six semesters is listed in **Table 4**.

Table 4

Details of Discipline Specific Elective (DSE) Courses

DISCIPLINE SPECIFIC ELECTIVE COURSES (4 Credits each)			
SEMESTER	**COURSE CODE**	**NAME OF THE COURSE**	**CREDITS** **T = Theory Credits** **P = Practical Credits**
III	DSE 1	Biophysics	T = 4 P = 0
III	DSE 2	Numerical Analysis	T = 2 P = 2
IV	DSE 3	Advanced Mathematical Physics I	T = 4 P = 0
IV	DSE 4	Physics of Devices	T = 2 P = 2
IV	DSE 5	Physics of Earth	T = 4 P = 0
V	DSE 6	Astronomy and Astrophysics	T = 4 P = 0
V	DSE 7	Physics of Materials	T = 2 P = 2
V	DSE 8	Communication System	T = 2 P = 2
VI	DSE 9	Advanced Mathematical Physics II	T = 4 P = 0
VI	DSE 10	Microprocessor	T = 2 P = 2
VI	DSE 11	Research Methodology	T = 4 P = 0
VII	DSE 12	Nano Science	T = 2 P = 2
VII	DSE 13	Plasma Physics	T = 4 P = 0
VII	DSE 14	Introduction to Particle Physics	T = 4 P = 0
VII	DSE 15	Group Theory and Applications	T = 4 P = 0

DISCIPLINE SPECIFIC ELECTIVE COURSES (4 Credits each)			
SEMESTER	**COURSE CODE**	**NAME OF THE COURSE**	**CREDITS** **T = Theory Credits** **P = Practical Credits**
VII	DSE 16	Radiation and its Applications	T = 2 P = 2
VII	DSE 17	Advanced Mathematical Physics III	T = 4 P = 0
VII	DSE 18	Physics of Atmosphere and Climate Change	T = 3 P = 1
VII	DSE 19	Research Methodology	T = 4 P = 0
VIII	DSE 20	Applied Dynamics	T = 4 P = 0
VIII	DSE 21	Applied Optics	T = 2 P = 2
VIII	DSE 22	Introduction to Field Theory	T = 4 P = 0
VIII	DSE 23	Nuclear and Particle Detectors	T = 4 P = 0
VIII	DSE 24	Quantum Information	T = 4 P = 0
VIII	DSE 25	General Theory of Relativity	T = 4 P = 0

Note: It is to be ensured that while choosing DSEs or SECs a student should not opt for a paper where the course content is similar to the paper previously studied by the student.

7.3 Details of Skill Enhancement Courses (SECs)

To enhance the skills required for advanced studies, research and employability of students various Skill Enhancement Courses will be offered to students as listed in **Table 5**.

Table 5
Details of Skill Enhancement Courses

SKILL ENHANCEMENT COURSE (2 Credits each)		
COURSE CODE	**NAME OF THE COURSE**	**CREDITS** **T = Theory Credits** **P = Practical Credits**
POOL A: (TO BE OFFERED IN SEMESTERS 1/3/5)		
SEC 1	Basic of Instruments	T = 0 P = 2
SEC 2	Programming for Physical Applications (C/C++ or Python)	T = 0 P = 2
SEC 3	Numerical Techniques	T = 0 P = 2
SEC 4	Electric Circuits and Networks	T = 0 P = 2
SEC 5	Sensors and Detection Technology	T = 1 P = 1
SEC 6	Renewable Energy and Energy Harvesting	T = 1 P = 1
SEC 7	Introduction to Scilab Programming	T = 0 P = 2
SEC 8	Technical Drawing and 3D Printing	T = 0 P = 2

SKILL ENHANCEMENT COURSE (2 Credits each)		
COURSE CODE	**NAME OF THE COURSE**	**CREDITS** **T = Theory Credits** **P = Practical Credits**
POOL B: (TO BE OFFERED IN SEMESTERS 2/4/6)		
SEC 9	Data Analysis and Statistical Methods	T = 0 P = 2
SEC 10	Radiation Safety	T = 1 P = 1
SEC 11	Introduction to Physics of Devices	T = 1 P = 1
SEC 12	Introduction to Laser and Fibre Optics	T = 1 P = 1
SEC 13	Weather Forecasting	T = 1 P = 1
SEC 14	Embedded System Programming	T = 0 P = 2
SEC 15	Verilog and FPGA Programming	T = 0 P = 2

7.4 Details of Generic Elective (GE) Courses

Generic Elective courses provide multidisciplinary or interdisciplinary education to students. Various GE courses offered by the Physics Department are listed below in **Table 6**.

Table 6
Details of Generic Elective (GE) Courses

GENERIC ELECTIVE COURSE (4 Credits each)		
COURSE CODE	**NAME OF THE COURSE**	**CREDITS** **T = Theory Credits** **P = Practical Credits** **Tut = Tutorial Credits**
POOL A **(TO BE OFFERED IN SEMESTERS 1/3/5/7)**		
GE 1	Mechanics	T = 3 P = 1 Tut = 0
GE 2	Mathematical Physics	T = 3 P = 0 Tut = 1
GE 3	Waves and Optics	T = 3 P = 1 Tut = 0
GE 4	Introduction to Electronics	T = 2 P = 2 Tut = 0
GE 5	Solid State Physics	T = 3 P = 0 Tut = 1
GE 6	Introductory Astronomy	T = 3 P = 0 Tut = 1
GE 7	Biological Physics	T = 3 P = 0 Tut = 1
GE 8	Numerical Analysis and Computational Physics	T = 2 P = 2 Tut = 0
GE 9	Applied Dynamics	T = 3 P = 0 Tut = 1
GE 10	Quantum Information	T = 3 P = 0 Tut = 1

GENERIC ELECTIVE COURSE (4 Credits each)		
COURSE CODE	**NAME OF THE COURSE**	**CREDITS** **T = Theory Credits** **P = Practical Credits** **Tut = Tutorial Credits**
POOL B **(TO BE OFFERED IN SEMESTERS 2/4/6/8)**		
GE 11	Electricity and Magnetism	T = 3 P = 1 Tut = 0
GE 12	Thermal Physics	T = 3 P = 1 Tut = 0
GE 13	Modern Physics	T = 3 P = 1 Tut = 0
GE 14	Introductory Astronomy	T = 3 P = 0 Tut = 1
GE 15	Quantum Mechanics	T = 3 P = 0 Tut = 1
GE 16	Introduction to Embedded System Design	T = 2 P = 2 Tut = 0
GE 17	Nano Physics	T = 2 P = 2 Tut = 0
GE 18	Physics of Detectors	T = 3 P = 0 Tut = 1
GE 19	Nuclear and Particle Physics	T = 3 P = 0 Tut = 1
GE 20	Atomic and Molecular Physics	T = 3 P = 0 Tut = 1

The GE courses will be offered in Pool.
GE 1 to **GE 10** constitutes **Pool A** and should be offered in **ODD semester.**
GE 11 to **GE 20** constitutes **Pool B** and should be offered in **EVEN semester.**

8. Teaching-Learning Process

The undergraduate programme in Physics is designed to provide students with a sound theoretical background, practical training in all aspects of physics and research. It will help them develop an appreciation of the importance of physics in different contexts. The programme includes foundational as well as in-depth courses that span the traditional sub-disciplines of physics. Along with the DSCs there are DSEs, GEs, SECs, AECs and VACs which address the need of the hour. The pre-requisite for this programme is CUET UG entrance exam syllabus.

These courses will be delivered through the conventional chalk and talk method, laboratory work, projects, case studies, field work, seminars, hands-on training/workshops in a challenging, engaging, and inclusive manner that accommodates a variety of learning styles and ICT enabled teaching-learning tools (PowerPoint presentations, audio visual resources, e-resources, models, softwares, simulations, virtual labs etc).

Students will be encouraged to carry out short term projects and participate in industrial and institutional visits and outreach programmes. They will be introduced to scientific reasoning and discovery, innovative problem-solving methodologies, online quizzes, surveys, critical analysis etc. to develop convergent and divergent thinking abilities.

The laboratory training complements the theoretical principles learned in the classroom and includes hands-on experience with modern instruments, computational data analysis, modelling, error estimation and laboratory safety procedures.

Different pedagogies such as experiential learning, participative learning, project-based learning, inquiry-based learning and ICT pedagogy integration instruction (blended and flipped learning) will be adopted wherever possible. Students will be encouraged to work in groups to develop their interpersonal skills like communication and team work.

Students' diligent and active participation/ engagement in industrial visits/ internships/ academic projects/ dissertations will lay a strong foundation for a successful career in academics, industry, research, entrepreneurship and community outreach.

9. Assessment Methods

The primary objective of assessment will be to assess the learning outcomes of the course in tune with the broad outcomes of strengthening core theoretical knowledge base, practical laboratory skills, and research. Assessment will be based on continuous evaluation (class test, presentation, group discussion, quiz, assignment etc.) and end of semester examination of University of Delhi.

(i) **Internal Assessment or Continuous Evaluation:** During a semester, students' mastery of the various learning outcomes as described in the syllabus will be assessed through class tests, assignments, group assignments, laboratory record files, project reports, quizzes, MCQs, presentations etc. Each theory paper will have 25% marks for internal assessment. The component of internal assessment for each practical paper will be 50% marks. The critical analysis of internal assessment/ continuous evaluation outcomes will provide opportunities to improve the teaching-learning process by focusing on the areas that need conceptual strengthening, laboratory exposure or design of new experiments, and research.

(ii) **End of Semester University Examinations**: The summative end-semester university examinations will be conducted for both theory and practical courses. Besides internal assessment, each theory paper will have 75% marks and each practical paper will be of 50% marks for end of semester examination of the university.

10. Scheme of Examination

The total marks for a four credit course is 100 and for a two credit course is 50. The distribution of 100 marks for each of DSC (4T+0P and 0T+4P), DSE (4T+0P and 2T+2P) and GE (2T+2P+0Tut, 3T+1P+0Tut and 3T+0P+1Tut) courses is shown in **Table 7**.

Further, the distribution of 50 marks for each of SEC course in 0T+2P /1T+1P format is also given in **Table 7**.

Table 7

Distribution of total marks for DSC/DSE/SEC/GE courses in different credit formats.

Type of Paper	Credit Format	Theory Component	Practical Component
Discipline Specific Core (DSC)	**4 T + 0 P**	**Theory: 100 Marks** **Internal assessment:** 25 Marks a) Class Test: 10 Marks b) Assignment/Presentation/Quiz/Group Discussion: 10 Marks c) Attendance: 05 Marks **End Semester Theory Examination:** 75 Marks	NA
Discipline Specific Core (DSC)	**3 T + 1 P**	**Theory: 75 Marks** **Internal assessment:** 25 Marks a) Class Test: 10 Marks b) Assignment/Presentation/Quiz/Group Discussion: 10 Marks c) Attendance: 05 Marks **End Semester Theory Examination:** 50 Marks	**Practical: 25 Marks** **Practical Examination:** 12.5 Marks: a) Experiment: 10 Marks b) Viva Voce: 2.5 Marks **Continuous Evaluation:** 12.5 Marks: a) Performance Assessment: 7.5 Marks b) Record File: 5 Marks
Discipline Specific Core (DSC)	**2 T + 2 P**	**Theory: 50 Marks** **Internal assessment:** 12 Marks a) Class Test: 05 Marks b) Assignment/Presentation/Quiz/Group Discussion: 05 Marks c) Attendance: 02 Marks **End Semester Theory Examination:** 38 Marks	**Practical: 50 Marks** **Practical Examination:** 25 Marks a) Experiment: 20 Marks b) Viva Voce: 05 Marks **Continuous Evaluation:** 25 Marks a) Performance Assessment: 15 Marks b) Record File: 10 Marks
Discipline Specific Elective (DSE)	**4 T + 0 P**	**Theory: 100 Marks** **Internal assessment:** 25 Marks a) Class Test: 10 Marks b) Assignment/Presentation/Quiz/Group Discussion: 10 Marks c) Attendance: 05 Marks **End Semester Theory Examination:** 75 Marks	NA

Type of Paper	Credit Format	Theory Component	Practical Component
Discipline Specific Elective (DSE)	**3 T + 1 P**	**Theory: 75 Marks** **Internal assessment:** 25 Marks a) Class Test: 10 Marks b) Assignment/Presentation/Quiz/Group Discussion: 10 Marks c) Attendance: 05 Marks **End Semester Theory Examination:** 50 Marks	**Practical: 25 Marks** **Practical Examination:** 12.5 Marks: a) Experiment: 10 Marks b) Viva Voce: 2.5 Marks **Continuous Evaluation:** 12.5 Marks: a) Performance Assessment: 7.5 Marks b) Record File: 5 Marks
Discipline Specific Elective (DSE)	**2 T + 2 P**	**Theory: 50 Marks** **Internal assessment:** 12 Marks a) Class Test: 05 Marks b) Assignment/Presentation/Quiz/Group Discussion: 05 Marks c) Attendance: 02 Marks **End Semester Theory Examination:** 38 Marks	**Practical: 50 Marks** **Practical Examination:** 25 Marks a) Experiment: 20 Marks b) Viva Voce: 05 Marks **Continuous Evaluation:** 25 Marks a) Performance Assessment: 15 Marks b) Record File: 10 Marks
Skill Enhancement Course (SEC)	**0 T + 2 P**	NA	**Practical: 50 Marks** **Practical Examination:** 25 Marks a) Experiment: 20 Marks b) Viva Voce: 05 Marks **Continuous Evaluation:** 25 Marks a) Performance Assessment:15 Marks b) Record File: 10 Marks
Skill Enhancement Course (SEC)	**1 T + 1 P**	**Theory: 25 Marks** **Internal assessment:** 06 Marks: a) Class Test: 2.5 Marks b) Assignment/Presentation/Quiz/Group discussion: 2.5 Marks c) Attendance: 1 Marks **End Semester Theory Examination:** 19 Marks	**Practical: 25 Marks** **Practical Examination:** 12.5 Marks: a) Experiment: 10 Marks b) Viva Voce: 2.5 Marks **Continuous Evaluation:** 12.5 Marks: a) Performance Assessment: 7.5 Marks b) Record File: 5 Marks
Generic Elective (GE)	**2 T + 2 P**	**Theory: 50 Marks** **Internal assessment:** 12 Marks a) Class Test: 05 Marks b) Assignment/Presentation/Quiz/Group Discussion: 05 Marks c) Attendance: 02 Marks **End Semester Theory Examination:** 38 Marks	**Practical: 50 Marks** **Practical Examination:** 25 Marks a) Experiment: 20 Marks b) Viva Voce: 05 Marks **Continuous Evaluation:** 25 Marks a) Performance Assessment: 15 Marks b) Record File: 10 Marks
Generic Elective (GE)	**3T + 1P + 0Tut**	**Theory: 75 Marks** **Internal assessment:** 25 Marks a) Class Test: 10 Marks b) Assignment/Presentation/Quiz/Group Discussion: 10 Marks c) Attendance: 05 Marks **End Semester Theory Examination:** 50 Marks	**Practical: 25 Marks** **Practical Examination:** 12.5 Marks: a) Experiment: 10 Marks b) Viva Voce: 2.5 Marks **Continuous Evaluation:** 12.5 Marks: a) Performance Assessment: 7.5 Marks b) Record File: 5 Marks

Type of Paper	Credit Format	Theory Component	Practical Component
Generic Elective (GE)	**3T + 0P + 1Tut**	**Theory: 100 Marks** **Internal assessment:** 25 Marks a) Class Test: 10 Marks b) Assignment/Presentation/Quiz/Group Discussion/Performance in Tutorial Session: 10 Marks c) Attendance: 05 Marks **End Semester Theory Examination:** 75 Marks	NA

* Performance Assessment: Performance throughout the semester including viva after every practical
Duration of end-semester theory and practical examinations of different credit courses will be as per University regulations/ordinances.

Minimum Acceptable Level of Academic Standards

The minimum acceptable level of achievement that a student must demonstrate to be eligible for the award of academic credit or a qualification is the minimum acceptable level of academic standards. The Letter Grades and Grade Points which shall be used to reflect the outcome of assessment process of the student's performance is indicated in **Table 8**.

TABLE 8
Letter Grades and Grade Points

Letter Grade	Grade point
O (outstanding)	10
A+ (Excellent)	9
A (Very good)	8
B+ (Good)	7
B (Above average)	6
C (Average)	5
P (Pass)	4
F (Fail)	0
AB (Absent)	0

Computation of the grade cut-offs on a 10-point grading system

The results for all the Undergraduate courses under the UGCF 2022 shall be based on a 10 point grading system with Letter Grades as per the formula prescribed in amendment to Ordinance IX clause 12(3) dated 08th May, 2017 of the University of Delhi in the computation of the grade cut offs as shown in **Table 9**.

Table 9

The computation of the grade cut-offs on a 10 point grading system with Letter Grades

Letter Grade	Numerical Grade	Formula	Computation of Grade Cut off
O (Outstanding)	10	$m \geq \bar{X} + 2.5\ \sigma$	the value of $\bar{X}$ + 2.5 σ a to be taken into account for grade computation will be Actual $\bar{X}$ + 2.5 σ or90% whichever is lower
A+ (Excellent)	9	$\bar{X} + 2.0\ \sigma \leq m < \bar{X} + 2.5\ \sigma$	the value of $\bar{X}$ + 2.0 σ a to be taken into account for grade computation will be Actual $\bar{X}$ + 2.0 σ or80% whichever is lower
A (Very Good)	8	$\bar{X} + 1.5\ \sigma \leq m < \bar{X} + 2.0\ \sigma$	the value of $\bar{X}$ + 1.5 σ a to be taken into account form grade computation will be Actual $\bar{X}$ + 1.5 σ or 70% whichever is lower
B+ (Good)	7	$\bar{X} + 1.0\ \sigma \leq m < \bar{X} + 1.5\ \sigma$	the value of $\bar{X}$ + 1.0 σ a to be taken into account for grade computation will be Actual $\bar{X}$ + 1.0 σ or 60% whichever is lower
B (Above average)	6	$\bar{X} \leq m < \bar{X} + 1.0\ \sigma$	the value of $\bar{X}$ a to be taken into account for grade computation will be Actual $\bar{X}$ or 50% whichever is lower
C (Average)	5	$\bar{X} - 0.5\ \sigma \leq m < \bar{X}$	the value of $\bar{X}$ - 0.5 σ a to be taken into account for grade computation will be Actual $\bar{X}$ - 0.5 σ or 40% whichever is lower
D (Pass)	4	$\bar{X} - \sigma \leq m < \bar{X} - 0.5\ \sigma$	the value of $\bar{X}$ - 1.0 σ a to be taken into account for grade computation will be Actual $\bar{X}$ - 1.0 σ or 30% whichever is lower

m is the marks obtained by a student in a particular paper in that semester.

$\bar{X}$ is the average of marks obtained by all the students appeared in that particular paper in that semester.

σ is the standard deviation.

DISCIPLINE SPECIFIC CORE (DSC) COURSES

SEMESTER I

Course Code: DSC 1

Course Title: MATHEMATICAL PHYSICS I

Total Credits: 04 (Credits: Theory: 02, Practical: 02)

Total Hours: Theory: 30, Practical: 60

Course Objectives: The emphasis of course is on applications in solving problems of interest to physicists. The course will teach the students to model a physics problem mathematically and then solve those numerically using computational methods. The course will expose the students to fundamental computational physics skills enabling them to solve a wide range of physics problems. The skills developed during course will prepare them not only for doing fundamental and applied research but also for a wide variety of careers.

Course Learning Outcomes: After completing this course, student will be able to,

- Draw and interpret graphs of various elementary functions and their combinations.
- Understand the vector quantities as entities with Cartesian components which satisfy appropriate rules of transformation under rotation of the axes.
- Use index notation to write the product of vectors in compact form easily applicable in computational work.
- Solve first and second order differential equations and apply these to physics problems.
- Understand the functions of more than one variable and concept of partial derivatives.
- Understand the concept of scalar field, vector field and gradient of scalar fields.
- Understand the properties of discrete and continuous distribution functions.

In the laboratory course, the students will learn to,

- Prepare algorithms and flowcharts for solving a problem.
- Design, code and test programs in Python in the process of solving various problems.
- Perform various operations of 1-d and 2-d arrays.
- Visualize data and functions graphically by use of Matplotlib
- Perform least square fitting of a given data
- Solve physics problems involving differentiation

THEORY (Credit: 02; 30 Hours)

Unit 1

Functions: Plotting elementary functions and their combinations, Interpreting graphs of functions using the concepts of calculus, Taylor's series expansion for elementary functions.

(2 Hours)

Vector Algebra: Transformation of Cartesian components of vectors under rotation of the axes, Introduction to index notation and summation convention, Product of vectors – scalar and vector product of two, three and four vectors in index notation using δ_{ij} and ε_{ijk} (as symbols only – no rigorous proof of properties), Invariance of scalar product under rotation transformation

(5 Hours)

Unit 2

Ordinary Differential Equations: First order differential equations of degree one and those reducible to this form, Exact and Inexact equations, Integrating Factor, Applications to physics problems

(4 Hours)

Higher order linear homogeneous differential equations with constant coefficients, Wronskian and linearly independent functions. Non-homogeneous second order linear differential equations with constant coefficients, complimentary function, particular integral and general solution, Determination of particular integral using method of undetermined coefficients and method of variation of parameters, Cauchy-Euler equation, Initial value problems. Applications to physics problems

(12 Hours)

Unit 3

Multi-Variable Functions: Functions of more than one variable, Partial derivatives, chain rule for partial derivatives. Scalar and vector fields, concept of directional derivative, the vector differential operator $\vec{\nabla}$, gradient of a scalar field and its geometrical interpretation.

(3 Hours)

Probability Distributions: Discrete and continuous random variables, Probability distribution functions, Binomial, Poisson and Gaussian distributions, Mean and variance of these distributions.

(4 Hours)

References:

Essential Readings:

1) An introduction to ordinary differential equations, E.A. Coddington, 2009, PHI learning.
2) Differential Equations, George F. Simmons, 2007, McGraw Hill.
3) Mathematical methods for Scientists and Engineers, D.A. McQuarrie, 2003, Viva Book.
4) Advanced Engineering Mathematics, D.G. Zill and W.S. Wright, 5 Ed., 2012, Jones and Bartlett Learning.

5) Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India.
6) Probability and Statistics, Murray R Spiegel, John J Schiller and R Alu Srinivasan, 2018, McGraw Hill Education Private Limited.
7) Essential Mathematical Methods, K.F.Riley and M.P.Hobson, 2011, Cambridge Univ. Press.
8) Vector Analysis and Cartesian Tensors, D.E. Bourne and P.C. Kendall, 3 Ed. , 2017, CRC Press.
9) Vector Analysis, Murray Spiegel, 2 Ed., 2017, Schaum's outlines series.
10) John E. Freund's Mathematical Statistics with Applications, I. Miller and M. Miller, 7th Ed., 2003, Pearson Education, Asia.

Additional Readings:

1) Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber, F.E. Harris, 7 Ed., 2013, Elsevier.
2) Introduction to Electrodynamics, Chapter 1, David J. Griffiths, 4 Ed., 2017, Cambridge University Press.
3) The Feynman Lectures on Physics, Volume II, Feynman, Leighton and Sands, 2008, Narosa Publishing House.
4) Introduction to Vector Analysis, Davis and Snider, 6 Ed., 1990, McGraw Hill.
5) Differential Equations, R. Bronson and G.B. Costa, Schaum's outline series.
6) Mathematical Physics, A.K. Ghatak, I.C. Goyal and S.J. Chua, Laxmi Publications Private Limited (2017)
7) Mathematical Tools for Physics, James Nearing, 2010, Dover Publications.

PRACTICAL (Credit: 02; 60 Hours)

The aim of this laboratory is not just to teach computer programming and numerical analysis but to emphasize its role in solving problems in Physics. The course will consist of practical sessions and lectures on the related theoretical aspects of the laboratory. Assessment is to be done not only on the programming but also on the basis of formulating the problem.

At least 12 programs must be attempted covering each unit.

Basics of scientific computing (Mandatory):

(a) Binary and decimal arithmetic, Floating point numbers, single and double precision arithmetic, underflow and overflow, numerical errors of elementary floating point operations, round off and truncation errors with examples.

(b) Introduction to Algorithms and Flow charts. Branching with examples of conditional statements, for and while loops.

Unit 1

Basic Elements of Python: The Python interpreter, the print statement, comments, Python as simple calculator, objects and expressions, variables (numeric, character and sequence types) and assignments, mathematical operators. Strings, Lists, Tuples and Dictionaries, type conversions, input statement, list methods. List mutability Formatting in the print statement.

Control Structures: Conditional operations, if, if-else, if-elif-else, while and for Loops, indentation, break and continue, List comprehension.

Functions: Inbuilt functions, user-defined functions, local and global variables, passing functions, modules, importing modules, math module, making new modules.

Recommended List of Programs (At least two)

(a) Make a python function that takes a number N as input and returns the value of factorial of N and compare with the output of math.factorial() method. Use this function to print the number of ways a set of m red and n blue balls can be arranged.

(b) Generate random numbers (integers and floats) in a given range and calculate area and volume of regular shapes with random dimensions.

(c) Generate data for coordinates of a projectile and plot the trajectory. Determine the range, maximum height and time of flight for a projectile motion.

Unit 2

NumPy Fundamentals: Importing Numpy, Difference between List and NumPy array, Adding, removing and sorting elements, creating arrays using ones(), zeros(), random(), arange(), linspace(). Basic array operations (sum, max, min, mean, variance), 2-d and 3-d arrays, matrix operations, reshaping and transposing arrays, savetxt() and loadtxt(), create a Pandas dataframe from an array and then write the data frame to a csv file.

Plotting with Matplotlib: matplotlib.pyplot functions, Plotting of functions given in closed form as well as in the form of discrete data and making histograms.

Recommended List of Programs (At least two)

(a) Plot the displacement-time and velocity-time graph for the undamped, under damped critically damped and over damped oscillator using matplotlib

(b) Use recurrence relation for Legendre polynomials to generate and plot these polynomials for the first few orders using matplotlib.

(c) To generate array of N random numbers drawn from a given distribution (uniform, binomial, poisson and gaussian) and plot them using matplotlib for increasing N to verify the distribution. Verify the central limit theorem.

(d) To implement the transformation of physical observables under Galilean, Lorentz and Rotation transformation

Unit 3

Least Square fitting: Algorithm for least square fitting and its relation to maximum likelihood for normally distributed data.

Make Python function for least square fitting, use it for fitting given data (x,y) and estimate the parameters a, b as well as uncertainties in the parameters for the following cases :

(a) Linear ($y = ax + b$)
(b) Power law ($y = ax^b$) and
(c) exponential ($y = ae^{bx}$).

Unit 4

(a) To find value of π and to integrate a given function using acceptance-rejection method.

(b) Taylor's series expansion: To approximate the functions (e.g. exp(x), sin(x), cos(x), ln(1+x), etc.) by a finite number of terms of Taylor's series and discuss the truncation error. To plot the function as well the nth partial sum of its series for various values of n on the same graph and visualise the convergence of series using matplotlib.

Unit 5

Numerical Differentiation: Left, right and central approximations for derivative of a function

(a) Program to find the derivative of a function given in closed form. Plot both the function and derivative on the same graph. Plot the error as a function of step size on a log-log graph, study the behaviour of the plot as step size decreases and hence discuss the effect of round off error.
(b) Applications e.g. determination of slope of tangent to a curve, points of extrema of a given function, etc.
(c) Write program to calculate velocity and acceleration using given data of position at equidistant and small time intervals.

References:

1) Documentation at the Python home page (https://docs.python.org/3/) and the tutorials there (https://docs.python.org/3/tutorial/).
2) Documentation of NumPy and Matplotlib : https://numpy.org/doc/stable/user/ and https://matplotlib.org/stable/tutorials/
3) Computational Physics, Darren Walker, 1st Edn, Scientific International Pvt. Ltd (2015).
4) Elementary Numerical Analysis, K. E. Atkinson, 3rd Edn, 2007, Wiley India Edition.
5) An Introduction to Computational Physics, T. Pang, Cambridge University Press (2010).
6) Introduction to Numerical Analysis, S. S. Sastry, 5th Edn., 2012, PHI Learning Pvt. Ltd.
7) Applied numerical analysis, Cutis F. Gerald and P. O. Wheatley, Pearson Education, India (2007).
8) Numerical Recipes: The art of scientific computing, William H. Press, Saul A. Teukolsky and William Vetterling, Cambridge University Press; 3rd edition (2007), ISBN-13 : 978-0521880688

Course Code: DSC 2

Course Title: Mechanics

Total Credits: 04 (Credits: Theory: 03, Practical: 01)

Total Hours: Theory: 45, Practical: 30

Course Objectives: This course reviews the concepts of mechanics learnt at school from a more advanced perspective and goes on to build new concepts. It begins with Newton's Laws of Motion and ends with the Special Theory of Relativity. The students will learn the collisions in the centre of mass frame, rotational motion and central forces. They will be able to apply the concepts learnt to several real world problems. In the laboratory part of the course, the students will learn to use various instruments, estimate the error for every experiment performed and report the result of experiment along with the uncertainty in the result up to correct significant figures.

Course Learning Outcomes: Upon completion of this course, students will be able to,

- Learn the Galilean invariance of Newton's laws of motion.
- Understand translational and rotational dynamics of a system of particles.
- Apply Kepler's laws to describe the motion of planets and satellite in circular orbit.
- Understand Einstein's postulates of special relativity.
- Apply Lorentz transformations to describe simultaneity, time dilation and length contraction.
- Use various instruments for measurements and perform experiments related to rotational dynamics, elastic properties, fluid dynamics, acceleration due to gravity, collisions, etc.
- Use propagation of errors to estimate uncertainty in the outcome of an experiment and perform the statistical analysis of the random errors in the observations.

THEORY (Credit: 03; 45 Hours)

Unit 1:

Fundamentals of Dynamics: Inertial and Non-inertial frames, Newton's Laws of Motion and their invariance under Galilean transformations. Momentum of variable mass system: motion of rocket. Dynamics of a system of particles, principle of conservation of momentum. Impulse. Determination of centre of mass of discrete and continuous objects having cylindrical and spherical symmetry, Differential Analysis of a static vertically hanging massive rope.

(7 Hours)

Work and Energy: Work and Kinetic Energy Theorem. Conservative forces and examples (Gravitational and electrostatic), non-conservative forces and examples (velocity dependent forces e.g. frictional force, magnetic force). Potential Energy. Energy diagram. Stable, unstable and neutral equilibrium. Force as gradient of the potential energy. Work done by non-conservative forces.

(4 Hours)

Collisions: Elastic and inelastic collisions. Kinematics of 2 → 2 scattering in centre of mass and laboratory frames.

(3 Hours)

Unit 2:

Rotational Dynamics: Angular momentum of a particle and system of particles. Torque. Principle of conservation of angular momentum. Rotation about a fixed axis. Determination of moment of inertia of symmetric rigid bodies (rectangular, cylindrical and spherical) using parallel and perpendicular axes theorems. Kinetic energy of rotation. Motion involving both translation and rotation

(8 Hours)

Non-Inertial Systems: Non-inertial frames and fictitious forces. Uniformly rotating frame. Centrifugal force. Coriolis force and its applications.

(4 Hours)

Unit 3:

Central Force Motion: Central forces, Law of conservation of angular momentum for central forces, Two-body problem and its reduction to equivalent one-body problem and its solution. Concept of effective potential energy and stability of orbits for central potentials of the form kr^n for n = 2 and -1 using energy diagram, discussion on trajectories for $n = -2$. Solution of Kepler's problem, Kepler's laws for planetary motion, orbit for artificial satellites.

(7 Hours)

Unit 4:

Relativity: Postulates of special theory of relativity, Lorentz transformations, simultaneity, length contraction, time dilation, proper length and proper time, Life time of a relativistic particle (for example muon decay time and decay length). Space-like, time-like and light-like separated events. Relativistic transformation of velocity and acceleration. Variation of mass with velocity, Mass-energy Equivalence. Transformation of Energy and Momentum.

(12 Hours)

References:

Essential Readings:

1) An Introduction to Mechanics (2/e), Daniel Kleppner and Robert Kolenkow, 2014, Cambridge University Press.
2) Mechanics Berkeley Physics Course, Vol. 1, 2/e: Charles Kittel, et. al., 2017, McGraw Hill Education

3) Theory and Problems of Theoretical Mechanics, Murray R. Spiegel, 1977, McGraw Hill Education.
4) Classical Mechanics by Peter Dourmashkin, 2013, John Wiley and Sons.
5) https://phys.libretexts.org/Bookshelves/Classical_Mechanics/classical_Mechanics_(Dourmashkin)/
6) Introduction to Classical Mechanics With Problems and Solutions, David Morin, 2008, Cambridge University Press.
7) Fundamentals of Physics, Resnick, Halliday and Walker 10/e, 2013, Wiley.
8) Introduction to Special Relativity, Robert Resnick, 2007, Wiley.

Additional Readings:

1) Feynman Lectures, Vol. 1, R. P. Feynman, R. B. Leighton, M. Sands, 2008, Pearson Education.
2) University Physics, H. D. Young, R. A. Freedman, 14/e, 2015, Pearson Education.
3) Classical Mechanics, H. Goldstein, C. P. Poole, J. L. Safko, 3/e, 2002, Pearson Education.
4) Newtonian Mechanics, A.P. French, 2017, Viva Books.

PRACTICAL (Credit: 01; 30 Hours)

Introductory Concepts and related activities (Mandatory)

Use of Basic Instruments:

Determination of least count and use of instruments like meter scale, vernier callipers, screw gauge and travelling microscope for measuring lengths.

Errors:

(a) Types of errors in measurements (instrumental limitations, systematic errors and random errors), Accuracy and Precision of observations, significant figures.

(b) Introduction to error estimation, propagation of errors and reporting of results along with uncertainties with correct number of significant figures.

(c) Statistical analysis of random errors, need for making multiple observations, standard error in the mean as estimate of the error.

Graph Plotting:

Pictorial visualisation of relation between two physical quantities, Points to be kept in mind while plotting a graph manually.

Data Analysis:

Principle of least square fitting (LSF) and its application in plotting linear relations. Estimation of LSF values of slope, intercept and uncertainties in slope and intercept.

Mandatory Activities:

- Determine the least count of meter scale, vernier callipers, screw gauge and travelling microscope, use these instruments to measure the length of various objects multiple time, find the mean and report the result along with the uncertainty up to appropriate number of significant digits.

- Take multiple observations of the quantities like length, radius etc. for some spherical, cylindrical and cubic objects, find mean of these observations and use them to determine the surface area and volume of these objects. Estimate the uncertainties in the outcome using law of propagation of errors. Report the result to appropriate number of significant figures.
- Given a data (x, y) corresponding to quantities x and y related by a relation $y = f(x)$ that can be linearized. Plot the data points (manually) with appropriate choice of scale, perform least square fitting to determine the slope and intercept of the LSF line and use them to determine some unknown quantity in the relation. Determine the uncertainties in slope and intercept and use these to estimate the uncertainty in the value of unknown quantity.

Every student must perform at least 4 experiments from the following list.

1) To study the random errors in observations. It is advisable to keep observables of the order of least count of the instruments.
2) To determine the moment of inertia of a symmetric as well as asymmetric flywheel
3) To determine Coefficient of Viscosity of water by Capillary Flow Method (Poiseuille's method).
4) To determine g and velocity for a freely falling body using Digital Timing Technique.
5) To determine the Young's Modulus of a Wire by Optical Lever Method.
6) To determine the vertical distance between two given points using sextant.
7) To determine the coefficients of sliding and rolling friction experienced by a trolley on an inclined plane.
8) To verify the law of conservation of linear momentum in collisions on air track.

Suggested additional Activities:

1) Virtual lab collision experiments on two dimensional elastic and inelastic collisions (for example available on
   a) https://archive.cnx.org/specials/2c7acb3c-2fbd-11e5-b2d9-e7f92291703c/collision-lab/#sim-advanced-sim)
   b) https://phet.colorado.edu/en/simulations/collision-lab
2) Amrita Virtual Mechanics Lab : https://vlab.amrita.edu/?sub=1&brch=74

References (for Laboratory Work):

1) Advanced Practical Physics for students, B. L. Flint and H. T. Worshnop, 1971, Asia Publishing House.

2) Engineering Practical Physics, S. Panigrahi and B. Mallick, 2015, Cengage Learning India Pvt. Ltd.

3) Practical Physics, G. L. Squires, 2015, 4/e, Cambridge University Press.

4) A Text Book of Practical Physics, Vol I, Prakash and Ramakrishna, 11/e, 2011, Kitab Mahal.

5) An introduction to Error Analysis: The study of uncertainties in Physical Measurements, J. R. Taylor, 1997, University Science Books

Course Code: DSC 3

Course Title: Waves and Oscillations

Total Credits: 04 (Credits: Theory: 02, Practical: 02)

Total Hours: Theory: 30, Practical: 60

Course Objectives: This course reviews the concepts of waves and oscillations learnt at school from a more advanced perspective and goes on to build new concepts. It begins with explaining ideas of free oscillations and superposition of harmonic motion leading to physics of damped and forced oscillations. The course will also introduce students to coupled oscillators, normal modes of oscillations and free vibrations of stretched strings. Concurrently, in the laboratory component of the course students will perform experiments that expose them to different aspects of real oscillatory systems.

Course Learning Outcomes: On successful completion of this course, the students will have the skill and knowledge to,

- Understand travelling and standing waves, stretched strings
- Understand simple harmonic motion
- Understand superposition of N collinear harmonic oscillations
- Understand superposition of two perpendicular harmonic oscillations
- Understand free, damped and forced oscillations
- Understand coupled oscillators and normal modes of oscillations

THEORY (Credit: 02; 30 Hours)

Unit 1: Wave Motion **Hours: 4**

One dimensional plane wave, classical wave equation, standing wave on a stretched string (both ends fixed), normal modes. Travelling wave solution

Unit 2: Simple Harmonic Motion **Hours: 12**

Differential equation of simple harmonic oscillator, its solution and characteristics, energy in simple harmonic motion, linearity and superposition principle, rotating vector representation of simple harmonic oscillation, motion of simple and compound pendulum (Bar and Kater's pendulum), loaded spring.

Superposition of N collinear harmonic oscillations with (1) equal phase differences and (2) equal frequency differences, Beats

Superposition of two perpendicular harmonic oscillations: Graphical and Analytical Methods. Lissajous Figures with equal and unequal frequencies, effect of variation of phase

Unit 3: Damped and Forced Oscillations **Hours: 8**

Damped Oscillations: Equation of motion, dead beat motion, critically damped system, lightly damped system: relaxation time, logarithmic decrement, quality factor

Forced Oscillations: Equation of motion, complete solution, steady state solution, resonance, sharpness of resonance, power dissipation, quality factor

Unit 4: Coupled Oscillations **Hours: 6**

Coupled oscillators, normal coordinates and normal modes, energy relation and energy transfer, di-atomic molecules, representation of a general solution as a linear sum of normal modes, normal modes of N coupled oscillators.

References:

Essential Readings:

1) Vibrations and Waves by A. P. French. (CBS Pub. and Dist., 1987)
2) The Physics of Waves and Oscillations by N.K. Bajaj (Tata McGraw-Hill, 1988)
3) Fundamentals of Waves and Oscillations By K. Uno Ingard (Cambridge University Press, 1988)
4) An Introduction to Mechanics by Daniel Kleppner, Robert J. Kolenkow (McGraw-Hill, 1973)
5) Waves: BERKELEY PHYSICS COURSE by Franks Crawford (Tata McGrawHill, 2007).
6) Classical Mechanics by Peter Dourmashkin, John Wiley and Sons
7) https://phys.libretexts.org/Bookshelves/Classical_Mechanics/classical_Mechanics_(Dourmashkin)

Additional Readings:

1) Fundamentals of Physics, Resnick, Halliday and Walker 10/e, 2013, Wiley.
2) Feynman Lectures, Vol. 1, R. P. Feynman, R. B. Leighton, M. Sands, 2008, Pearson Education.
3) University Physics, H. D. Young, R. A. Freedman, 14/e, 2015, Pearson Education.

PRACTICAL (Credit: 02; 60 Hours)

Every student must perform at least 5 experiments

1) Experiments using bar pendulum:
    - **a)** Estimate limits on angular displacement for SHM by measuring the time period at different angular displacements and compare it with the expected value of time period for SHM.
    - **b)** Determine the value of g using bar pendulum.
    - **c)** To study damped oscillations using bar pendulum
    - **d)** Study the effect of area of the damper on damped oscillations. Plot amplitude as a function of time and determine the damping coefficient and Q factor for different dampers.

2) To determine the value of acceleration due to gravity using Kater's pendulum for both the cases (a) $T_1 \approx T_2$ and (b) $T_1 \neq T_2$ and discuss the relative merits of both cases by estimation of error in the two cases.
3) Understand the applications of CRO by measuring voltage and time period of a periodic waveform using CRO
4) Study the superposition of two simple harmonic oscillations using CRO: Study of Lissajous figures
5) Experiments with spring and mass system
    a) To calculate g, spring constant and mass of a spring using static and dynamic methods.
    b) To calculate spring constant of series and parallel combination of two springs.
6) To study normal modes and beats in coupled pendulums or coupled springs.
7) To determine the frequency of an electrically maintained tuning fork by Melde's experiment and to verify $\lambda^2 - T$ Law.

References (For Laboratory Work):

1) Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
2) Engineering Practical Physics, S. Panigrahi and B. Mallick, 2015, Cengage Learning India Pvt. Ltd.
3) Practical Physics, G. L. Squires, 2015, 4/e, Cambridge University Press.
4) A Text Book of Practical Physics, Vol I and II, Prakash and Ramakrishna, 11/e, 2011, Kitab Mahal.
5) An introduction to error analysis: The study of uncertainties in Physical Measurements, J. R. Taylor, 1997, University Science Books List of experiments

SEMESTER II

Course Code: DSC 4

Course Title: Mathematical Physics II

Total Credits: 04 (Credits: Theory: 02, Practical: 02)

Total Hours: Theory: 30, Practical: 60

Course Objectives: The emphasis of course is on applications in solving problems of interest to physicists. The course will also expose students to fundamental computational physics skills enabling them to solve a wide range of physics problems. The skills developed during course will prepare them not only for doing fundamental and applied research but also for a wide variety of careers.

Course Learning Outcomes: After completing this course, student will be able to,

- Understand the concept of divergence and curl of vector fields.
- Perform line, surface and volume integration and apply Green's, Stokes' and Gauss's theorems to compute these integrals. The students will be also enabled to apply these to physics problems.
- Use curvilinear coordinates to problems with spherical and cylindrical symmetries.
- Represent a periodic function by a sum of harmonics using Fourier series

Pre-requisite: DSC course - Mathematical Physics I

THEORY (Credit: 02; 30 Hours)

Unit 1:

Vector Calculus: Divergence and curl of a vector field and their physical interpretation. Laplacian operator. Vector identities, Integrals of vector-valued functions of single scalar variable. 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 (no proofs) and their applications.

(15 Hours)

Unit 2:

Orthogonal Curvilinear Coordinates: Orthogonal Curvilinear Coordinates. Scale factors, element of area and volume in spherical and cylindrical coordinate Systems. Derivation of

Gradient, Divergence, Curl and Laplacian in Spherical and Cylindrical Coordinate Systems

(6 Hours)

Some Special Integrals: Beta and Gamma Functions and relation between them, expression of integrals in terms of Gamma and Beta Functions.

(3 Hours)

Unit 3:

Fourier Series: Periodic functions. Orthogonality of sine and cosine functions, Convergence of Fourier series and Dirichlet Conditions (Statement only). Expansion of periodic functions in a series of sine and cosine functions and determination of Fourier coefficients. Even and odd functions and their Fourier expansions (Fourier Cosine Series and Fourier Sine Series). Parseval's Identity.

(6 Hours)

References:

Essential Readings:

1) Mathematical methods for Scientists and Engineers, D. A. McQuarrie, 2003, Viva Book.
2) Advanced Engineering Mathematics, D. G. Zill and W. S. Wright, 5 Ed., 2012, Jones and Bartlett Learning.
3) Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India.
4) Essential Mathematical Methods, K. F. Riley and M. P. Hobson, 2011, Cambridge Univ. Press.
5) Vector Analysis and Cartesian Tensors, D. E. Bourne and P. C. Kendall, 3 Ed., 2017, CRC Press.
6) Vector Analysis, Murray Spiegel, 2nd Ed., 2017, Schaum's outlines series.
7) Fourier analysis: With Applications to Boundary Value Problems, Murray Spiegel, 2017, McGraw Hill Education.

Additional Readings:

1) Mathematical Methods for Physicists, G. B. Arfken, H. J. Weber, F. E. Harris, 7 Ed., 2013, Elsevier.
2) Introduction to Electrodynamics, Chapter 1, David J. Griffiths, 4 Ed., 2017, Cambridge University Presss.
3) The Feynman Lectures on Physics, Volume II, Feynman, Leighton and Sands, 2008, Narosa Publishing House.
4) Introduction to Vector Analysis, Davis and Snider, 6 Ed., 1990, McGraw Hill.
5) Mathematical Tools for Physics, James Nearing, 2010, Dover Publications.

PRACTICAL (Credit: 02; 60 Hours)

The aim of this laboratory is not just to teach computer programming and numerical analysis but to emphasize its role in solving problems in Physics. The course will consist of practical sessions and lectures on the related theoretical aspects of the laboratory. Assessment is to be done not only on the programming but also on the basis of formulating the problem.

At least 12 programs must be attempted covering each unit.
Although Python is recommended for implementation of the algorithms, however, any programming language may used.

Unit 1: Root Finding: Bisection, Newton Raphson and Secant methods for solving roots of equations. Convergence analysis.

Recommended List of Programs (At least two):

a) Determine the depth up to which a spherical homogeneous object of given radius and density will sink into a fluid of given density.
b) Solve transcendental equations like $\alpha = \tan(\alpha)$.
c) To approximate nth root of a number up to a given number of significant digits.

Unit 2: Interpolation: Concept of Interpolation, Lagrange form of Interpolating polynomial. Error estimation, optimal points for interpolation.

Recommended List of Programs (At least one):

a) Write program to determine the unique polynomial of a degree n that agrees with a given set of $(n+1)$ data points (x_i,y_i) and use this polynomial to find the value of y at a value of x not included in the data.
b) Generate a tabulated data containing a given number of values $(x_i, f(x_i))$ of a function f(x) and use it to interpolate at a value of x not used in table.

Unit 3: Numerical Integration:
Newton Cotes Integration methods (Trapezoidal and Simpson rules) for definite integrals. Derivation of composite formulae for these methods and discussion of error estimation.
Gauss quadrature methods of integration with example of Legendre Gauss quadrature.

Recommended List of Programs (At least three):

a) Given acceleration at equidistant time values, calculate position and velocity and plot them.
b) Use integral definition of ln(x) to compute and plot ln(x) in a given range. Use Trapezoidal, Simpson and Gauss quadrature methods and compare the results.
c) Verify the rate of convergence of the composite Trapezoidal, Simpson and Gauss quadrature methods by approximating the value of a given definite integral.
d) Evaluate the Fourier coefficients of a given periodic function (e.g. square wave, triangle wave, half wave and full wave rectifier etc.)
e) Verify the Orthogonality of Legendre Polynomials.
f) Verify the properties of Dirac Delta function using its representation as a sequence of functions.

Unit 4: Solution of Linear system of equations: Solve system of linear equations using Gauss elimination method, need for pivoting. Iterative methods like Gauss Seidel method for solving system of equations, discussion of convergence of the method.

Recommended List of Programs (At least one with each method):

a) Use Kirchoff's laws to write down the set of mesh equations for a given linear electric circuit and solve these equations using the Gauss elimination and Gauss Seidel method
b) Solution of coupled spring mass system using Gauss elimination and Gauss Seidel method

Unit 5: Numerical Solutions of Ordinary Differential Equations: Euler, modified Euler, and Runge-Kutta (RK) second and fourth order methods for solving first order initial value problems (IVP), System of first order differential equations and second order initial value problems. Discussion of errors involved in the approximate solutions obtained by these numerical methods.

Recommended List of Programs (At least four):

a) Solve given first order differential equation (Initial value problems) numerically using Euler RK2 and RK4 methods and apply to the following physics problems:
    a. Radioactive decay
    b. Current in RC and LR circuits with DC source
    c. Newton's law of cooling
b) Write a code to compare the errors in various numerical methods learnt by solving a first order IVP with known solution.
c) Solve a system of first order IVP numerically using Euler and Runge-Kutta methods.
d) Solve second order IVP numerically using Euler and Runge-Kutta methods. Study the solution of a free undamped, overdamped and critically damped harmonic oscillator with application to a mechanical oscillator or a LCR circuit.
e) Solve a forced oscillator problem and study the resonance.

References (for Laboratory work):

1) Documentation at the Python home page (https://docs.python.org/3/) and the tutorials there (https://docs.python.org/3/tutorial/).
2) Documentation of NumPy and Matplotlib: https://numpy.org/doc/stable/user/ and https://matplotlib.org/stable/tutorials/
3) Computational Physics, Darren Walker, 1st Edn., Scientific International Pvt. Ltd (2015).
4) Elementary Numerical Analysis, K. E. Atkinson, 3rd Edn., 2007, Wiley India Edition.
5) An Introduction to Computational Physics, T. Pang, Cambridge University Press (2010).
6) Introduction to Numerical Analysis, S. S. Sastry, 5th Edn., 2012, PHI Learning Pvt. Ltd.
7) Applied numerical analysis, Cutis F. Gerald and P. O. Wheatley, Pearson Education, India (2007).
8) Numerical Recipes: The art of scientific computing, William H. Press, Saul A. Teukolsky and William Vetterling, Cambridge University Press; 3rd Edition (2007)
9) Computational Problems for Physics, R.H. Landau and M.J. Paez, 2018, CRC Press.

Course Code: DSC 5

Course Title: Electricity and Magnetism

Total Credits: 04 (Credits: Theory: 03, Practical: 01)

Total Hours: Theory: 45, Practical: 30

Course Objectives: This course reviews the concepts of electromagnetism learnt at school from a more advanced perspective and goes on to build new concepts. The course covers static and dynamic electric and magnetic fields due to continuous charge and current distributions respectively.

Course Learning Outcomes: After completing this course, student will be able to,

- Apply Coulomb's law to line, surface, and volume distributions of charges.
- Apply Gauss's law of electrostatics to distribution of charges
- Solve boundary value problems using method of images
- Comprehend the genesis of multipole effects in arbitrary distribution of charges
- Understand the effects of electric polarization and concepts of bound charges in dielectric materials
- Understand and calculate the vector potential and magnetic field of arbitrary current distribution
- Understand the concept of bound currents and ferromagnetism in magnetic materials

---

THEORY (Credit: 03; 45 Hours)

Unit 1: **Hours: 15**

Electric Field and Electric Potential for continuous charge distributions: Electric field due to a line charge, surface charge and volume charge. Divergence of electric field using Dirac Delta function, Curl of electric field, electric field vector as negative gradient of scalar potential, Ambiguities of Electric potential, Differential and integral forms of Gauss's Law, Applications of Gauss's Law to various charge distributions with spherical, cylindrical and planar symmetries.

Boundary Value Problems in Electrostatics: Formulation of Laplace's and Poisson equations. The first and second uniqueness theorems. Solutions of Laplace's and Poisson equations in one dimension using spherical and cylindrical coordinate systems and solutions in three-dimensional using Cartesian coordinates applying separable variable technique. Electrostatic boundary conditions for conductors and capacitors.

Unit 2: Hours: 15

Special techniques for the calculation of Potential and Field: The Method of Images is applied to a system of a point charge and finite continuous charge distribution (line charge and surface charge) in the presence of (i) a Plane infinite sheet maintained at constant potential, and (ii) a Sphere maintained at constant potential.

Multipole Expansion: Monopole, dipole and quadrupole potentials at large distances due to an arbitrary charge distribution expressed in terms of Legendre polynomials, negative Gradient of Dipole potential in spherical coordinates.

Electric Field in Matter: Polarization in matter, Bound charges and their physical interpretation. Field inside a dielectric, Displacement vector D, Gauss' Law in the presence of dielectrics, Boundary conditions for D, Linear dielectrics, Electric Susceptibility and Dielectric Constant, idea of complex dielectric constant due to varying electric field. Boundary value problems with linear dielectrics

Unit 3: Hours: 15

Magnetic Field: Divergence and curl of magnetic field B, Magnetic field due to arbitrary current distribution using Biot-Savart law, Ampere's law, Integral and differential forms of Ampere's Law, Vector potential and its ambiguities, Coulomb gauge and possibility of making vector potential divergenceless, Vector potential due to line, surface and volume currents using Poisson equations for components of vector potential.

Magnetic Properties of Matter: Magnetization vector. Bound currents, Magnetic intensity. Differential and integral form of Ampere's Law in the presence of magnetised materials. Magnetic susceptibility and permeability. Ferromagnetism (Hund's rule).

Electrodynamics: Faraday's Law, Lenz's Law, inductance, electromotive force, Ohm's law ($\vec{J} = \sigma\vec{E}$), energy stored in a magnetic Field.

References:

Essential Readings:

1) Introduction to Electrodynamics, D. J. Griffiths, 3rd Edn., 1998, Benjamin Cummings
2) Schaum's Outlines of Electromagnetics by J. A. Edminister and M. Nahvi
3) Fundamentals of Electricity and Magnetism, Arthur F. Kip, 2nd Edn.1981, McGraw-Hill.
4) Electricity and Magnetism, Edward M. Purcell, 1986 McGraw-Hill Education
5) Electricity and Magnetism, J. H. Fewkes and J. Yarwood, Vol. I, 1991, Oxford Univ. Press.

Additional Readings:

1) Feynman Lectures Vol.2, R. P. Feynman, R. B. Leighton, M. Sands, 2008, Pearson Education
2) Electricity, Magnetism and Electromagnetic Theory, S. Mahajan and Choudhury, 2012, Tata McGraw
3) Electricity and Magnetism, J. H. Fewkes and J. Yarwood, Vol. I, 1991, Oxford Univ. Press.

4) Problems and Solutions in Electromagnetics (2015), Ajoy Ghatak, K Thyagarajan and Ravi Varshney.

PRACTICAL (Credit: 01; 30 Hours)

Every student must perform at least 06 experiments.

1) Measurement of current and charge sensitivity of ballistic galvanometer
2) Measurement of critical damping resistance of ballistic galvanometer
3) Determination of a high resistance by leakage method using ballistic galvanometer
4) Measurement of field strength B and its variation in a solenoid (determine dB/dx)
5) Determination of an unknown low resistance by Carey Foster's Bridge
6) Measurement of self-inductance of a coil by Anderson's Bridge.
7) Measurement of self-inductance of a coil by Owen's Bridge.
8) To determine the mutual inductance of two coils by the Absolute method.
9) Explore magnetic properties of matter using Arduino: To verify Faraday's law and Lenz's law by measuring the induced voltage across a coil subjected to the varying magnetic field. Also, estimate the dipole moment of the magnet.

References (for Laboratory Work):

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

Course Code: DSC 6

Course Title: Electrical Circuit Analysis

Total Credits: 04 (Credits: Theory: 02, Practical: 02)

Total Hours: Theory: 30, Practical: 60

Course Objectives: This course covers the basic circuit concepts in a systematic manner which is suitable for analysis and design. It aims at study and analysis of electric circuits using network theorems and two-port parameters.

Course Learning Outcomes: At the end of the course the student will be able to,

- Understand the basic concepts, basic laws and methods of analysis of DC and AC networks and their difference
- Solve complex electric circuits using network theorems.
- Discuss resonance in series and parallel circuits and also the importance of initial conditions and their evaluation.
- Evaluate the performance of two port networks.

THEORY (Credit: 02; 30 Hours)

Unit 1: **Hours: 10**

Circuit Analysis: Ideal voltage source, real voltage source, current source, Kirchhoff's current law, Kirchhoff's voltage law, node analysis, mesh analysis, Star and Delta conversion.
DC Transient Analysis: Charging and discharging with initial charge in RC circuit, RL circuit with initial current, time constant, RL and RC Circuits with source

Unit 2: **Hours: 10**

AC Circuit Analysis: Sinusoidal voltage and current, Definitions of instantaneous, peak to peak, root mean square and average values, form factor and peak factor (for half-rectified and full-rectified sinusoidal wave, rectangular wave and triangular wave), voltage-current relationship in resistor, inductor and capacitor, phasor, complex impedance, power in AC circuits, sinusoidal circuit analysis for RL, RC and RLC Circuits, resonance in series and parallel RLC Circuits (Frequency Response, Bandwidth, Quality Factor), selectivity, application of resonant circuits

Unit 3: **Hours: 10**

Network Theorems: Principal of duality, Superposition theorem, Thevenin theorem, Norton theorem. Their applications in DC and AC circuits with more than one source, Maximum

Power Transfer theorem for AC circuits, Reciprocity Theorem, Millman's Theorem, Tellegen's theorem

Two Port Networks: Impedance (Z) Parameters, Admittance (Y) Parameters, Transmission Parameters, Impedance matching

References:

Essential Readings:

1) Electric Circuits, S. A. Nasar, Schaum's outline series, Tata McGraw Hill (2004)

2) Essentials of Circuit Analysis, Robert L. Boylestad, Pearson Education (2004)

3) Electrical Circuits, M. Nahvi and J. Edminister, Schaum's Outline Series, Tata McGraw-Hill (2005)

4) Fundamentals of Electric Circuits, C. Alexander and M. Sadiku, McGraw Hill (2008)

Additional Reading:

1) Network analysis, M. E. Van Valkenburg, Third edition, Prentice Hall

PRACTICAL (Credit: 02; 60 Hours)

Every student must perform at least seven experiments

1) Verification of Kirchoff's Law.
2) Verification of Norton's theorem.
3) Verification of Thevenin's Theorem.
4) Verification of Superposition Theorem.
5) Verification of Maximum Power Transfer Theorem.
6) Determination of time constant of RC and RL circuit
7) Study of frequency response of RC circuit
8) Study of frequency response of a series and parallel LCR Circuit and determination of its resonant frequency, impedance at resonance, quality factor and bandwidth.
9) Explore electrical properties of matter using Arduino:
   a. To study the characteristics of a series RC Circuit.
   b. To study the response curve of a Series LCR circuit and determine its resonant frequency, impedance at resonance, quality factor and bandwidth

References (for Laboratory Work):

1) A Textbook of Electrical Technology, B. L. Thareja, A.K. Thareja, Volume II, S. Chand

2) Fundamentals of Electric Circuits, C. Alexander and M. Sadiku, McGraw Hill (2008)

3) Electric Circuits, S. A. Nasar, Schaum's outline series, Tata McGraw Hill (2004)

4) Electrical Circuits, K.A. Smith and R.E. Alley, 2014, Cambridge University Press

5) Electrical Circuit Analysis, K. Mahadevan and C. Chitran, 2nd Edition, 2018, PHI learning Pvt. Ltd.

SEMESTER III

Course Code: DSC 7

Course Title: Mathematical Physics III

Total Credits: 04 (Credits: Theory: 04, Practical: 00)

Total Hours: Theory: 60, Practical: 00

Syllabus to be prepared later

Course Code: DSC 8

Course Title: Thermal Physics

Total Credits: 04 (Credits: Theory: 03, Practical: 01)

Total Hours: Theory: 45, Practical: 30

Syllabus to be prepared later

Course Code: DSC 9

Course Title: Light and Matter

Total Credits: 04 (Credits: Theory: 02, Practical: 02)

Total Hours: Theory: 30, Practical: 60

Syllabus to be prepared later

SEMESTER IV

Course Code: DSC 10

Course Title: MODERN PHYSICS

Total Credits: 04 (Credits: Theory: 03, Practical: 01)

Total Hours: Theory: 45, Practical: 30

Syllabus to be prepared later

Course Code: DSC 11

Course Title: SOLID STATE PHYSICS

Total Credits: 04 (Credits: Theory: 03, Practical: 01)

Total Hours: Theory: 45, Practical: 30

Syllabus to be prepared later

Course Code: DSC 12

Course Title: Analog Electronics

Total Credits: 04 (Credits: Theory: 02, Practical: 02)

Total Hours: Theory: 30, Practical: 60

Syllabus to be prepared later

SEMESTER V

Course Code: DSC 13

Course Title: ATOMIC, MOLECULAR AND NUCLEAR PHYSICS

Total Credits: 04 (Credits: Theory: 04, Practical: 00)

Total Hours: Theory: 60, Practical: 00

Syllabus to be prepared later

Course Code: DSC 14

Course Title: QUANTUM MECHANICS - I

Total Credits: 04 (Credits: Theory: 03, Practical: 01)

Total Hours: Theory: 45, Practical: 30

Syllabus to be prepared later

Course Code: DSC 15

Course Title: DIGITAL ELECTRONICS

Total Credits: 04 (Credits: Theory: 02, Practical: 02)

Total Hours: Theory: 30, Practical: 60

Syllabus to be prepared later

SEMESTER VI

Course Code: DSC 16

Course Title: STATISTICAL MECHANICS

Total Credits: 04 (Credits: Theory: 04, Practical: 00)

Total Hours: Theory: 60, Practical: 00

Syllabus to be prepared later

Course Code: DSC 17

Course Title: ELECTROMAGNETIC THEORY

Total Credits: 04 (Credits: Theory: 03, Practical: 01)

Total Hours: Theory: 45, Practical: 30

Syllabus to be prepared later

Course Code: DSC 18

Course Title: MODELLING AND STATISTICAL ANALYSIS IN PHYSICS

Total Credits: 04 (Credits: Theory: 02, Practical: 02)

Total Hours: Theory: 30, Practical: 60

Syllabus to be prepared later

SEMESTER VII

Course Code: DSC 19

Course Title: CLASSICAL MECHANICS

Total Credits: 04 (Credits: Theory: 04, Practical: 00)

Total Hours: Theory: 60, Practical: 00

Syllabus to be prepared later

SEMESTER VIII

Course Code: DSC 20

Course Title: QUANTUM MECHANICS - II

Total Credits: 04 (Credits: Theory: 04, Practical: 00)

Total Hours: Theory: 60, Practical: 00

Syllabus to be prepared later

DISCIPLINE SPECIFIC ELECTIVE (DSE) COURSES

Course Code: DSE 1

Course Title: BIOPHYSICS

Total Credits: 04 (Credits: Theory: 04, Practical: 00)

Total Hours: Theory: 60, Practical: 00

Syllabus to be prepared later

Course Code: DSE 2

Course Title: NUMERICAL ANALYSIS

Total Credits: 04 (Credits: Theory: 02, Practical: 02)

Total Hours: Theory: 30, Practical: 60

Syllabus to be prepared later

Course Code: DSE 3

Course Title: ADVANCED MATHEMATICAL PHYSICS – I

Total Credits: 04 (Credits: Theory: 04, Practical: 00)

Total Hours: Theory: 60, Practical: 00

Syllabus to be prepared later

Course Code: DSE 4

Course Title: PHYSICS OF DEVICES

Total Credits: 04 (Credits: Theory: 02, Practical: 02)

Total Hours: Theory: 30, Practical: 60

Syllabus to be prepared later

Course Code: DSE 5

Course Title: PHYSICS OF EARTH

Total Credits: 04 (Credits: Theory: 04, Practical: 00)

Total Hours: Theory: 60, Practical: 00

Syllabus to be prepared later

Course Code: DSE 6

Course Title: ASTRONOMY AND ASTROPHYSICS

Total Credits: 04 (Credits: Theory: 04, Practical: 00)

Total Hours: Theory: 60, Practical: 00

Syllabus to be prepared later

Course Code: DSE 7

Course Title: PHYSICS OF MATERIALS

Total Credits: 04 (Credits: Theory: 02, Practical: 02)

Total Hours: Theory: 30, Practical: 60

Syllabus to be prepared later

Course Code: DSE 8

Course Title: COMMUNICATION SYSTEM

Total Credits: 04 (Credits: Theory: 02, Practical: 02)

Total Hours: Theory: 30, Practical: 60

Syllabus to be prepared later

Course Code: DSE 9

Course Title: ADVANCED MATHEMATICAL PHYSICS – II

Total Credits: 04 (Credits: Theory: 04, Practical: 00)

Total Hours: Theory: 60, Practical: 00

Syllabus to be prepared later

Course Code: DSE 10

Course Title: MICROPROCESSORS

Total Credits: 04 (Credits: Theory: 02, Practical: 02)

Total Hours: Theory: 30, Practical: 60

Syllabus to be prepared later

Course Code: DSE 11

Course Title: RESEARCH METHODOLOGY

Total Credits: 04 (Credits: Theory: 04, Practical: 00)

Total Hours: Theory: 60, Practical: 00

Syllabus to be prepared later

Course Code: DSE 12

Course Title: NANO SCIENCE

Total Credits: 04 (Credits: Theory: 02, Practical: 02)

Total Hours: Theory: 30, Practical: 60

Syllabus to be prepared later

Course Code: DSE 13

Course Title: PLASMA PHYSICS

Total Credits: 04 (Credits: Theory: 04, Practical: 00)

Total Hours: Theory: 60, Practical: 00

Syllabus to be prepared later

Course Code: DSE 14

Course Title: INTRODUCTION TO PARTICLE PHYSICS

Total Credits: 04 (Credits: Theory: 04, Practical: 00)

Total Hours: Theory: 60, Practical: 00

Syllabus to be prepared later

Course Code: DSE 15

Course Title: GROUP THEORY AND APPLICATIONS

Total Credits: 04 (Credits: Theory: 04, Practical: 00)

Total Hours: Theory: 60, Practical: 00

Syllabus to be prepared later

Course Code: DSE 16

Course Title: RADIATION AND ITS APPLICATIONS

Total Credits: 04 (Credits: Theory: 02, Practical: 02)

Total Hours: Theory: 30, Practical: 60

Syllabus to be prepared later

Course Code: DSE 17

Course Title: ADVANCED MATHEMATICAL PHYSICS - III

Total Credits: 04 (Credits: Theory: 04, Practical: 00)

Total Hours: Theory: 60, Practical: 00

Syllabus to be prepared later

Course Code: DSE 18

Course Title: PHYSICS OF ATMOSPHERE AND CLIMATE CHANGE

Total Credits: 04 (Credits: Theory: 03, Practical: 01)

Total Hours: Theory: 45, Practical: 30

Syllabus to be prepared later

Course Code: DSE 19

Course Title: RESEARCH METHODOLOGY

Total Credits: 04 (Credits: Theory: 04, Practical: 00)

Total Hours: Theory: 60, Practical: 00

Syllabus to be prepared later

Course Code: DSE 20

Course Title: APPLIED DYNAMICS

Total Credits: 04 (Credits: Theory: 04, Practical: 00)

Total Hours: Theory: 60, Practical: 00

Syllabus to be prepared later

Course Code: DSE 21

Course Title: APPLIED OPTICS

Total Credits: 04 (Credits: Theory: 02, Practical: 02)

Total Hours: Theory: 30, Practical: 60

Syllabus to be prepared later

Course Code: DSE 22

Course Title: INTRODUCTION TO FIELD THEORY

Total Credits: 04 (Credits: Theory: 04, Practical: 00)

Total Hours: Theory: 60, Practical: 00

Syllabus to be prepared later

Course Code: DSE 23

Course Title: NUCLEAR AND PARTICLE DETECTORS

Total Credits: 04 (Credits: Theory: 04, Practical: 00)

Total Hours: Theory: 60, Practical: 00

Syllabus to be prepared later

Course Code: DSE 24

Course Title: QUANTUM INFORMATION

Total Credits: 04 (Credits: Theory: 04, Practical: 00)

Total Hours: Theory: 60, Practical: 00

Syllabus to be prepared later

Course Code: DSE 25

Course Title: GENERAL THEORY OF RELATIVITY

Total Credits: 04 (Credits: Theory: 04, Practical: 00)

Total Hours: Theory: 60, Practical: 00

Syllabus to be prepared later

SKILL ENHANCEMENT COURSE (SEC)

Course Code: SEC 1

Course Title: BASIC OF INSTRUMENTS

Total Credits: 02 (Credits: Theory: 00, Practical: 02)

Total Hours: Theory: 00, Practical: 60

Course Objectives: To expose the students to various aspects of instruments and their usage through hands-on mode. To provide them a thorough understanding of basics of measurement, measurement devices such as electronic voltmeter, oscilloscope, signal and pulse generators, impedance bridges, digital instruments etc.

Course Learning Outcomes: At the end of this course the students will learn the following.

- The student is expected to have the necessary working knowledge on accuracy, precision, resolution, range and errors/uncertainty in measurements.
- Course learning begins with the basic understanding of the measurement and errors in measurement. It then familiarizes about each and every specification of a multimeter, multivibrators, rectifiers, amplifiers, oscillators and high voltage probes and their significance with hands on mode.
- Explanation of CRO and their significance. Complete explanation of CRT.
- Students learn the use of CRO for the measurement of voltage (DC and AC), frequency and time period. Covers the Digital Storage Oscilloscope and its principle of working.
- Students learn principles of voltage measurement. Students should be able to understand the advantages of electronic voltmeter over conventional multimeter in terms of sensitivity etc. Types of AC millivoltmeter should be covered.
- Covers the explanation and specifications of Signal and pulse Generators: low frequency signal generator and pulse generator. Students should be familiarized with testing and specifications.
- Students learn about the working principles and specifications of basic LCR Bridge.
- Hands on ability to use digital multimeter and frequency counter.

PRACTICAL (Credit: 02; 60 Hours)

The list of experiments for this course is based on the following topics.

- **Basics of Measurement:** Instruments accuracy, precision, sensitivity, resolution range etc. Errors in measurements and loading effects. Working principle of time interval, frequency and period measurement, time-base stability, accuracy and resolution.
- **Multimeter:** Measurement of dc voltage and dc current, ac voltage, ac current and

resistance. Specifications of electronic voltmeter/multimeter and their significance. AC milli-voltmeter, working of a digital multimeter.

- **Cathode Ray Oscilloscope:** Specifications of CRO with block diagram and their significance. Measurement of voltage (dc and ac), frequency and time period. Special features of dual trace. Digital storage Oscilloscope: principle of working.
- **Signal and Pulse Generators:** Block diagram and specifications of low frequency signal and pulse generators. Distortion factor meter, wave analysis.
- **Impedance Bridges:** Block diagram, working principles of RLC Bridge. Specifications of RLC Bridge. Block diagram and working principles of a Q-Meter. Digital LCR bridges.

List of Experiments:

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) To measure Q of a coil and its dependence on frequency, using Q-meter.
4) Measurement of voltage, frequency, time period and phase using an oscilloscope.
5) Measurement of time period, frequency, average period using universal counter/frequency counter.
6) Measurement of rise, fall and delay times using oscilloscope.
7) Measurement of distortion of a RF signal generator using distortion factor meter.
8) Measurement of R, L and C using LCR Bridge/Universal Bridge.

Open Ended Experiments:

1) Using a Dual Trace Oscilloscope
2) Converting the range of a given measuring instrument (voltmeter, ammeter).

It is further suggested that students may be motivated to pursue semester long dissertation wherein he/she may do a hands-on extensive project based on the extension of the experiments enumerated above.

References:

Essential Readings:

1) Logic circuit design, Shimon P. Vingron, 2012, Springer.
2) Digital Electronics, Subrata Ghoshal, 2012, Cengage Learning.
3) Electronic Devices and circuits, S. Salivahanan and N. S. Kumar, 3rd Ed., 2012, Tata Mc-Graw Hill
4) Digital Circuits and Systems, Venugopal, 2011, Tata McGraw Hill.
5) Electronic Instrumentation, H.S. Kalsi, 3rd Ed. Tata McGraw Hill.

Additional Readings:

1) A text book in Electrical Technology - B L Theraja - S Chand and Co.
2) Performance and design of AC machines - M G Say ELBS Edn.

Course Code: SEC 2

Course Title: PROGRAMMING FOR PHYSICAL APPLICATIONS (C/C++ OR PYTHON)

Total Credits: 02 (Credits: Theory: 00, Practical: 02)

Total Hours: Theory: 00, Practical: 60

Course Learning Outcomes: The aim of this course is to teach computer programming and basic idea of numerical analysis, emphasizing its role in solving problems in Physics, and other fields.

- Use computers for solving problems in Physics
- Prepare algorithms and flowcharts for solving a problem.
- Design, code and test simple programs in C/C++ or Python in the process of solving various problems.
- Perform various operations of 1-d and 2-d arrays
- Visualise data and functions graphically

The course will consist of practical sessions including relevant lectures on the related theoretical aspects of the Laboratory.

- Evaluation to be done not only on the programming but also on the basis of formulating the problem.
- Aim at teaching students to construct the computational problem to be solved.
- Students can use any one operating system: Linux or Microsoft Windows.
- At least 12 programs must be attempted from the following covering the entire syllabus.
- The list of programs here is only suggestive. Students should be encouraged to do more practice.

C/C++

1) Basics of scientific computing: Binary and decimal arithmetic, Floating point numbers, single and double precision arithmetic, underflow and overflow, Iterative method. Algorithms and Flow charts: Purpose, symbols and description.
2) Introduction to C++: Introduction to Programming: Algorithms: Sequence, Selection and Repetition, Structured programming, basic idea of Compilers. Idea of Headers, Data Types, Enumerated Data, Conversion and casting, constants and variables, Mathematical, Relational, Logical and Bit wise Operators. Precedence of Operators, Expressions and Statements, Scope and Visibility of Data, block, Local and Global variables, Auto, static and External variables. Input and output statements. Reading Input and sending output from/to files.

Programs (indicative only):

- To calculate area of a rectangle
- To check size of variables in bytes (Use of sizeof( ) Operator)
- Converting plane polar to Cartesian coordinates and vice versa

3) C++ Control Statements: if-statement, if-else statement, Nested if Structure, Else-if statement, Ternary operator, Goto statement, switch statement, Unconditional and Conditional looping, While loop, Do-while loop, For loop, nested loops, break and continue statements

Programs (indicative only):

- To find roots of a quadratic equation
- To find largest of three numbers
- To check whether a number is prime or not
- To list Prime numbers up to 1000

4) Functions and Arrays: Introduction, inbuilt functions, local vs. global variables, function definition and prototype, user-defined functions, void functions, return statement, passing arguments by value, arrays, array definition, passing arrays to functions, 2D arrays, matrix operations (sum, product, transpose etc)

Programs (indicative only):

- Sum and average of a list of numbers
- Largest of a given list of numbers and its location
- Sorting numbers in ascending descending order using Bubble sort and Sequential sort
- Binary search
- Matrix operations (sum, product, transpose etc)
- Approximate functions like sin(x), cos(x) by a finite number of terms of Taylor's series.

5) Introduction to gnuplot for plotting functions and data for graphical visualization. Curve fitting: Linear least square fitting of data.

Programs (indicative only):

- Plotting data from the output file created by a c-program
- Plotting functions (inbuilt), histograms, and graphs.
- Overlapping plots
- Least square fit of data points
- Generation of pseudo-random numbers using inbuilt functions and plot frequency distribution

References:

1) Schaum's Outline of Programming with C++', J. Hubbard, 2000, McGraw-Hill Education.
2) C++ How to Program', Paul J. Deitel and Harvey Deitel, Pearson (2016).
3) Introduction to Numerical Analysis, S.S. Sastry, 5th Edn., 2012, PHI Learning Pvt. Ltd.

4) Computational Physics, Darren Walker, 1st Edn., Scientific International Pvt. Ltd (2015).
5) Elementary Numerical Analysis, K.E. Atkinson, 3rd Edn., 2007, Wiley India Edition.

OR

PYTHON

Introduction : Binary and decimal arithmetic, Floating point numbers, single and double precision arithmetic, underflow and overflow, numerical errors of elementary floating point operations, round off and truncation errors with examples.

Introduction to Algorithms and Flow charts. Branching with examples of conditional statements, for and while loops.

Basic Elements of Python: The Python interpreter, the print statement, comments, Python as simple calculator, objects and expressions, variables(numeric and sequence types) and assignments, mathematical operators. Help() in Python, Strings, Lists, Tuples and Dictionaries, type conversions, input statement, list methods. List mutability, Formatting in the print statement.

Control Structures: Conditional operations, if, if-else, if-elif-else, while and for Loops, indentation, break and continue, List comprehension.

Functions: Inbuilt functions, user-defined functions, local and global variables, passing functions, modules, importing modules, math module, making new modules.

File Handling: 'r', 'w', 'a' modes, Reading from files and writing into text and csv files. Exception handling with try-except, the with statement.

List of Programs:

- To calculate area of a rectangle
- To check size of variables in bytes (Use of sizeof( ) Operator)
- Converting plane polar to Cartesian coordinates and vice versa
- To find roots of a quadratic equation
- To find largest of three numbers
- To check whether a number is prime or not
- To list Prime numbers up to 1000

Numpy, Pandas and Matplotlib:

Use of Numpy module to (i) determine max, min, mean, variance, standard deviation of a given array, (i) perform matrix manipulations and (iii) compute scalar, vector and scalar triple product of vectors.

Use matplotlib to (i) plot of functions given in closed form as well as in the form of discrete data and (ii) make histogram (iii) contour maps

List of Programs:

- Sum and average of a list of numbers
- Largest of a given list of numbers and its location
- Sorting numbers in ascending descending order using Bubble sort and Sequential sort

- Binary search
- Matrix operations (sum, product, transpose etc)
- Approximate functions like sin(x), cos(x) by a finite number of terms of Taylor's series.
- Plotting data from the output file
- Plotting functions (inbuilt), histograms, and graphs.
- Overlapping plots
- Least square fit of data points
- Generation of pseudo-random numbers using inbuilt functions and plot frequency distribution

References:

1) Documentation at the Python home page (https://docs.python.org/3/) and the tutorials there (https://docs.python.org/3/tutorial/).

2) Computational Physics, Darren Walker, 1st Edn., Scientific International Pvt. Ltd (2015).

3) Elementary Numerical Analysis, K. E. Atkinson, 3rd Edn., 2007, Wiley India Edition.

4) An Introduction to Computational Physics, T. Pang, Cambridge University Press (2010).

5) Introduction to Numerical Analysis, S. S. Sastry, 5th Edn., 2012, PHI Learning Pvt. Ltd.

6) Applied numerical analysis, Cutis F. Gerald and P. O. Wheatley, Pearson Education, India

7) Numerical Recipes: The art of scientific computing, William H. Press, Saul A. Teukolsky and William Vetterling, Cambridge University Press; 3rd edition

Course Code: SEC 3

Course Title: NUMERICAL TECHNIQUES

Total Credits: 02 (Credits: Theory: 00, Practical: 02)

Total Hours: Theory: 00, Practical: 60

Course Objectives: The emphasis of course is to equip students with the mathematical tools required in solving problem of interest to physicists and to expose them to fundamental computational physics skills and hence enable them to solve a wide range of physics problems. To help students develop critical skills and knowledge that will prepare them not only for doing fundamental and applied research but also prepare them for a wide variety of careers.

Course Learning Outcomes: The numerical methods given below will be implemented using C/C++ or Python programming language, and hence a basic knowledge of the programming language is desirable. The course will consist of practical sessions including relevant lectures on the following theoretical aspects of the laboratory.

- Errors and iterative methods: Truncation and Round-off Errors. Floating Point Computation, Overflow and underflow. Single and Double Precision Arithmetic
- Solutions of Algebraic and Transcendental Equations: Fixed point iteration method, Bisection method, Secant Method, Newton Raphson method
- Interpolation, Numerical Differentiation, and Integration: Forward and Backward Differences. Symbolic Relation, Newton's Forward and Backward Interpolation Formulas, Integration using Trapezoidal Rule, and Simpson's 1/3 and 3/8 Rules.
- Solution of Ordinary Differential Equations: First Order ODE's: solution of Initial Value problems: Euler's Method, Modified Euler's method, Runge-Kutta method
- Least Square fitting: Linear least square fit on data points, Linearization of exponential function fitting, Fitting using Polynomial of *n*th degree.

PRACTICAL (Credit: 02; 60 Hours)

Every student must perform at least 08 programs from the following list.

Algebraic and transcendental equation:

a. To find the roots of an algebraic equation by Bisection method.

b. To find the roots of an algebraic equation by Secant method.

c. To find the roots of an algebraic equation by Newton-Raphson method.
d. To find the roots of a transcendental equation by Bisection method.

Interpolation
a. To find the forward difference table from a given set of data values.
b. To find a backward difference table from a given set of data values.

Differentiation
a. To find the first and second derivatives near the beginning of the table of values of (x,y).
b. To find the first and second derivatives near the end of the table of values of (x,y).

Integration
a. To evaluate a definite integral by trapezoidal rule.
b. To evaluate a definite integral by Simpson 1/3 rule.
c. To evaluate a definite integral by Simpson 3/8 rule.

Differential Equations
a. To solve differential equations by Euler's method
b. To solve differential equations by modified Euler's method
c. To solve differential equations by Runge-Kutta method

Curve fitting
a. To fit a straight line to a given set of data values.
b. To fit a polynomial to a given set of data values.
c. To fit an exponential function to a given set of data values.

References:

1) Elementary Numerical Analysis, K.E. Atkinson, 3rd Edn., 2007, Wiley India Edition.
2) Introduction to Numerical Analysis, S.S. Sastry, 5th Edn., 2012, PHI Learning Pvt. Ltd.
3) Schaum's Outline of Programming with C++. J. Hubbard, 2000, McGraw Hill Pub.
4) Numerical Recipes in C++: The Art of Scientific Computing, W.H. Press et.al., 2nd Edn., 2013, Cambridge University Press.
5) An introduction to Numerical methods in C++, Brian H. Flowers, 2009, Oxford University Press.
6) C++ How to Program', Paul J. Deitel and Harvey Deitel, Pearson (2016).
7) Documentation at the Python home page (https://docs.python.org/3/) and the tutorials there (https://docs.python.org/3/tutorial/).

Course Code: SEC 4

Course Title: ELECTRIC CIRCUITS AND NETWORKS

Total Credits: 02 (Credits: Theory: 00, Practical: 02)

Total Hours: Theory: 00, Practical: 60

Syllabus to be prepared later

Course Code: SEC 5

Course Title: SENSORS AND DETECTION TECHNOLOGY

Total Credits: 02 (Credits: Theory: 01, Practical: 01)

Total Hours: Theory: 15, Practical: 30

Syllabus to be prepared later

Course Code: SEC 6

Course Title: RENEWABLE ENERGY AND ENERGY HARVESTING

Total Credits: 02 (Credits: Theory: 01, Practical: 01)

Total Hours: Theory: 15, Practical: 30

Syllabus to be prepared later

Course Code: SEC 7

Course Title: INTRODUCTION TO SCILAB PROGRAMMING

Total Credits: 02 (Credits: Theory: 00, Practical: 02)

Total Hours: Theory: 00, Practical: 60

Course Objectives: This course focuses on the core skills necessary to work with Scilab and present an overview of Scilab features to get familiar with this environment. The Scilab language, especially its structured programming features containing real matrices and the linear algebra library are covered in this course. The definition of functions and the elementary management of input and output variables are presented. Scilab's graphical features to create 2D/3D plots and how to export that plot into a vectorial or bitmap format are also included in this course.

Course Learning Outcomes: This course will help students in the following ways.

- Awareness and understanding of the free software, Scilab, which provides a powerful computing environment for engineering and scientific applications.
- Scilab software includes a lot of mathematical functions and is based on a high level programming language, comprising of advanced data structures and graphical functions.
- The syntax of Scilab enables the students to visualize solutions of non-trivial problems, which are otherwise difficult to perform in a laboratory set-up. It also helps them to gain insight into complicated physics problems.
- The graphical features of Scilab are a boon to the students for visually understanding the complex nature of diverse scientific and engineering problems.
- Scicos/Xcos: an additional tool in Scilab offers a graphical analysis of the complex electrical circuits, wave phenomenon, etc.

- Teacher may give long duration projects based on this paper.
- Sessions on the review of experimental data analysis and its application to the specific experiments done in the lab.

Introduction to Scilab

Scilab installation and familiarization with Scilab environment, Command window, Figure window, Edit window, Variables and arrays, Initializing variables in Scilab, Multidimensional arrays, Sub-array, Special values, Displaying output data, data file, Scalar and array operations, Hierarchy of operations, Built in Scilab functions, Introduction to plotting, 2D and 3D plotting and graphics design, Branching Statements and program design, Relational and logical operators, the while loop, for loop, details of loop operations, break and continue statements, nested loops, logical arrays and vectorization. User defined functions, Introduction to Scilab functions, Variable passing in Scilab, optional arguments, preserving data between calls to a function, Complex and Character data, string function, Multidimensional arrays an introduction to Scilab file processing, file opening and closing, Binary I/O functions, comparing binary and formatted functions, numerical methods and developing the skills of writing a program.

Programs:
At least 08 programs must be attempted from the following covering the entire syllabus.
The list of programs here is only suggestive. Students should be encouraged to do more practice.

- **Series Expansion**

Evaluate trigonometric, logarithmic, and exponential functions by series expansion and compare the results with built-in Scilab functions.
Application to evaluation of π (using $\tan^{-1} 1 = \frac{\pi}{4}$)

- **Matrix Algebra**

Addition/subtraction and multiplication of matrices, trace, transpose, inverse, determinant of a matrix. Eigenvalues, eigenvector, diagonalization, and function of matrix with application to physics problem.

- **Plotting of graphs**

The pre-defined functions and a variety of powerful in-built tools of Scilab should be extensively utilized for producing self-explanatory and meaningful 2D/3D graphs. This experiment should also explain how to write user-defined functions for formatting the coordinate axes of the graph and for customizing the line style, data markers, title and legends of the graphs.
The plotting can be learnt by following suggestive problems.

- Superposition of waves and formation of wave group
- Familiarization with Cartesian, cylindrical and spherical polar coordinates
- Normal and anomalous dispersion
- Blackbody radiation spectrum
- Plotting of band structure in 3D
- Plotting of vector functions: 2D/3D vector fields and its application in graphical understanding of the concept of gradient, divergence, and curl.

- **Graphics Design**

Application to computer graphics: create any arbitrary object of own choice by considering data points or functions and implement translation, reflection, shear, strain and rotation operator on the same. Plot old and new object.

- **Integration and Differentiation**

Introduction of differentiation and integration using inbuilt Scilab functions. Application to various mathematical and physical problems may be included, such as differential (gradient, divergence, and curl) and integral (line, surface, and volume) calculus. Further, this may be useful in verification of fundamental theorems for gradient, divergence, and curl.

- **Ordinary Differential Equation**

Applications of first and second order differential equations in physics problems, such as radioactive decay, motion of a freely falling object, simple harmonic motion, damped and forced oscillations etc. using Scilab built in functions.

- **Fourier Analysis**

Generating different periodic functions and their Fourier series. It should also explain how to perform integral Fourier transform of common functions like square, sine-cosine and Gaussian functions.

- **Special Functions**

Generation of special functions using user defined functions and comparison with Scilab built-in functions. This experiment is based on the implementation of special functions such as Bessel function, Legendre function, Laguerre function and Hermite function and verification of related recurrence relations. Some applications of these functions in diverse physical problems such as the study of planetary motion, diffraction of light at circular aperture and propagation of electromagnetic waves through cavity resonators can be included.

- **Scicos/Xcos**

Generating different wave function, such as square wave, sine wave, saw tooth wave etc. An application to understanding,

- Superposition of waves by concept of Lissajous figures and beat phenomenon.
- Electrical circuits, such as RC, RL, LC, series and parallel LCR etc.
- Diode circuits and its applications

References:

Essential Readings:

1) Urroz, G. E. (2001). Introduction to SCILAB. Retrieved from https://www.scilab.org.

2) Urroz, G. E. (2001). ODEs with SCILAB. Retrieved from https://www.scilab.org.

3) Urroz, G. E. (2001). Ordinary differential equations with SCILAB. Retrieved from https://www.math.utah.edu.

4) Urroz, G. E. (2001). Orthogonal Functions, Gaussian Quadrature, and Fourier analysis with SCILAB. Retrieved from https:// www.scilab.org.

5) Sharma, M. (2016). Scilab Codes and Programs for Physics as well as Mathematical Problems. Retrieved from https://www.bragitoff.com/

6) Jain, M. C. (2014). Vector Spaces and Matrices in Physics (2nd Edition). Narosa Publishing House.

7) Coddington, E. A. (2009). An introduction to ordinary differential equations. PHI Learning Pvt. Ltd.

8) Sastry, S. S. Introductory Methods of Numerical Analysis (3rd Edition). Prentice Hall of India Private Limited.

9) Jain, M. K.; Iyengar, S. R. K.; Jain, R. K. (2012). Numerical Methods for Scientific and Engineering Computation (6th Edition). New Age International Publisher.
10) Fausett, L. V. (2012). Applied Numerical Analysis-Using MATLAB. (2nd Edition). Pearson Education.
11) Folland, G. B. (1992). Fourier Analysis and Its Applications (Wadsworth and Brooks/ Cole Mathematics Series). Thomson Brooks/Cole.
12) Introduction to Electrodynamics, D.J. Griffiths, 3rd Ed., 1998, Benjamin Cummings.

Course Code: SEC 8

Course Title: TECHNICAL DRAWING AND 3D PRINTING

Total Credits: 02 (Credits: Theory: 00, Practical: 02)

Total Hours: Theory: 00, Practical: 60

Syllabus to be prepared later

Course Code: SEC 9

Course Title: DATA ANALYSIS AND STATISTICAL METHODS

Total Credits: 02 (Credits: Theory: 00, Practical: 02)

Total Hours: Theory: 00, Practical: 60

Course Objectives: The emphasis of course is to equip students with the data analysis tools for solving problems in Physics, and in general. Further, students will be exposed to computational skills required to implement the data analysis techniques.

Course Learning Outcomes: The data analysis methods given below will be implemented using C/C++ or Python programming language, and hence a basic knowledge of the programming language is desirable.

After completing this course, student will be able to:

- Idea of random variable and probability distribution function, which is very important for uncertainty (or error) propagations
- Fitting data points using least square fits, with uncertainties on data values
- Basic idea of interpolation, integration, and solution of ode
- Monte Carlo technique and idea of random number

The course will consist of practical sessions including relevant lectures on the following theoretical aspects of the laboratory.

Introduction to Probability and Random Variables: Review of probability, Idea of 1D random variable, probability density function – discrete (binomial) and continuous (Gaussian), Expectation value or mean value, Variance and Standard deviation.

Least Square fitting: Covariance and correlations in 2D random distributions, propagation of errors, Linear least square fit of data points both with and without uncertainties (or errors), Finding errors on the estimated parameters.

Integration, Interpolation, and Solution of ODE: Integration using Gauss quadrature, Lagrange Interpolation, Solution of ODE using Runge-Kutta (order 4 method)

Random Number generation: Idea of Monte Carlo technique, pseudo random number generation, Idea of Monte Carlo integration: estimating value of pi (or find area of circle) using Monte Carlo acceptance-rejection method.

Every student must perform experiments covering the entire syllabus.

The list of programs here is only suggestive. Students should be encouraged to do more practice.

1) To plot discrete and continuous distributions and find mean, median and mode.
2) Fitting data points with and without errors using least square fitting technique, and estimate the errors on the obtained parameters,
3) Perform error propagation on functions of two variables, while understanding the effect of covariance.
4) Performing polynomial interpolation using Lagrange Interpolating function
5) Performing Integration using Gauss quadrature method
6) Solving ODE (both first and 2nd order) using RK4 method.
7) Generating random numbers using inbuilt functions and plot the frequency distribution
8) Estimate value of pi (or find area of circle) using Monte Carlo acceptance-rejection method

References:

1) Statistics and Data Analysis: from elementary to intermediate, Ajit C. Tamhane and Dorothy D. Dunlop, Prentice Hall.

2) Numerical Analysis, Richard L. Burden, J. Douglas Faires and Annette M. Burden, Cengage Learning; 10th edition

3) Data Reduction and Error Analysis for the Physical Sciences, by Philip Bevington and D. Keith Robinson, McGraw-Hill Education; 3rd edition

Course Code: SEC 10

Course Title: RADIATION SAFETY

Total Credits: 02 (Credits: Theory: 01, Practical: 01)

Total Hours: Theory: 15, Practical: 30

Course Objectives: This course focuses on the applications of nuclear techniques and radiation protection. It will not only enhance the skills towards the basic understanding of the radiation but will also provide the knowledge about the protective measures against radiation exposure. It imparts all the skills required by a radiation safety officer or any job dealing with radiation such as X-ray operators, jobs dealing with nuclear medicine: chemotherapists, operators of PET, MRI, CT scan, gamma camera etc.

Course Learning Outcomes: This course will help students in the following ways.

- Awareness and understanding the hazards of radiation and the safety measures to guard against these hazards.
- Having a comprehensive knowledge about the nature of interaction of matter with radiations like gamma, beta, alpha rays, neutrons etc. and radiation shielding by appropriate materials.
- Knowing about the units of radiations and their safety limits, the devices to detect and measure radiation.
- Learning radiation safety management, biological effects of ionizing radiation, operational limits and basics of radiation hazards evaluation and control, radiation protection standards,
- Learning about the devices which apply radiations in medical sciences, such as X-ray, MRI, PET, CT-scan

---

THEORY (Credit: 01; 15 Hours)

Unit 1: **Hours: 6**

Radiation and its interaction with matter: Basic idea of different types of radiation electromagnetic (X-ray, gamma rays, cosmic rays etc.), nuclear radiation and their origin.
Nuclear Radiation: Basic idea of Alpha, Beta, Gamma neutron radiation and their sources (sealed and unsealed sources).
Interaction of Charged Particles (including alpha particles): Heavy charged particles (e.g. accelerated ions) - Beth-Bloch Formula, Scaling laws, Mass Stopping Power, Range, Straggling.

Interaction of Beta Particles: Collision and Radiation loss (Bremsstrahlung).
Interaction of Photons: Linear and Mass Attenuation Coefficients.
Interaction of Neutrons: Collision, slowing down and Moderation.

Unit 2: **Hours: 4**

Radiation detection and monitoring devices: Basic concepts and working principle of gas detectors, Scintillation Detectors, Solid State Detectors and Neutron Detectors, Thermo-luminescent Dosimetry.
Radiation Quantities and Units:
Basic idea of different units of activity, KERMA, exposure, absorbed dose, equivalent dose, effective dose, collective equivalent dose, annual limit of intake (ALI) and derived air concentration (DAC).

Unit 3: **Hours: 2**

Radiation Units, dosage and safety management:
Basic idea of different units of activity, KERMA, exposure, absorbed dose, equivalent dose, effective dose, collective equivalent dose, annual limit of intake (ALI) and Derived air concentration (DAC).
Radiation safety management: Biological effects of ionizing radiation, Operational limits and basics of radiation hazards, its evaluation and control: radiation protection standards.

Unit 4: **Hours: 3**

Application of radiation as a technique: Application in medical science (e.g., basic principles of X-rays, MRI, PET, CT scan, Projection Imaging Gamma Camera, Radiation therapy), Archaeology, Art, Crime detection, Mining and oil. Industrial Uses: Tracing, Gauging, Material Modification, Sterilization, Food preservation.

PRACTICAL (Credit: 01; 30 Hours)

Minimum five experiments need to be performed from the following, graphs to be plotted using any graphical plotting software

1) Estimate the energy loss of different projectiles/ions in Water and carbon, using SRIM/TRIM etc. simulation software, (different projectiles/ions to be used by different students).
2) Simulation study (using SRIM/TRIM or any other software) of radiation depth in materials (Carbon, Silver, Gold, Lead) using H as projectile/ion.
3) Comparison of interaction of projectiles with Z_P = 1 to 92 (where Z_P is atomic number of projectile/ion) in a given medium (Mylar, Carbon, Water) using simulation software (SRIM etc).
4) SRIM/TRIM based experiments to study ion-matter interaction of heavy projectiles on heavy atoms. The range of investigations will be Z_P = 6 to 92 on Z_A = 16 to 92 (where Z_P and Z_A are atomic numbers of projectile and atoms respectively). Draw and infer

appropriate Bragg Curves.

5) Calculation of absorption/transmission of X-rays, γ-rays through Mylar, Be, C, Al, Fe and Z_A = 47 to 92 (where Z_A is atomic number of atoms to be investigated as targets) using XCOM, NIST (https://physics.nist.gov/PhysRefData/Xcom/html/xcom1.html).
6) Study the background radiation in different places and identify the source material from gamma ray energy spectrum. (Gamma ray energies are available in the website http://www.nndc.bnl.gov/nudat2/).
7) Study the background radiation levels using Radiation meter.
8) Study of characteristics of GM tube and determination of operating voltage and plateau length using background radiation as source (without commercial source).
9) Study of counting statistics using background radiation using GM counter.
10) Study of radiation in various materials (e.g. KSO4 etc.). Investigation of possible radiation in different routine materials by operating GM counter at operating voltage.
11) Study of absorption of beta particles in Aluminum using GM counter.
12) Measurement of gamma ray attenuation co-efficient of aluminium using GM counter.
13) Estimation of half thickness for aluminium using GM Counter.

References:

Essential Readings:

1) Basic ideas and concepts in Nuclear Physics: An introductory approach by K Heyde, third edition, IOP Publication, 1999.
2) Nuclear Physics by S N Ghoshal, First edition, S. Chand Publication, 2010.
3) Nuclear Physics: Principles and Applications by J Lilley, Wiley Publication, 2006.
4) Fundamental Physics of Radiology by W J Meredith and B Massey, John Wright and Sons, UK, 1989.
5) An Introduction to Radiation Protection by A Martin and S A Harbisor , John Willey and Sons, Inc. NewYork, 1981.

Additional Readings:

1) Radiation detection and measurement by G F Knoll, 4th Edition, Wiley Publications, 2010.
2) Techniques for Nuclear and Particle Physics experiments by W R Leo, Springer, 1994.
3) Thermoluminescence dosimetry by A F Mcknlay, Bristol, Adam Hilger (Medical Physics Hand book 5
4) Medical Radiation Physics by W R Hendee, Year book Medical Publishers, Inc., London, 1981.
5) Physics and Engineering of Radiation Detection by S N Ahmed, Academic Press Elsevier, 2007.
6) IAEA Publications: (a) General safety requirements Part 1, No. GSR Part 1 (2010), Part 3 No. GSR Part 3 (Interium) (2010); (b) Safety Standards Series No. RS-G-1.5 (2002), Rs-G-1.9 (2005), Safety Series No. 120 (1996); (c) Safety Guide GS-G-2.1 (2007).

References (for Laboratory Work):

1) Schaum's Outline of Modern Physics, McGraw-Hill, 1999.
2) Schaum's Outline of College Physics, by E. Hecht, 11^{th} edition, McGraw Hill, 2009.
3) Modern Physics by K Sivaprasath and R Murugeshan, S Chand Publication, 2010.
4) AERB Safety Guide (Guide No. AERB/RF-RS/SG-1), Security of radioactive sources in radiation facilities, 2011
5) AERB Safety Standard No. AERB/SS/3 (Rev. 1), Testing and Classification of sealed Radioactivity Sources., 2007.

Course Code: SEC 11

Course Title: INTRODUCTION TO PHYSICS OF DEVICES

Total Credits: 02 (Credits: Theory: 01, Practical: 01)

Total Hours: Theory: 15, Practical: 30

Course Objectives: This paper is based on basic electrical and electronics instruments which cover the devices such as diode, photodiode, solar cell, electromagnet etc. This course also covers working of ideal and constant current source; ideal and constant voltage source; and dependent and independent current and voltage source.

Course Learning Outcomes: At the end of this course, students will be able to,

- Develop the basic knowledge of semiconductor device physics and electronic circuits along with the practical technological considerations and applications.
- Understand the operation of devices such as multimeter, current source and voltage source etc.

THEORY (Credit: 01; 15 Hours)

Unit 1: **Hours: 4**

Measurement of Voltage and current: Working of ideal and constant current source, Ideal and constant voltage source, Dependent and independent current and voltage source. Working of moving coil galvanometer, its use as Voltmeter and Ammeter, Use of digital multimeter for measurement of R, L, C, ac and dc voltage and current, type of transistor etc.

Unit 2: **Hours: 6**

Two layered devices: Working principle and I-V characteristics of p-n junction diode, Zener diode, LED, photo-diode and solar cell. Centre-tapped and Bridge Full-wave Rectifiers, Calculation of ripple factor and rectification efficiency, basic idea about capacitor filter, Working of regulator IC 7805.

Unit 3: **Hours: 5**

Electrical Appliances: Use of capacitor/condenser in electrical motor, Uses of electrical fuses, MCBs, difference between power, neutral and ground in electrical circuits, Use of ground terminal in electrical circuits, Working of IR remote control, microwave oven and water purifier

PRACTICAL (Credit: 01; 30 Hours)

Every student must perform at least 06 experiments for the following list.

1) To examine the performance of a constant current source and constant voltage source.
2) Making voltmeter and ammeter using galvanometer.
3) I-V characteristics of LED
4) Zener diode as voltage regulator.
5) Measurement of efficiency and fill factor of solar cell.
6) Measurement of photocurrent using photodiode with variation in intensity of incident light.
7) To design a regulated power supply (adapter) using bridge rectifier and regulator IC (7805).
8) Design an electrical switch board with fuse and power indicator.
9) The basic idea of First Aid for Electrical Emergencies.

References (For Theory):

Essential Readings:

1) Physics of Semiconductor Devices, S. M. Sze and K. K. Ng, 3rd Edition 2008, John Wiley and Sons

2) Electronic Devices and Circuits, A. Mottershead, 1998, PHI Learning Pvt. Ltd.

3) H. S. Kalsi, Electronic Instrumentation, TMH (2006).

References (For Laboratory Work):

1) PC based instrumentation; Concepts and Practice, N. Mathivanan, 2007, Prentice-Hall of India

2) Basic Electronics: A text lab manual, P. B. Zbar, A. P. Malvino, M. A. Miller,1994, McGraw Hill

3) Electrical Wiring Components and Accessories and First Aid for Electrical Emergencies kvdl103.pdf (ncert.nic.in)

Course Code: SEC 12

Course Title: INTRODUCTION TO LASER AND FIBRE OPTICS

Total Credits: 02 (Credits: Theory: 01, Practical: 01)

Total Hours: Theory: 15, Practical: 30

Syllabus to be prepared later

Course Code: SEC 13

Course Title: WEATHER FORECASTING

Total Credits: 02 (Credits: Theory: 01, Practical: 01)

Total Hours: Theory: 15, Practical: 30

Syllabus to be prepared later

Course Code: SEC 14

Course Title: EMBEDDED SYSTEM PROGRAMMING

Total Credits: 02 (Credits: Theory: 00, Practical: 02)

Total Hours: Theory: 00, Practical: 60

Syllabus to be prepared later

Course Code: SEC 15

Course Title: VERILOG AND FPGA PROGRAMMING

Total Credits: 02 (Credits: Theory: 00, Practical: 02)

Total Hours: Theory: 00, Practical: 60

Syllabus to be prepared later

GENERIC ELECTIVE COURSES (GE)

Course Code: GE 1

Course Title: MECHANICS

Total Credits: 04 (Credits: Theory: 03, Practical: 01)

Total Hours: Theory: 45, Practical: 30

Course Objectives: This course reviews the concepts of mechanics learnt at school in a more advanced perspective and goes on to build new concepts. It begins with dynamics of a system of particles and ends with the special theory of relativity. Students will appreciate the concept of rotational motion, gravitation and oscillations. The students will be able to apply the concepts learnt to several real world problems. A brief recapitulation of vector algebra and differential equations is also done to familiarize students with basic mathematical concepts which are necessary for a course on mechanics.

Course Learning Outcomes: Upon completion of this course, students are expected to understand the following concepts.

- Laws of motion and their application to various dynamical situations. And their applications to conservation of momentum, angular momentum and energy.
- Motion of a simple and compound pendulum
- Application of Kepler's laws to describe the motion of satellites in circular orbit.
- The concept of geosynchronous orbits
- Concept of stress and strain and relation between elastic constants
- Postulates of Special Theory of Relativity, Lorentz transformation, relativistic effects on the mass and energy of a moving body.

In the laboratory course, after acquiring knowledge of how to handle measuring instruments (like vernier calliper, screw gauge and travelling microscope) student shall embark on verifying various principles and associated measurable quantities.

THEORY (Credit: 03; 45 Hours)

Unit 1: Recapitulation of Vectors and Ordinary Differential Equation **Hours: 8**

Vector algebra, scalar and vector product, gradient of a scalar field, divergence and curl of vectors field

Ordinary Differential Equations: First order homogeneous differential equations, second order homogeneous differential equation with constant coefficients

Unit 2: Fundamentals of Dynamics **Hours: 10**

Review of Newton's laws of motion, dynamics of a system of particles, centre of mass, determination of centre of mass for discrete and continuous systems having spherical symmetry, Conservation of momentum and energy, Conservative and non-Conservative forces, work – energy theorem for conservative forces, force as a gradient of potential energy.

Unit 3: Rotational Dynamics and Oscillatory Motion **Hours: 14**

Angular velocity, angular momentum, torque, conservation of angular momentum, Moment of inertia, Theorem of parallel and perpendicular axes, Calculation of moment of inertia of discrete and continuous objects (1-D and 2-D).

Idea of simple harmonic motion, Differential equation of simple harmonic motion and its solution, Motion of a simple pendulum and compound pendulum

Unit 4: Gravitation **Hours: 5**

Newton's Law of Gravitation, Motion of a particle in a central force field, Kepler's Laws (statements only), Satellite in circular orbit and applications, geosynchronous orbits

Unit 5: Elasticity **Hours: 3**

Concept of stress and strain, Hooke's law, elastic moduli, twisting torque on a wire, tensile strength, relation between elastic constants, Poisson's ratio, rigidity modulus

Unit 6: Special Theory of Relativity **Hours: 5**

Postulates of Special Theory of Relativity, Lorentz transformation, length contraction, time dilation, relativistic transformation of velocity, relativistic variation of mass, mass-energy equivalence

References:

Essential Readings:

1) Vector Analysis – Schaum's Outline, M.R. Spiegel, S. Lipschutz, D. Spellman, 2nd Edn., 2009, McGraw- Hill Education.
2) An Introduction to Mechanics (2/e), Daniel Kleppner and Robert Kolenkow, 2014, Cambridge University Press.
3) Mechanics Berkeley Physics Course, Vol. 1, 2/e: Charles Kittel, et. al., 2017, McGraw Hill Education
4) Mechanics, D. S. Mathur, P. S. Hemne, 2012, S. Chand.
5) Fundamentals of Physics, Resnick, Halliday and Walker 10/e, 2013, Wiley.

Additional Readings:

1) Feynman Lectures, Vol. 1, R. P. Feynman, R. B. Leighton, M. Sands, 2008, Pearson Education.
2) University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole.

3) University Physics, H. D. Young, R. A. Freedman, 14/e, 2015, Pearson Education.
4) Engineering Mechanics, Basudeb Bhattacharya, 2/e, 2015, Oxford University Press.
5) Physics for Scientists and Engineers, Randall D Knight, 3/e, 2016, Pearson Education.

PRACTICAL (Credit: 01; 30 Hours)

The teacher is expected to give basic idea and working of various apparatus and instruments related to different experiments. Students should also be given knowledge of recording and analyzing experimental data.

Every student should perform at least 06 experiments from the following list.

1) Measurement of length (or diameter) using vernier calliper, screw gauge and travelling microscope.
2) Study the random error in observations.
3) Determination of height of a building using a sextant.
4) Study of motion of the spring and calculate (a) spring constant and, (b) acceleration due to gravity (g)
5) Determination of moment of inertia of a flywheel.
6) Determination of g and velocity for a freely falling body using digital timing technique.
7) Determination of modulus of rigidity of a wire using Maxwell's needle.
8) Determination of elastic constants of a wire by Searle's method.
9) Determination of value of g using bar pendulum.
10) Determination of value of g using Kater's pendulum.

References (for Laboratory Work):

1) Advanced practical physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
2) Engineering practical physics, S. Panigrahi and B. Mallick, 2015, Cengage Learning India Pvt. Ltd.
3) Practical physics, G. L. Squires, 2015, 4/e, Cambridge University Press.
4) A text book of practical physics, I. Prakash and Ramakrishna, 11/e, 2011, Kitab Mahal.
5) B. Sc. practical physics, Geeta Sanon, R. Chand and Co., 2016.

Course Code: GE 2

Course Title: MATHEMATICAL PHYSICS

Total Credits: 04 (Credits: Theory: 03, Tutorial: 01)

Total Hours: Theory: 45, Tutorial: 15

Course Objectives: The emphasis of course is to equip students with the mathematical tools required in solving problem of interest to physicists. The course will expose students to fundamental computational physics skills and hence enable them to solve a wide range of physics problems.

Course Learning Outcomes: At the end of this course, the students will be able to,

- Understand functions of several variables.
- Represent a periodic function by a sum of harmonics using Fourier series and their applications in physical problems such as vibrating strings etc.
- Obtain power series solution of differential equation of second order with variable coefficient using Frobenius method.
- Understand properties and applications of special functions like Legendre polynomials, Bessel functions and their differential equations and apply these to various physical problems such as in quantum mechanics.
- Learn about gamma and beta functions and their applications.
- Solve linear partial differential equations of second order with separation of variable method.
- Understand the basic concepts of complex analysis and integration.
- During the tutorial classes, students' skill will be developed to solve more problems related to the concerned topics.

Unit 1: **Hours: 6**

Fourier series: Periodic functions. Orthogonality of sine and cosine functions, Convergence of Fourier series and Dirichlet Conditions (Statement only). Expansion of periodic functions in a series of sine and cosine functions and determination of Fourier coefficients. Even and odd functions and their Fourier expansions (Fourier Cosine Series and Fourier Sine Series).

Unit 2: **Hours: 10**

Frobenius Method and Special Functions: Singular Points of Second Order Linear Differential Equations and their importance. Frobenius method and its applications to differential equations. Legendre and Bessel Differential Equations.

Unit 3: **Hours: 14**

Some Special Integrals: Beta and Gamma Functions and Relation between them. Expression of integrals in terms of Gamma Functions.

(4 Hours)

Partial Differential Equations: Multivariable functions, Partial derivatives, Functions Solutions to partial differential equations, using separation of variables: Laplace's Equation in problems of rectangular geometry, Solution of 1D wave equation.

(10 Hours)

Unit 4: **Hours: 15**

Complex Analysis: Functions of complex variable, limit, continuity, Analytic function, Cauchy-Riemann equations, singular points, Cauchy Goursat Theorem, Cauchy's Integral Formula, Residues, Cauchy's Residue Theorem.

References:

Essential Readings:

1) Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India.
2) Complex Variables and Applications, J. W. Brown and R. V. Churchill, 7th Ed. 2003, Tata McGraw-Hill.
3) Advanced Mathematics for Engineers and Scientists: Schaum Outline Series, M. R Spiegel, 2009, McGraw Hill Education.
4) Applied Mathematics for Engineers and Physicists, L.A. Pipes and L.R. Harvill, 2014, Dover Publications.
5) Mathematical Methods for Physics and Engineers, K.F Riley, M.P. Hobson and S. J. Bence, 3rd Ed., 2006, Cambridge University Press.

Additional Readings:

1) Mathematical Physics, A.K. Ghatak, I.C. Goyal and S.J. Chua, 2017, Laxmi Publications Private Limited.
2) Advanced Engineering Mathematics, D. G. Zill and W.S.Wright, 5 Ed., 2012, Jones and Bartlett Learning.
3) An introduction to ordinary differential equations, E.A.Coddington, 2009, PHI Learning.
4) Differential Equations, George F. Simmons, 2007, McGraw Hill.
5) Mathematical methods for Scientists and Engineers, D.A.Mc Quarrie, 2003, Viva Books.

Course Code: GE 3

Course Title: WAVES AND OPTICS

Total Credits: 04 (Credits: Theory: 03, Practical: 01)

Total Hours: Theory: 45, Practical: 30

Course Objectives: This coursework reviews the concept of waves and optics learnt at school level from a more advanced perspective and builds new concepts. This course is divided into two main parts. The first part deals with vibrations and waves. The second part pertains to optics and provides the details of interference, diffraction and polarization.

Course Learning Outcomes: After the completion of this course, the students will have learnt the following.

- Simple harmonic motion, superposition principle and its application to find the resultant of superposition of harmonic oscillations.
- Concepts of vibrations in strings.
- Interference as superposition of waves from coherent sources.
- Basic concepts of Diffraction: Fraunhoffer and Fresnel Diffraction.
- Elementary concepts of the polarization of light.

THEORY (Credit: 03; 45 Hours)

Unit 1: **Hours: 10**

Superposition of Harmonic Oscillations: Simple harmonic motion (SHM). Linearity and Superposition Principle. Superposition of two collinear harmonic oscillations having (1) equal frequencies and (2) different frequencies (Beats). Superposition of two perpendicular harmonic oscillations: Graphical and Analytical Methods. Lissajous Figures (1:1 and 1:2) and their uses.

Unit 2: **Hours: 5**

Waves Motion: Types of waves: Longitudinal and Transverse (General idea). Travelling waves in a string, wave equation. Energy density. Standing waves in a string - modes of vibration. Phase velocity.

Unit 3: **Hours: 12**

Interference of Light: Electromagnetic nature of light. Definition and properties of wave front. Huygens Principle. Interference: Division of amplitude and division of wave front. Young's Double Slit experiment. Fresnel's Biprism. Phase change on reflection: Stoke's treatment. Interference in Thin Films: parallel and wedge-shaped films. Newton's Rings: measurement of wavelength and refractive index.

Unit 4: Hours: 12

Diffraction: Fraunhofer diffraction - Single slit, Double slit and Diffraction grating. Fresnel Diffraction - Half-period zones, Zone plate, Fresnel Diffraction pattern of a straight edge using half-period zone analysis.

Unit 5: Hours: 6

Polarization: Transverse nature of light waves. Plane polarized light. Production and detection of linearly polarized light. Malus's Law. Idea of circular and elliptical polarization.

References:

Essential Readings:

1) The Physics of Waves and Oscillations: N K Bajaj, Tata Mcgraw Hill
2) Optics: Ajoy Ghatak, Seventh edition, Mcgraw Hill
3) Principle of Optics: B. K. Mathur and T. P. Pandya, Gopal Printing Press
4) Optics: Brij Lal and N. Subramanyam, S. Chand
5) The Fundamentals of Optics: A. Kumar, H. R. Gulati and D. R. Khanna, R. Chand

Additional Readings:

1) Vibrations and Waves: A. P. French, CRC
2) The physics of Vibrations and Waves: H. J. Pain, Wiley
3) Fundamentals of Optics: Jenkins and White, McGraw Hill
4) Optics: E. Hecht and A R. Ganesan, Pearson, India
5) Introduction to Optics: F. Pedrotti, L. M. Pedrotti and L. S. Pedrotti, Pearson, India

PRACTICAL (Credit: 01; 30 Hours)

Every student must perform at least 05 experiments out of the list following experiments.

1) To determine the frequency of an electrically maintained tuning fork by Melde's experiment and to verify λ^2 – T Law.
2) To study Lissajous Figures.
3) Familiarization with Schuster`s focusing and determination of the angle of prism.
4) To determine the refractive index of the material of a prism using sodium light.
5) To determine the dispersive power of a prism using mercury light.
6) To determine wavelength of sodium light using Newton's rings.
7) To determine wavelength of sodium light using a plane diffraction grating.
8) To verify Malus's Law.
9) To determine the wavelength of Laser light using single slit diffraction. (Due care should be taken not to see Laser light source directly as it may cause injury to eyes.)

References (for Laboratory Work):

1) Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, Asia Publishing House
2) A Text Book of Practical Physics, Indu Prakash and Ramakrishna, Kitab Mahal
3) An advanced course in practical physics, D. Chattopadhyay and P. C. Rakshit, New Central Book Agency

Course Code: GE 4

Course Title: INTRODUCTION TO ELECTRONICS

Total Credits: 04 (Credits: Theory: 02, Practical: 02)

Total Hours: Theory: 30, Practical: 60

Syllabus to be prepared later

Course Code: GE 5

Course Title: SOLID STATE PHYSICS

Total Credits: 04 (Credits: Theory: 03, Tutorial: 01)

Total Hours: Theory: 45, Tutorial: 15

Syllabus to be prepared later

Course Code: GE 6

Course Title: INTRODUCTORY ASTRONOMY

Total Credits: 04 (Credits: Theory: 03, Tutorial: 01)

Total Hours: Theory: 45, Tutorial: 15

Course Objectives: This course is meant to introduce undergraduate students to the wonders of the Universe. Students will understand how astronomers over millennia have come to understand mysteries of the universe using laws of geometry and physics, and more recently chemistry and biology. They will be introduced to the Indian contribution to astronomy starting from ancient times up to the modern era. They will learn about diverse set of astronomical phenomenon, from the daily and yearly motion of stars and planets in the night sky which they can observe themselves, to the expansion of the universe deduced from the latest observations and cosmological models. Students will also be introduced to internet astronomy and the citizen science research platform in astronomy. The course presupposes school level understanding of mathematics and physics.

Course Learning Outcomes: After completing this course, student will gain an understanding of,

- Different types of telescopes, diurnal and yearly motion of astronomical objects, astronomical coordinate systems and their transformations
- Brightness scale for stars, types of stars, their structure and evolution on HR diagram
- Components of solar system and its evolution
- Current research in detection of exoplanets
- Basic structure of different galaxies and rotation of the Milky Way galaxy
- Distribution of chemical compounds in the interstellar medium and astrophysical conditions necessary for the emergence and existence of life
- Internet based astronomy and the collaborative citizen astronomy projects
- India’s contribution to astronomy, both in ancient times and in modern era.

Unit 1: **Hours: 8**

Introduction to Astronomy and Astronomical Scales: History of astronomy, wonders of the Universe, overview of the night sky, diurnal and yearly motions of the Sun, size, mass, density and temperature of astronomical objects, basic concepts of positional astronomy: Celestial sphere, Astronomical coordinate systems, Horizon system and Equatorial system

Unit 2: **Hours: 6**

Basic Parameters of Stars: Stellar energy sources, determination of distance by parallax method, aberration, proper motion, brightness, radiant flux and luminosity, apparent and absolute magnitude scales, distance modulus, determination of stellar temperature and radius, basic results of Saha ionization formula and its applications for stellar astrophysics, stellar spectra, dependence of spectral types on temperature, luminosity classification, stellar evolutionary track on Hertzsprung-Russell diagram

Unit 3: **Hours: 7**

Astronomical Instruments: Observing through the atmosphere (Scintillation, Seeing, Atmospheric Windows and Extinction). Basic Optical Definitions for Telescopes: Magnification, Light Gathering Power, Limiting magnitude, Resolving Power, Diffraction Limit. Optical telescopes, radio telescopes, Hubble space telescope, James Web space telescope, Fermi Gamma ray space telescope.

Astronomy in the Internet Age: Overview of Aladin Sky Atlas, Astrometrica, Sloan Digital Sky Survey, Stellarium, virtual telescope

Citizen Science Initiatives: Galaxy Zoo, SETI@Home, RAD@Home India

Unit 4: **Hours: 8**

Sun and the solar system: Solar parameters, Sun's internal structure, solar photosphere, solar atmosphere, chromosphere, corona, solar activity, origin of the solar system, the nebular model, tidal forces and planetary rings

Exoplanets: Detection methods and characterization

Unit 5: **Hours: 12**

Physics of Galaxies: Basic structure and properties of different types of Galaxies, Nature of rotation of the Milky Way (Differential rotation of the Galaxy), Idea of dark matter

Cosmology and Astrobiology: Standard Candles (Cepheids and SNe Type1a), Cosmic distance ladder, Olber's paradox, Hubble's expansion, History of the Universe, Chemistry of life, Origin of life, Chances of life in the solar system

Unit 6: **Hours: 4**

Astronomy in India: Astronomy in ancient, medieval and early telescopic era of India, current Indian observatories (Hanle-Indian Astronomical Observatory, Devasthal Observatory, Vainu Bappu Observatory, Mount Abu Infrared Observatory, Gauribidanur Radio Observatory, Giant Metre-wave Radio Telescope, Udaipur Solar Observatory, LIGO-India) (qualitative discussion), Indian astronomy missions (Astrosat, Aditya)

References:

Essential Readings:

1) Seven Wonders of the Cosmos, Jayant V Narlikar, Cambridge University Press
2) Fundamental of Astronomy, H. Karttunen et al. Springer
3) Modern Astrophysics, B.W. Carroll and D.A. Ostlie, Addison-Wesley Publishing Co.
4) Introductory Astronomy and Astrophysics, M. Zeilik and S.A. Gregory, Saunders College Publishing.
5) The Molecular Universe, A.G.G.M. Tielens (Sections I, II and III), Reviews of Modern

Physics, Volume 85, July-September, 2013
6) Astronomy in India: A Historical Perspective, Thanu Padmanabhan, Springer

Useful websites for astronomy education and citizen science research platform

1) https://aladin.u-strasbg.fr/
2) http://www.astrometrica.at/
3) https://www.sdss.org/
4) http://stellarium.org/
5) https://www.zooniverse.org/projects/zookeeper/galaxy-zoo/
6) https://setiathome.berkeley.edu/
7) https://www.radathomeindia.org/

Additional Readings:

1) Explorations: Introduction to Astronomy, Thomos Arny and Stephen Schneider, McGraw Hill
2) Astrophysics Stars and Galaxies K D Abhyankar, Universities Press
3) Textbook of Astronomy and Astrophysics with elements of cosmology, V.B. Bhatia, Narosa Publication.
4) Baidyanath Basu, An introduction to Astrophysics, Prentice Hall of India Private Limited.
5) The Physical Universe: An Introduction to Astronomy, F H Shu, University Science Books

Course Code: GE 7

Course Title: BIOLOGICAL PHYSICS

Total Credits: 04 (Credits: Theory: 03, Tutorial: 01)

Total Hours: Theory: 45, Tutorial: 15

Syllabus to be prepared later

Course Code: GE 8

Course Title: NUMERICAL ANALYSIS AND COMPUTATIONAL PHYSICS

Total Credits: 04 (Credits: Theory: 02, Practical: 02)

Total Hours: Theory: 30, Practical: 60

Syllabus to be prepared later

Course Code: GE 9

Course Title: APPLIED DYNAMICS

Total Credits: 04 (Credits: Theory: 03, Tutorial: 01)

Total Hours: Theory: 45, Tutorial: 15

Syllabus to be prepared later

Course Code: GE 10

Course Title: QUANTUM INFORMATION

Total Credits: 04 (Credits: Theory: 03, Tutorial: 01)

Total Hours: Theory: 45, Tutorial: 15

Syllabus to be prepared later

Course Code: GE 11

Course Title: ELECTRICITY AND MAGNETISM

Total Credits: 04 (Credits: Theory: 03, Practical: 01)

Total Hours: Theory: 45, Practical: 30

Course Objectives: This course begins with theorems of network analysis which are required to perform the associated experiments in the laboratory. Then course delves into the elementary vector analysis, an essential mathematical tool for understanding static electric field and magnetic field. By the end of the course student should appreciate Maxwell's equations.

Course Learning Outcomes (Theory): At the end of this course the student will be able to,

- Apply Coulomb's law to line, surface, and volume distributions of charges.
- Apply Gauss's law of electrostatics to distribution of charges
- Understand the effects of electric polarization and concepts of bound charges in dielectric materials
- Understand and calculate the vector potential and magnetic field of arbitrary current distribution
- Understand the concept of bound currents and ferromagnetism in magnetic materials

THEORY (Credit: 03; 45 Hours)

Unit 1: **Hours: 15**

Network Analysis: Superposition, Thevenin, Norton theorems and their applications in DC and AC circuits with more than one sources. Maximum Power Transfer theorem for AC circuits

(6 Hours)

Mathematical Preliminaries:

Concept of scalar and vector fields, Gradient of a scalar field, Divergence and curl of vector fields and their physical interpretation, Conservative forces and Laplace and Poisson equations.

(4 Hours)

Concept of a line integral of a scalar and vector field, surface integral of vector fields and volume integral. Gauss's theorem, Stoke's theorem.

(5 Hours)

Unit 2: **Hours: 15**

Electric Field and Electric Potential for continuous charge distributions: Electric field due to a line charge, surface charge and volume charge distributions, Electric field vector as negative gradient of scalar potential, Ambiguities of Electric potential, Differential and integral forms of Gauss's Law, Applications of Gauss's Law to various charge distributions with spherical, cylindrical and planar symmetries. Uniqueness theorem.

(7 Hours)

Electric Field in Matter: Bound charges due to polarization and their physical interpretation. Average electric field inside a dielectric, Electric Field in spherical and cylindrical cavities of a dielectric, Displacement vector and its boundary conditions, Gauss' Law in the presence of dielectrics, Linear dielectrics: electric susceptibility and dielectric constant, Boundary value problems with linear dielectrics.

(8 Hours)

Unit 3: **Hours: 15**

Magnetic Field: Divergence and curl of magnetic field B, Magnetic field due to arbitrary current distribution using Biot-Savart law, Ampere's law, integral and differential forms of Ampere's Law, Vector potential and its ambiguities.

(4 Hours)

Magnetic Properties of Matter: Magnetization vector. Bound Currents, Magnetic Intensity. Differential and integral form of Ampere's Law in the presence of magnetised materials. Magnetic susceptibility and permeability. Ferromagnetism (Hund's rule).

(6 hours)

Electrodynamics: Faraday's Law, Lenz's Law, inductance. Electromotive force, Ohm's Law ($\vec{J} = \sigma\vec{E}$). Energy stored in a Magnetic Field. Charge Conservation, Continuity equation, Differential and integral forms of Maxwell's equations in matter.

(5 hours)

References:

Essential Readings:

1) Introduction to Electrodynamics, D. J. Griffiths, 4th Edn., 2015, Pearson Education India Learning Private Limited.
2) Schaum's Outlines of Electromagnetics, M. Nahvi and J. A. Edminister, 2019, McGraw-Hill Education.
3) Electromagnetic Fields and Waves, Paul Lorrain and Dale Corson, 1991, W. H. Freeman.
4) Electricity and Magnetism, Edward M. Purcell, 1986, McGraw-Hill Education
5) Network, Lines and Fields, John D. Ryder, 2nd Edn., 2015, Pearson.
6) Introductory circuit analysis, R. Boylestead, 2016, Pearson.
7) Electricity and Magnetism, Tom Weideman, University of California Davis. [url: https://zhu.physics.ucdavis.edu/Physics9C-C_2021/Physics%209C_EM%20by%20Tom%20Weideman.pdf]

Additional Readings:

1) Feynman Lectures Vol. 2, R. P. Feynman, R. B. Leighton, M. Sands, 2008, Pearson Education
2) Electricity, Magnetism and Electromagnetic Theory, S. Mahajan and Choudhury, 2012, Tata McGraw
3) Fundamentals of Physics, Resnick, Halliday and Walker 10/e, 2013, Wiley

PRACTICAL (Credit: 01; 30 Hours)

Course Learning Outcome (Practical):

- To understand working of Arduino Microcontroller System
- To use Arduino to measure time, count events and time between events
- To use Arduino to measure voltage/current/resistance
- To use Arduino to measure various physical parameters like magnetic field

Unit I (Mandatory)

Arduino Programming

Introduction to Arduino Microcontroller platform. Getting acquainted with the Arduino IDE and Basic Sketch structure. Digital Input and output. Measuring time and events. Measuring analog voltage. Generating analog voltage using Pulse Width Modulation. Serial communication and serial monitor. Programming using Interrupts.

Unit II Exploring electrical properties of matter using Arduino (at least one experiment)

1) To study the characteristics of a series RC Circuit.
2) To study response curve of a Series LCR circuit and determine its (a) Resonant frequency, Impedance at resonance, (c) Quality factor Q, and (d) Band width.
3) Diode Charateristics:
    a) To study characteristics of diode and estimate Boltzman constant.
    b) To study characteristics of LED and estimate Planck's constant

Unit III Exploring magnetic properties of matter using Arduino

To verify Faraday's law and Lenz's law by measuring induced voltage across a coil subjected to varying magnetic field. Also, estimate dipole moment of the magnet.

Unit IV DC and AC Bridges (at least one experiment)

1) To compare capacitances using De Sauty's Bridge
2) To determine a Low Resistance by Carey - Foster Bridge

Unit V Network Theorems (at least one experiment)

1) To verify the Thevenin and Norton theorems
2) To verify the Superposition, and Maximum Power Transfer Theorems

References (for Laboratory Work):

1) Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
2) Engineering Practical Physics, S. Panigrahi and B.Mallick, 2015, Cengage Learning India Pvt. Ltd.
3) A Text Book of Practical Physics, I. Prakash and Ramakrishna, 11th Ed.2011, Kitab Mahal
4) Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press

Course Code: GE 12

Course Title: THERMAL PHYSICS

Total Credits: 04 (Credits: Theory: 03, Practical: 01)

Total Hours: Theory: 45, Practical: 30

Course Objectives: This course will review the basic concepts of Thermodynamics, Kinetic Theory of gases with a brief introduction to Statistical Mechanics. The primary goal is to understand the applications of fundamental laws of thermodynamics to various systems and processes. This coursework will also enable the students to understand the connection between the macroscopic observations of physical systems and microscopic behavior of atoms and molecule through statistical mechanics.

Course Learning Outcomes: At the end of this course, students will,

- Get an essence of the basic concepts of thermodynamics, the first and the second law of thermodynamics, the concept of entropy and the associated theorems, the thermodynamic potentials and their physical interpretations. They are also expected to learn Maxwell's thermodynamic relations.
- Know the fundamentals of the kinetic theory of gases, Maxwell-Boltzman distribution law, mean free path of molecular collisions, viscosity, thermal conductivity and diffusion.
- Learn about the black body radiations, Stefan- Boltzmann's law, Rayleigh-Jean's law and Planck's law and their significances.
- Learn the basics of quantum statistical distributions, viz., the Bose-Einstein statistics and the Fermi-Dirac statistics.

In the laboratory course, the students are expected to: Measure of Planck's constant using black body radiation, determine Stefan's Constant, coefficient of thermal conductivity of a bad conductor and a good conductor, determine the temperature coefficient of resistance, study variation of thermo-emf across two junctions of a thermocouple with temperature etc.

THEORY (Credit: 03; 45 Hours)

Unit 1: **Hours: 12**

Laws of Thermodynamics: Fundamental basics of Thermodynamic system and variables, Zeroth Law of Thermodynamics and temperature, First law and internal energy, various thermodynamical processes, Applications of First Law: general relation between C_P and C_V, work done during various processes, Compressibility and Expansion Coefficient, reversible and irreversible processes, Second law: Kelvin-Planck and Clausius statements , Carnot engine, Carnot cycle and theorem, basic concept of Entropy, Entropy changes in reversible and irreversible processes, Clausius inequality, Entropy-temperature diagrams.

Unit 2: **Hours: 8**

Thermodynamical Potentials: Enthalpy, Gibbs, Helmholtz and Internal Energy functions, Maxwell's relations and applications - Clausius Clapeyron Equation, Expression for (C_P – C_V), C_P/C_V, TdS equations, energy equations for ideal gases.

Unit 3: **Hours: 8**

Kinetic Theory of Gases: Derivation of Maxwell's law of distribution of velocities and its experimental verification, Mean free path (zeroth order only), Transport Phenomena: Viscosity, Conduction and Diffusion (for vertical case).

Unit 4: **Hours: 7**

Theory of Radiation: Blackbody radiation, Spectral distribution, Derivation of Planck's law, Deduction of Wien's law, Rayleigh-Jeans Law, Stefan Boltzmann Law and Wien's displacement law from Planck's law.

Unit 5: **Hours: 10**

Statistical Mechanics: Macrostate and Microstate, phase space, Entropy and Thermodynamic Probability, Maxwell-Boltzmann law, Fermi-Dirac distribution law - Bose-Einstein distribution law - comparison of three statistics.

PRACTICAL (Credit: 01; 30 Hours)

- Sessions on the construction and use of specific measurement instruments and experimental apparatuses used in the thermal physics lab, including necessary precautions.
- Sessions on the review of experimental data analysis, sources of error and their estimation in detail, writing of scientific laboratory reports including proper reporting of errors.
- Application to the specific experiments done in the lab.

Every student must perform at least four experiments from the following list.

1) To determine Mechanical Equivalent of Heat, J, by Callender and Barne's constant flow method.
2) Measurement of Planck's constant using black body radiation.
3) To determine Stefan's Constant.
4) To determine the coefficient of thermal conductivity of Cu by Searle's Apparatus.
5) To determine the coefficient of thermal conductivity of a bad conductor by Lee and Charlton's disc method by steam or electrical heating.
6) To determine the temperature co-efficient of resistance by Platinum resistance thermometer.

7) To study the variation of thermos-emf across two junctions of a thermocouple with temperature.

References (For Theory):

Essential Readings:

1) A Treatise on Heat, Meghnad Saha, and B.N. Srivastava, 1969, Indian Press.
2) Heat and Thermodynamics, M.W.Zemasky and R. Dittman, 1981, McGraw Hill.
3) Thermodynamics, Kinetic theory and statistical thermodynamics, F. W. Sears and G. L. Salinger. 1988, Narosa.
4) Thermal Physics, A. Kumar and S.P. Taneja, 2014, R. Chand Publications.
5) Thermal Physics: S.C.Garg, R. M.Bansal and C.K. Ghosh, 2nd Ed. Tata McGraw-Hill.

Additional Readings:

1) An Introduction to Thermal Physics: D. Schroeder 2021, Oxford Univ. Press (earlier published by Pearsons).
2) Concepts in Thermal Physics: Blundell and Blundell, 2nd Ed. 2009, Oxford Univ. Press.
3) Heat, Thermodynamics and Statistical Physics, Brij Lal, N. Subrahmanyam and P. S. Hemne, S. Chand and Company.

References (For Laboratory Work):

1) Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
2) A Text Book of Practical Physics, Indu Prakash and Ramakrishna, 11th Edition, 2011, Kitab Mahal.
3) A Laboratory Manual of Physics for Undergraduate Classes, D.P. Khandelwal, 1985, Vani Publication.
4) Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press.
5) An Advanced Course in Practical Physics: D. Chattopadhyay and P.C. Rakshit, New Central Book Agency

Course Code: GE 13

Course Title: MODERN PHYSICS

Total Credits: 04 (Credits: Theory: 03, Practical: 01)

Total Hours: Theory: 45, Practical: 30

Course Objectives: The objective of this course is to teach the physics foundation necessary for learning various topics in modern physics which are crucial for understanding atoms, molecules, photons, nuclei and elementary particles. These concepts are also important to understand phenomena in Laser physics, condensed matter physics and astrophysics.

Course Learning Outcomes: After getting exposure to this course, the following topics would have learnt,

- Main aspects of the inadequacies of classical mechanics as well as understanding of the historical development of quantum mechanics, laying the foundation of modern physics.
- Formulation of Schrodinger equation and the idea of probability interpretation associated with wave-functions.
- The spontaneous and stimulated emission of radiation, optical pumping and population inversion. Basic lasing action.
- The properties of nuclei like density, size, binding energy, nuclear force and structure of atomic nucleus, liquid drop model and mass formula.
- Radioactive decays like alpha, beta, gamma decay. Neutrino, its properties and its role in theory of beta decay.
- Fission and fusion: Nuclear processes to produce nuclear energy in nuclear reactor and stellar energy in stars.

In the laboratory course, the students will get opportunity to measure Planck's constant, verify photoelectric effect, determine e/m of electron and work function of a metal. They will also find wavelength of Laser sources by single and double slit experiment, wavelength and angular spread of He-Ne Laser using plane diffraction grating.

THEORY (Credit: 03; 45 Hours)

Unit 1: **Hours: 10**

Origin of Modern Physics Blackbody Radiation: Failure of explanation from classical theory; Planck's idea of a quantum; 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.

Unit 2 **Hours: 10**

Problems with Rutherford model: Instability of atoms and observation of discrete atomic spectra; Bohr's quantization rule and atomic stability; calculation of energy levels for hydrogen-like atoms and their spectra.

Uncertainty principle: Gamma ray microscope thought experiment; Wave-particle duality leading to Heisenberg uncertainty principle; Impossibility of an electron being in the nucleus. Energy-time uncertainty principle; origin of natural width of emission lines.

Unit 3 **Hours: 10**

Basics of quantum Mechanics: Two-slit interference experiment with photons and electrons; Concept of wave functions, linearity and superposition. Time independent Schrodinger wave equation for non-relativistic particles; Momentum and Energy operators; physical interpretation of a wave function, probabilities, normalization and probability current densities in one dimension. Problem: One dimensional infinitely rigid box. An application: Quantum dot.

Unit 4 **Hours: 5**

X-rays: Ionizing Power, X-ray Diffraction, Bragg's Law. Critical Potentials, X-rays-Spectra: Continuous and Characteristic X-rays, Moseley's Law.

LASERs: Properties and applications of Lasers. Emission (spontaneous and stimulated emissions) and absorption processes, Metastable states, components of a laser and lasing action.

Unit 5 **Hours: 10**

Nuclear Physics: Size and structure of atomic nucleus and its relation with atomic weight; Nature of nuclear force, Stability of the nucleus; N-Z graph, Drip line nuclei, Binding Energy, Liquid Drop model: semi-empirical mass formula.

Radioactivity: Different equilibrium, Alpha decay; Beta decay: energy released, spectrum and Pauli's prediction of neutrino; Gamma ray emission, energy-momentum conservation:

Fission and fusion: Mass deficit and generation of energy; Fission: nature of fragments and emission of neutrons. Fusion and thermonuclear reactions driving stellar evolution (brief qualitative discussions only).

References:

Essential Readings:

1) Concepts of Modern Physics, Arthur Beiser, 2002, McGraw-Hill.

2) Modern Physics by R A Serway, C J Moses and C A Moyer, 3rd edition, Thomson Brooks Cole, 2012.

3) Modern Physics for Scientists and Engineers by S T Thornton and A Rex, 4th edition, Cengage Learning, 2013.

4) Concepts of Nuclear Physics by B L Cohen, Tata McGraw Hill Publication, 1974.
5) Quantum Mechanics: Theory and Applications, (2019), Ajoy Ghatak and S. Lokanathan, Laxmi Publications, New Delhi

Additional Readings:

1) Six Ideas that Shaped Physics: Particle Behave like Waves, T.A. Moore, 2003, McGraw Hill.
2) Thirty years that shook physics: the story of quantum theory, George Gamow, Garden City, NY: Doubleday, 1966.
3) New Physics, ed. Paul Davies, Cambridge University Press (1989).
4) Quantum Theory, David Bohm, Dover Publications, 1979.
5) Lectures on Quantum Mechanics: Fundamentals and Applications, eds. A. Pathak and Ajoy Ghatak, Viva Books Pvt. Ltd., 2019
6) Quantum Mechanics, Robert Eisberg and Robert Resnick, 2nd Edn., 2002, Wiley.
7) Basic ideas and concepts in Nuclear Physics: An introductory approach by K Heyde, third edition, IOP Publication, 1999.

PRACTICAL (Credit: 01; 30 Hours)

- Sessions on the construction and use of specific measurement instruments and experimental apparatuses used in the modern physics lab, including necessary precautions.
- Sessions on the review of experimental data analysis, sources of error and their estimation in detail, writing of scientific laboratory reports including proper reporting of errors. Application to the specific experiments done in the lab.

Every student must perform at least 06 experiments from the following list of experiments.

1) Measurement of Planck's constant using black body radiation and photo-detector.
2) Photo-electric effect: estimate Planck's constant using graph of maximum energy of photo-electrons versus frequency of light.
3) To determine work function of material of filament of directly heated vacuum diode.
4) To determine the Planck's constant using LEDs, using at least 4 LEDs.
5) To determine the wavelength of H-alpha emission line of Hydrogen atom.
6) To determine the value of e/m by (a) Magnetic focusing or (b) Bar magnet.
7) To setup the Millikan oil drop apparatus and determine the charge of an electron.
8) To show the tunneling effect in tunnel diode using I-V characteristics.
9) To determine the wavelength of laser source using diffraction of single slit.
10) To determine wavelength and angular spread of He-Ne laser using plane diffraction grating.
11) To determine the wavelength of laser source using diffraction of double slits.

References (for Laboratory Work):

1) Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.
2) Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4^{th} Edition, reprinted 1985, Heinemann Educational Publishers.
3) A Text Book of Practical Physics, Indu Prakash and Ramakrishna, 11^{th} Edition, 2011, Kitab Mahal, New Delhi.
4) Practical Physics, G.L. Squires, 2015, 4^{th} Edition, Cambridge University Press.
5) B. Sc. Practical Physics, Geeta Sanon, R. Chand, 2016.

Course Code: GE 14

Course Title: INTRODUCTORY ASTRONOMY

Total Credits: 04 (Credits: Theory: 03, Tutorial: 01)

Total Hours: Theory: 45, Tutorial: 15

Course Objectives: This course is meant to introduce undergraduate students to the wonders of the Universe. Students will understand how astronomers over millennia have come to understand mysteries of the universe using laws of geometry and physics, and more recently chemistry and biology. They will be introduced to the Indian contribution to astronomy starting from ancient times up to the modern era. They will learn about diverse set of astronomical phenomenon, from the daily and yearly motion of stars and planets in the night sky which they can observe themselves, to the expansion of the universe deduced from the latest observations and cosmological models. Students will also be introduced to internet astronomy and the citizen science research platform in astronomy. The course presupposes school level understanding of mathematics and physics.

Course Learning Outcomes: After completing this course, student will gain an understanding of,

- Different types of telescopes, diurnal and yearly motion of astronomical objects, astronomical coordinate systems and their transformations
- Brightness scale for stars, types of stars, their structure and evolution on HR diagram
- Components of solar system and its evolution
- Current research in detection of exoplanets
- Basic structure of different galaxies and rotation of the Milky Way galaxy
- Distribution of chemical compounds in the interstellar medium and astrophysical conditions necessary for the emergence and existence of life
- Internet based astronomy and the collaborative citizen astronomy projects
- India's contribution to astronomy, both in ancient times and in modern era.

Unit 1: **Hours: 8**

Introduction to Astronomy and Astronomical Scales: History of astronomy, wonders of the Universe, overview of the night sky, diurnal and yearly motions of the Sun, size, mass, density and temperature of astronomical objects, basic concepts of positional astronomy: Celestial sphere, Astronomical coordinate systems, Horizon system and Equatorial system

Unit 2: **Hours: 6**

Basic Parameters of Stars: Stellar energy sources, determination of distance by parallax method, aberration, proper motion, brightness, radiant flux and luminosity, apparent and absolute magnitude scales, distance modulus, determination of stellar temperature and radius, basic results of Saha ionization formula and its applications for stellar astrophysics, stellar spectra, dependence of spectral types on temperature, luminosity classification, stellar evolutionary track on Hertzsprung-Russell diagram

Unit 3: **Hours: 7**

Astronomical Instruments: Observing through the atmosphere (Scintillation, Seeing, Atmospheric Windows and Extinction). Basic Optical Definitions for Telescopes: Magnification, Light Gathering Power, Limiting magnitude, Resolving Power, Diffraction Limit. Optical telescopes, radio telescopes, Hubble space telescope, James Web space telescope, Fermi Gamma ray space telescope.

Astronomy in the Internet Age: Overview of Aladin Sky Atlas, Astrometrica, Sloan Digital Sky Survey, Stellarium, virtual telescope

Citizen Science Initiatives: Galaxy Zoo, SETI@Home, RAD@Home India

Unit 4: **Hours: 8**

Sun and the solar system: Solar parameters, Sun's internal structure, solar photosphere, solar atmosphere, chromosphere, corona, solar activity, origin of the solar system, the nebular model, tidal forces and planetary rings

Exoplanets: Detection methods

Unit 5: **Hours: 12**

Physics of Galaxies: Basic structure and properties of different types of Galaxies, Nature of rotation of the Milky Way (Differential rotation of the Galaxy), Idea of dark matter

Cosmology and Astrobiology: Standard Candles (Cepheids and SNe Type1a), Cosmic distance ladder, Olber's paradox, Hubble's expansion, History of the Universe, Chemistry of life, Origin of life, Chances of life in the solar system

Unit 6: **Hours: 4**

Astronomy in India: Astronomy in ancient, medieval and early telescopic era of India, current Indian observatories (Hanle-Indian Astronomical Observatory, Devasthal Observatory, Vainu Bappu Observatory, Mount Abu Infrared Observatory, Gauribidanur Radio Observatory, Giant Metre-wave Radio Telescope, Udaipur Solar Observatory, LIGO-India) (qualitative discussion), Indian astronomy missions (Astrosat, Aditya)

References:

Essential Readings:

1) Seven Wonders of the Cosmos, Jayant V Narlikar, Cambridge University Press
2) Fundamental of Astronomy, H. Karttunen et al. Springer
3) Modern Astrophysics, B.W. Carroll and D.A. Ostlie, Addison-Wesley Publishing Co.
4) Introductory Astronomy and Astrophysics, M. Zeilik and S.A. Gregory, Saunders College Publishing.
5) The Molecular Universe, A.G.G.M. Tielens (Sections I, II and III), Reviews of Modern

Physics, Volume 85, July-September, 2013
6) Astronomy in India: A Historical Perspective, Thanu Padmanabhan, Springer

Useful websites for astronomy education and citizen science research platform

1) https://aladin.u-strasbg.fr/
2) http://www.astrometrica.at/
3) https://www.sdss.org/
4) http://stellarium.org/
5) https://www.zooniverse.org/projects/zookeeper/galaxy-zoo/
6) https://setiathome.berkeley.edu/
7) https://www.radathomeindia.org/

Additional Readings:

1) Explorations: Introduction to Astronomy, Thomos Arny and Stephen Schneider, McGraw Hill
2) Astrophysics Stars and Galaxies K D Abhyankar, Universities Press
3) Textbook of Astronomy and Astrophysics with elements of cosmology, V.B. Bhatia, Narosa Publication.
4) Baidyanath Basu, An introduction to Astrophysics, Prentice Hall of India Private Limited.
5) The Physical Universe: An Introduction to Astronomy, F H Shu, University Science Books

Course Code: GE 15

Course Title: QUANTUM MECHANICS

Total Credits: 04 (Credits: Theory: 03, Tutorial: 01)

Total Hours: Theory: 45, Tutorial: 15

Syllabus to be prepared later

Course Code: GE 16

Course Title: INTRODUCTION TO EMBEDDED SYSTEM DESIGN

Total Credits: 04 (Credits: Theory: 02, Practical: 02)

Total Hours: Theory: 30, Practical: 60

Syllabus to be prepared later

Course Code: GE 17

Course Title: NANO PHYSICS

Total Credits: 04 (Credits: Theory: 02, Practical: 02)

Total Hours: Theory: 30, Practical: 60

Syllabus to be prepared later

Course Code: GE 18

Course Title: PHYSICS OF DETECTORS

Total Credits: 04 (Credits: Theory: 03, Tutorial: 01)

Total Hours: Theory: 45, Tutorial: 15

Syllabus to be prepared later

Course Code: GE 19

Course Title: NUCLEAR AND PARTICLE PHYSICS

Total Credits: 04 (Credits: Theory: 03, Tutorial: 01)

Total Hours: Theory: 45, Tutorial: 15

Syllabus to be prepared later

Course Code: GE 20

Course Title: ATOMIC AND MOLECULAR PHYSICS

Total Credits: 04 (Credits: Theory: 03, Tutorial: 01)

Total Hours: Theory: 45, Tutorial: 15

Syllabus to be prepared later

DEPARTMENT OF PHYSICS AND ASTROPHYSICS
UNIVERSITY OF DELHI

SEMESTER – III

Table of Contents

PHYSICS

COURSES OFFERED BY DEPARTMENT OF PHYSICS AND ASTROPHYSICS

CATEGORY – I

Physics Courses for Undergraduate Programme of study
With Physics as a Single Core Discipline

(B. Sc. Honours in Physics in three years)

STRUCTURE OF THIRD SEMESTER

Semester	Core (DSC) 4 credits	Elective (DSE) 4 credits	Generic Elective (GE) 4 credits	Ability Enhancement Course (AEC) 2 credits	Skill Enhancement Course (SEC) 2 credits	Internship/ Apprenticeship / Project/ Community outreach (IAPC) 2 credits	Value addition course (VAC) 2 credits	Total Credits
III	DSC – 7 DSC – 8 DSC – 9	Choose one from a pool of DSE or GE courses		Choose one from a pool of AEC courses	Choose one from a pool of SEC courses or IAPC		Choose one from a pool of VAC courses	**22**

A student who pursues undergraduate programme with Physics as single core discipline is offered the following courses.

a) **3 Discipline Specific Cores (DSCs)** - 3 courses of 4 credits = 12 credits (offered by the parent Department i.e. Department of Physics and Astrophysics)

b) **1 Discipline Specific Electives (DSE)** – One DSE course of 4 credits in Semester III
OR
1 Generic Elective (GE) – 1 course of 4 credits = 4 credits (one course to be chosen from the common pool of GE courses offered by Departments other than the parent Department)

c) **1 Ability Enhancement Course (AEC)** – 1 course of 2 credits = 2 credits (one course to be chosen from either 'Environmental Science: Theory to Practice' or one of the 22 Indian Languages listed in the 8th Schedule of the Constitution in the pool of AEC courses)

d) **1 Skill Enhancement Course (SEC)** - 1 course of 2 credits = 2 credits (one course to be chosen from the common pool of SEC courses offered by any Department)
OR
1 Internship/ Apprenticeship/ Project/ Community outreach of 2 credits

e) **1 Value Addition Course (VAC)** - 1 course of 2 credits = 2 credits (one course to be chosen from the common pool of VAC courses offered by any Department)

DISCIPLINE SPECIFIC CORE COURSE – 7: MATHEMATICAL PHYSICS III

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Mathematical Physics III DSC – 7	**4**	**3**	**0**	**1**	Should have studied DSC - 1 and DSC - 4 of this program or its equivalent

LEARNING OBJECTIVES

The emphasis of course is on applications in solving problems of interest to physicists. The course will also expose students to fundamental computational physics skills enabling them to solve a wide range of physics problems. The skills developed during course will prepare them not only for doing fundamental and applied research but also for a wide variety of careers.

LEARNING OUTCOMES

After completing this course, student will be able to,

- Determine continuity, differentiability and analyticity of a complex function, find the derivative of a function and understand the properties of elementary complex functions.
- Work with multi-valued functions (logarithmic, complex power, inverse trigonometric function) and determine branches of these functions.
- Evaluate a contour integral using parameterization, fundamental theorem of calculus and Cauchy's integral formula.
- Find the Taylor series of a function and determine its radius of convergence.
- Determine the Laurent series expansion of a function in different regions, find the residues and use the residue theory to evaluate a contour integral and real integral.
- Understand the properties of Fourier transforms and use these to solve boundary value problems.
- Solve linear partial differential equations of second order with separation of variable method.
- In the laboratory course, the students will learn to,
  - create, visualize and use complex numbers
  - use Gauss quadrature methods to numerically integrate proper and improper definite integrals
  - Solve the boundary value problems numerically
  - Compute the fast Fourier transform of a given function

SYLLABUS OF DSC – 7

THEORY COMPONENT

Unit - I **(25 Hours)**

Complex Analysis: The field of complex numbers. Graphical, Cartesian and polar representation. Algebra in the complex plane. Triangle inequality. Roots of complex numbers. Regions in the complex plane – idea of open sets, closed sets, connected sets, bounded sets and domain.

The complex functions and mappings. Limits of complex functions. Extended complex plane and limits involving the point at infinity. Continuity and differentiability of a complex function, Cauchy-Riemann equations in Cartesian and polar coordinates, sufficient conditions for differentiability, harmonic functions. Analytic functions, singular points. Elementary functions. Multi-functions, branch cuts and branch points.

Integration in complex plane: contours and contour integrals, Cauchy-Goursat Theorem (No proof) for simply and multiply connected domains. Cauchy's Inequality. Cauchy's Integral formula. Taylor's and Laurent's theorems (statements only), types of singularities, meromorphic functions, residues and Cauchy's residue theorem, application of contour integration in solving real integrals.

Unit – II **(10 Hours)**

Fourier Transform: Fourier Integral theorem (Statement only), Fourier Transform (FT) and Inverse FT, existence of FT, FT of single pulse, finite sine train, trigonometric, exponential, Gaussian functions, properties of FT, FT of Dirac delta function, sine and cosine function, convolution theorem. Fourier Sine Transform (FST) and Fourier Cosine Transform (FCT), Solution of one dimensional Wave Equation using FT.

Unit – III **(10 Hours)**

Partial Differential Equations: Solutions to partial differential equations (2 or 3 independent variables) using separation of variables: Laplace's Equation in problems of rectangular geometry. Solution of wave equation for vibrational modes of a stretched string. Solution of 1D heat flow equation. (Wave/Heat equation not to be derived).

References:

Essential Readings:

1) Mathematical methods for Scientists and Engineers, D.A. McQuarrie, 2003, Viva Book.
2) Essential Mathematical Methods, K. F. Riley and M. P. Hobson, 2011, Cambridge Univ. Press.
3) Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber, F.E. Harris, 7 Ed., 2013, Elsevier.
4) Complex Variables and Applications, J. W. Brown and R. V. Churchill, 9th Ed. 2021, Tata McGraw-Hill.
5) Complex Variables: Schaum's Outline, McGraw Hill Education (2009).
6) Fourier Analysis: With Applications to Boundary Value Problems, Murray Spiegel, 2017, McGraw Hill Education.
7) A Student's Guide to Laplace Transforms, Daniel Fleisch, Cambridge University Press; New edition (2022).
8) Laplace Transform: Schaum's Outline, M.R. Spiegel, McGraw Hill Education

Additional Readings:

1) Mathematical Physics with Applications, Problems and Solutions, V. Balakrishnan, Ane Books (2017).
2) Complex Variables, A.S.Fokas and M.J.Ablowitz, 8th Ed., 2011, Cambridge Univ. Press.
3) Fourier Transform and its Applications, third edition, Ronald New Bold Bracewell, McGraw Hill (2000).
4) A Students Guide to Fourier Transforms: With Applications In Physics And Engineering, 3rd edition, Cambridge University Press (2015).
5) Partial Differential Equations for Scientists and Engineers, S.J. Farlow, Dover Publications (1993).
6) Differential Equations – Theory, Technique and practice, George F. Simmons and Steven G. Krantz, Indian Edition McGraw Hill Education Pvt. Ltd (2014).

PRACTICAL COMPONENT

(15 Weeks with 4 hours of laboratory session per week)

The aim of this lab is not just to teach computer programming and numerical analysis but to emphasize its role in solving problems in Physics.

- The course will consist of practical sessions and lectures on the related theoretical aspects of the laboratory.
- Assessment is to be done not only on the programming but also on the basis of formulating the problem.
- The list of recommended programs is suggestive only. More programs may be done in the class with physics applications. Emphasis should be given to formulate a physics problem as mathematical one and solve it by computational methods.
- At least 6 programs must be attempted (taking at least one from each unit). The implementation can be either in Python/ C++/ Scilab. Inbuilt libraries can be used wherever applicable.

Unit 1

Handling of Complex Numbers: Syntax for creating complex numbers in Python/C++/Scilab, accessing real and imaginary parts, calculating the modulus and conjugate of a complex number, complex number arithmetic, plotting of complex numbers as ordered pairs of real numbers in a plane, conversion from Cartesian to polar representation.

Recommended List of Programs:

a) Determine the nth roots of a complex number and represent it in Cartesian and polar form.
b) Transformation of complex numbers as 2-D vectors e.g. translation, scaling, rotation, reflection.
c) Visualisation of mappings of some elementary complex functions w = f(z) from z-plane to w-plane.

Unit 2

Gauss Quadrature Integration Methods: Gauss quadrature methods for integration: Gauss Legendre, Gauss Lagaurre and Gauss Hermite methods.

Recommended List of Programs:

a) Solving a definite integral by Gauss Legendre quadrature method. Application – representation of a function as a linear combination of Legendre polynomials.
b) Solving improper integrals over entire real axis or the positive real axis using Gauss Lagaurre and Gauss hermite quadrature method. Comparison of results with the ones

obtained by contour integration analytically.

c) Comparison of convergence of improper integral computed by Newton Cotes and Gauss Quadrature Methods.

Unit 3

Fast Fourier Transform: Discrete Fourier transform, Any algorithm for fast Fourier transform.

a) Computation of Discrete Fourier Transform (DFT) using complex numbers.

b) Fast Fourier Transform of given function in tabulated or mathematical form e.g function $\exp(-x^2)$.

Unit 4

Numerical Solutions of Boundary Value Problems: Two-point boundary value problems, types of boundary conditions – (Dirichlet, Neumann and Robin), importance of converting a physics problem to dimensionless form before solving numerically. Finite difference method, Shooting method with bisection/Secant/Newton method for solving non-linear equation and using RK methods for solving IVP (The programs developed in the last semester may be used here).

Algorithm for any one numerical method to solve Partial Differential Equations e.g. Finite Difference method, relaxation methods, Crank-Nicolson method

Recommended List of Programs:

(a) The equilibrium temperature of a bar of length L with insulated horizontal sides and the ends maintained at fixed temperatures.

(b) Solve for the steady state concentration profile y(x) in the reaction-diffusion problem given by $y''(x) - y(x) = 0$ with $y(0) = 1, y'(1) = 0$.

(c) Use any numerical method to solve Laplace equation/ wave equation/ Heat Equation.

References (for Laboratory Work):

1) Documentation at the Python home page (https://docs.python.org/3/) and the tutorials there (https://docs.python.org/3/tutorial/).
2) Documentation of NumPy and Matplotlib : https://numpy.org/doc/stable/user/ and https://matplotlib.org/stable/tutorials/
3) Schaum's Outline of Programming with C++', J. Hubbard, 2000, McGraw-Hill Education.
4) An Introduction to Computational Physics, T. Pang, Cambridge University Press (2010).
5) Introduction to Numerical Analysis, S. S. Sastry, 5th Edn., 2012, PHI Learning Pvt. Ltd.
6) Numerical Recipes: The art of scientific computing, William H. Press, Saul A. Teukolsky and William Vetterling, Cambridge University Press; 3rd edition (2007)
7) Computational Problems for Physics, R.H. Landau and M.J. Páez, 2018, CRC Press.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE – 8: THERMAL PHYSICS

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Thermal Physics DSC – 8	**4**	**3**	**0**	**1**	--

LEARNING OBJECTIVES

This course deals with the relationship between the macroscopic and microscopic properties of physical systems in equilibrium. It reviews the concepts of thermodynamics learnt at school from a more advanced perspective and how to develop them further to build new concepts. The course gives an understanding about the fundamental laws of thermodynamics and their applications to various systems and processes. It also includes a basic idea about the kinetic theory of gases, transport phenomena involved in ideal gases, phase transitions and behavior of real gases. The students will be able to apply these concepts to several problems on heat. The lab course deals with providing the knowledge of the concepts of Thermodynamics studied in the theory paper with the help of experiments and give the students a hands-on experience on the construction and use of specific measurement instruments and experimental apparatuses used in the Thermal Physics lab, including necessary precautions.

LEARNING OUTCOMES

At the end of this course, students will be able to

- Comprehend the basic concepts of thermodynamics, the first and the second law of thermodynamics.
- Understand the concept of reversibility, irreversibility and entropy.
- Understand various thermodynamic potentials and their physical significance with respect to different thermodynamic systems and processes.
- Deduce Maxwell’s Thermodynamical relations and use them for solving various problems in Thermodynamics.
- Understand the concept and behaviour of ideal and real gases.
- Apply the basic concept of kinetic theory of gases in deriving Maxwell-Boltzman distribution law and its applications.
- Understand mean free path and molecular collisions in viscosity, thermal conductivity, diffusion and Brownian motion.
- While doing the practical, the students will have an opportunity to understand and hence use the specific apparatus required to study various concepts of thermodynamics. Hence, the student will be able to comprehend the errors they can encounter while performing the experiment and how to estimate them.

SYLLABUS OF DSC - 8

THEORY COMPONENT

Unit – I - Zeroth and First Law of Thermodynamics (6 Hours)

Fundamental idea of thermodynamic equilibrium and Zeroth Law of Thermodynamics, concept of work and heat, First law of Thermodynamics and its differential form, internal energy, applications of First law: General relation between C_P and C_v, work done during various processes (all four) and related problems, Compressibility and Expansion Co-efficient for various processes.

Unit – II - Second law of Thermodynamics (6 Hours)

Reversible and Irreversible processes, Carnot engine and Carnot's cycle, Refrigerator, efficiency of Carnot engine and refrigerator, Second Law of Thermodynamics: Kelvin-Planck and Clausius statements and their equivalence, Carnot's theorem, Applications of Second Law of Thermodynamics in the light of Phase Change, Thermodynamic Scale of Temperature and its equivalence to Perfect Gas Scale.

Unit – III – Entropy (6 Hours)

Concept of Entropy, Entropy changes in Reversible and Irreversible processes with examples, Clausius Theorem, Clausius inequality, Second Law of Thermodynamics in terms of Entropy. Temperature-Entropy diagrams for Carnot's cycle and related problems, Entropy of perfect and real gases, conceptual problems related to Entropy during a Phase Change, Nernst Heat Theorem: Unattainability of Absolute Zero and Third Law of Thermodynamics.

Unit – IV - Thermodynamic Potentials and Maxwell's Relations (12 Hours)

Basic concept of Thermodynamic Potentials, Internal Energy, Enthalpy, Helmholtz Free Energy, Gibb's Free Energy: their properties and applications, Surface Film and variation of Surface Tension with temperature, Magnetic work, Cooling due to Adiabatic Demagnetization, Phase Transitions : First order and Second order Phase Transitions with examples, Clausius Clapeyron Equation, Ehrenfest Equations, Derivation of Maxwell's Thermodynamic Relations and their applications in Clausius Clapeyron Equation, value of $C_P – C_v$, TdS equations, Energy equations, evaluation of C_P /C_v and Ratio of Adiabatic to Isothermal elasticity.

.

Unit – V - Kinetic Theory of Gases and Molecular Collisions (8 Hours)

Constrained maximization using Lagrange Multipliers, Maxwell-Boltzmann Law of Distribution of Velocities in an ideal gas and its experimental verification with any one method. Mean, Root Mean Square and Most Probable Speeds, Maxwell-Boltzman equation for distribution of Energy: Average Energy and Most Probable Energy, Mean Free Path, Collision Probability, estimation of Mean Free Path, Continuity Equation for Transport Phenomena in ideal gases: Viscosity, Thermal Conductivity and Diffusion

Unit – VI - Real Gases (7 Hours)

Behavior of Real Gases: Deviations from the Ideal Gas Equation, Andrew's Experiments on CO_2 Gas, Virial Equation, Continuity of liquid and gaseous states, Boyle Temperature, Van der Waals Equation of State for Real Gases, Comparison with Experimental Curves: P-V diagrams, Value of Critical Constants, Law of Corresponding States, Free Adiabatic Expansion of a Perfect Gas, Joule Thomson Porous - Plug Experiment, Joule Thomson

Coefficient for Ideal and Van der Waals Gases, Temperature of Inversion and Joule Thomson cooling.

References:

Essential Readings:

1) Heat and Thermodynamics: M.W. Zemansky and R. Dittman, 1981, Tata McGraw-Hill.
2) Thermal Physics: S. C. Garg, R. M. Bansal and C. K. Ghosh, 2^{nd} Edition, Tata McGraw-Hill.
3) Thermodynamics, Kinetic Theory and Statistical Thermodynamics: Sears and Salinger, 1988, Narosa.
4) Concepts in Thermal Physics: Blundell and Blundell, 2^{nd} Edition, 2009, Oxford University Press.
5) Thermal Physics, A. Kumar and S. P. Taneja, 2014, R. Chand Publications.
6) A Text Book of Heat and Thermodynamics for Degree Students, J.B Rajam, 1981, S. Chand.

Additional Readings:

1) An Introduction to Thermal Physics: D. Schroeder, 2021, Oxford University Press (earlier published by Pearsons).
2) Thermal Physics: C. Kittel and H. Kroemer , 1980, 2^{nd} Edition, W.H. Freeman
3) Heat, Thermodynamics and Statistical Physics, Brij Lal, N. Subrahmanyam and P. S. Hemne, S. Chand and Company

PRACTICAL COMPONENT

(15 Weeks with 2 hours of laboratory session per week)

At least six experiments to be done from the following:

1) To determine Mechanical Equivalent of Heat, J, by Callender and Barne's constant flow method.
2) To determine the Coefficient of Thermal Conductivity of Cu by Searle's Apparatus.
3) To determine the Coefficient of Thermal Conductivity of a bad conductor by Lee and Charlton's disc method using steam or electrical heating.
4) To determine the Temperature Coefficient of Resistance by Platinum Resistance Thermometer (PRT) using Carey Foster's Bridge.
5) To determine the Temperature Coefficient of Resistance using Platinum Resistance Thermometer (PRT) by Callender-Griffith Bridge.
6) To study the variation of Thermo-emf of a Thermocouple with difference of temperature of its two junctions using a null method.
7) To calibrate a thermocouple to measure temperature in a specified range by direct method and/or by using Op Amp and to determine Neutral Temperature.
8) To determine the coefficient of thermal conductivity of Copper (Cu) by Angstrom's method.

References (for Laboratory Work):

1) Advanced Practical Physics for students: B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
2) A Text Book of Practical Physics : Indu Prakash and Ramakrishna, 11^{th} Edition, Kitab Mahal
3) Advanced level Practical Physics: Nelkon and Ogborn, 4^{th} Ed, reprinted 1985, Heinemann Educational Publishers.
4) An Advanced Course in Practical Physics: D. Chattopadhyay and P. C. Rakshit, 1990, New Central Book Agency.
5) Practical Physics: G. L. Squires , 1985, Cambridge University Press.
6) B.Sc Practical Physics: Harnam Singh, P.S. Hemne, revised edition 2011 , S. Chand and Co.
7) B. Sc Practical Physics: C. L. Arora, 2001, S. Chand and Co.
8) B.Sc. Practical Physics: Geeta Sanon, R. Chand and Co.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE – 9: LIGHT AND MATTER

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Light and Matter DSC – 9	4	2	0	2	--

LEARNING OBJECTIVES

The objective of this course reviews the concepts of light and matter, their properties and their dual nature. This course provides an in depth understanding of dual nature of light, interference and diffraction with emphasis on practical applications of both.

LEARNING OUTCOMES

On successfully completing the requirement of this course the student will have the skill and knowledge to,

- Appreciate the dual nature of light which is part of EM spectrum and the dual nature of matter simultaneously.
- Understand the phenomena of interference and diffraction exhibited by light and matter, their nuances and details.
- Delve in to the depth of understanding wave optics with its various kinds of interference and diffraction exhibited by light.
- Demonstrate basic concepts of Diffraction: Superposition of wavelets diffracted from aperture, understand Fraunhoffer and Fresnel Diffraction.
- Learn about the application of matter waves in latest technological developments of electron microscope e.g. SEM and TEM used widely for characterization in several fields of physics such as material science, nanotechnology etc.
- In the laboratory course, student will gain hands-on experience of using various optical instruments and making finer measurements of wavelength of light using Newton Rings experiment. Wavelength of light sources, resolving power and dispersive power of optical equipment can be learnt first-hand.

SYLLABUS OF DSC - 9

THEORY COMPONENT

Unit – I - Duality of Light and matter (5 Hours)

Light an EM wave - Hertz's experiments; Particle characteristic by Photoelectric effect and Compton Effect (only concept) and wave characteristic by interference and diffraction

Wave properties of particles: de Broglie hypothesis, wavelength of matter waves; Particle wave complementarity: Velocity of de Broglie wave and need of a wave packet; Group and Phase velocities and relation between them; Equivalence of group and particle velocity, Dispersion of wave groups

Unit – II – Interference **(10 Hours)**

By Light waves: Division of amplitude and wave-front. Two-slit interference experiment with photons: Young's double slit experiment. Lloyd's Mirror. Phase change on reflection: Stokes' treatment. Interference in Thin Films: parallel and wedge-shaped films. Fringes of equal inclination (Haidinger Fringes); Fringes of equal thickness (Fizeau Fringe). Newton's Rings: Measurement of wavelength andrefractive index.

By matter waves: Two-slit interference experiment with electrons. Single photon interference, Quantum interference experiment

Unit – III – Diffraction **(15 Hours)**

By Light waves: Fraunhofer diffraction: Single slit. Double slit. Diffraction grating. Resolving power of grating. Fresnel Diffraction: Fresnel's Assumptions. Fresnel's Half-Period Zones for Plane Wave. Explanation of Rectilinear Propagation of Light. Theory of a Zone Plate: Multiple Foci of a Zone Plate. Fresnel diffraction of Straight edge, a slit and a wire by Fresnel Half Period Zones.

By matter waves: Experimental study of matter waves: Davisson-Germer experiment; Electron microscope: applications SEM, TEM.

References:

Essential Readings:

1) Concepts of Modern Physics, Arthur Beiser, 2002, McGraw-Hill.
2) Modern Physics by R A Serway, C J Moses and C A Moyer, Thomson Brooks Cole, 2012.
3) Modern Physics for Scientists and Engineers by S T Thornton and A Rex, 4th Edn. , Cengage Learning, 2013.
4) Optics, (2017), 7th Edition, Ajoy Ghatak, McGraw-Hill Education, New Delhi.
5) Fundamentals of Optics, F.A. Jenkins and H.E. White, 1981, McGraw-Hill.
6) Principles of Optics, Max Born and Emil Wolf, 7th Edn., 1999, Pergamon Press.
7) Fundamental of Optics, A. Kumar, H.R. Gulati and D.R. Khanna, 2011, R. Chand Publications.
8) Optics, Eugene Hecht, 4th Edn., 2014, Pearson Education.

PRACTICAL COMPONENT

(15 Weeks with 4 hours of laboratory session per week)

Mandatory activity: Familiarization with Schuster`s focusing; determination of angle of prism.

At least 5 experiments from the following:

1) Determination of refractive index of material of prism using mercury (Hg) light.
2) To determine the dispersive power and Cauchy constants of the material of a prism using mercury source.
3) To determine wavelength of sodium light using Newton's Rings.
4) To determine the thickness of a thin paper by measuring the width of the interference fringes produced by a wedge-shaped Film.

5) To determine wavelength of (1) Na source and (2) spectral lines of Hg source using plane diffraction grating.
6) To determine dispersive power of a plane diffraction grating using mercury lamp.
7) To determine resolving power of a plane diffraction grating using sodium lamp.
8) To determine the wavelength of laser source using diffraction of single slit.
9) To determine the wavelength of laser source using diffraction of double slit.
10) To determine wavelength and angular spread of He-Ne laser using plane diffraction grating.

References (for Laboratory Work):

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

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 1: BIOPHYSICS

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Biophysics DSE – 1	4	4	0	0	--

LEARNING OBJECTIVES

This course familiarizes the students with the basic facts and ideas of biology from a quantitative perspective. It shows them how ideas and methods of physics enrich our understanding of biological systems at diverse length and time scales. The course also gives them a flavour of the interface between biology, chemistry, physics and mathematics.

LEARNING OUTCOMES

After completing this course, students will

- Know basic facts about biological systems, including single cells, multicellular organisms and ecosystems from a quantitative perspective.
- Gain familiarity with various biological processes at different length and time scales, including molecular processes, organism level processes and evolution.
- Be able to apply the principles of physics from areas such as mechanics, electricity and magnetism, thermodynamics, statistical mechanics, and dynamical systems to understand certain living processes.
- Get exposure to complexity of life at i) the level of cell, ii) level of multi cellular organism and iii) at macroscopic system – ecosystem and biosphere.
- Gain a systems level perspective on organisms and appreciate how networks of interactions of many components give rise to complex behaviour.
- Perform mathematical and computational modelling of certain aspects of living systems.
- Get exposure to models of evolution.

SYLLABUS OF DSE – 1

THEORY COMPONENT

Unit – I **(4 Hours)**

Overview: The boundary, interior and exterior environment of living cells. Processes: exchange of matter and energy with environment, metabolism, maintenance, reproduction, evolution. Self-replication as a distinct property of biological systems. Time scales and spatial scales.

Unit - II **(16 Hours)**

Molecules of life: Metabolites, proteins and nucleic acids. Their sizes, types and roles in structures and processes. Transport, energy storage, membrane formation, catalysis, replication, transcription, translation, signaling. Typical populations of molecules of various types present in cells, their rates of production and turnover. Energy required to make a bacterial cell. Simplified mathematical models of transcription and translation, small genetic circuits and signaling pathways to be studied analytically and computationally.

Unit - III **(16 Hours)**

Molecular motion in cells: Random walks and applications to biology: Diffusion; models of macromolecules. Molecular motors: Transport along microtubules. Flagellar motion: bacterial chemotaxis. Mechanical, entropic and chemical forces.

Unit - IV **(16 Hours)**

The complexity of life: At the level of a cell: Metabolic, regulatory and signaling networks in cells. Dynamics of metabolic networks; the stoichiometric matrix. The implausibility of life based on a simplified probability estimate, and the origin of life problem. At the level of a multicellular organism: Numbers and types of cells in multicellular organisms. Cellular differentiation and development. Brain structure: neurons and neural networks. At the level of an ecosystem and the biosphere: Foodwebs. Feedback cycles and self-sustaining ecosystems. Allometric scaling laws.

Unit - V **(8 Hours)**

Evolution: The mechanism of evolution: variation at the molecular level, selection at the level of the organism. Models of evolution. The concept of genotype-phenotype map.

References:

Essential Readings:

1) Biological Physics: Energy, Information, Life; Philip Nelson (W H Freeman & Co, NY, 2004)
2) Cell Biology by the Numbers; Ron Milo and Rob Phillips (Garland Science, Taylor & Francis Group, NY USA and Abingdon UK, 2016)
3) Physical Biology of the Cell (2nd Edition); Rob Phillips et al (Garland Science, Taylor & Francis Group, NY USA and Abingdon UK, 2013)
4) Evolution; M. Ridley (Blackwell Publishers, 2009, 3rd edition).

Additional Readings:

1) Physics in Molecular Biology; Kim Sneppen and Giovanni Zocchi (Cambridge University Press, Cambridge UK, 2005)
2) Biophysics: Searching for Principles; William Bialek (Princeton University Press, Princeton USA, 2012).

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 2: NUMERICAL ANALYSIS

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
NUMERICAL ANALYSIS DSE – 2	**4**	**2**	**0**	**2**	--

LEARNING OBJECTIVES

The main objective of this course is to introduce the students to the field of numerical analysis enabling them to solve a wide range of physics problems. The skills developed during the course will prepare them not only for doing fundamental and applied research but also for a wide variety of careers.

LEARNING OUTCOMES

After completing this course, student will be able to,

- Analyze a physics problem, establish the mathematical model and determine the appropriate numerical techniques to solve it.
- Derive numerical methods for various mathematical tasks such as solution of non-linear algebraic and transcendental equations, system of linear equations, interpolation, least square fitting, numerical differentiation, numerical integration, eigen value problems and solution of initial value and boundary value problems.
- Analyse and evaluate the accuracy of the numerical methods learned.
- In the laboratory course, the students will learn to implement these numerical methods in Python/C++/Scilab and develop codes to solve various physics problems and analyze the results.

SYLLABUS OF DSE – 2

THEORY COMPONENT

Unit – I **(3 Hours)**

Approximation and Errors in computing: Introduction to numerical computation, Taylor's expansion and mean value theorem. Floating Point Computation, overflow and underflow. Single and double precision arithmetic. Rounding and truncation error, absolute and relative error, error propagation.

Unit – II **(8 Hours)**

Linear Systems: Solution of linear systems by Gaussian elimination method, partial and complete pivoting, LU decomposition, norms and errors, condition numbers, Gauss-Seidel

method, diagonally dominant matrix and convergence of iteration methods. Solution of Tridiagonal systems
Eigenvalue Problem: Power method, inverse power method.

Unit – III **(5 Hours)**
Interpolation: Lagrange and Newton's methods (divided difference) for polynomial interpolation, theoretical error of interpolation. Inverse Interpolation. Optimal points for interpolation and Chebyshev Polynomials. Minimax Theorem (Statement only)

Unit – IV **(7 Hours)**
Numerical Integration: Newton Cotes quadrature methods. Derivation of Trapezoidal and Simpson (1/3 and 3/8) rules from Lagrange interpolating polynomial. Error and degree of precision of a quadrature formula. Composite formulae for Trapezoidal and Simpson methods.
Gauss Quadrature methods. Legendre, Lagaurre and Hermite quadrature methods.

Unit – V **(7 Hours)**
Initial and Boundary Value Problems: Solution of initial value problems by Euler, modified Euler and Runge Kutta (RK) methods. Local and global errors, comparison of errors in the Euler and RK methods.
Finite difference and shooting method for solving two-point linear boundary value problems.

References:
Essential Readings:

1) Applied numerical analysis, Cutis F. Gerald and P. O. Wheatley, Pearson Education, India (2007).
2) Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India..
3) Introduction to Numerical Analysis, S. S. Sastry, 5th Edn., 2012, PHI Learning Pvt. Ltd.
4) Elementary Numerical Analysis, K. E. Atkinson, 3rd Edn., 2007, Wiley India Edition.

Additional Readings:

1) Numerical Recipes: The art of scientific computing, William H. Press, Saul A. Teukolsky and William Vetterling, Cambridge University Press; 3rd edition (2007), ISBN-13 : 978-0521880688 .
2) Applied numerical analysis, Cutis F. Gerald and P. O. Wheatley, Pearson Education, India (2007).
3) Numerical methods for scientific and engineering computation, M. K. Jain, S. R. K. Iyenger, New Age Publishers (2012).

PRACTICAL COMPONENT

(15 Weeks with 4 hours of laboratory session per week)

The aim of this lab is not just to teach computer programming and numerical analysis but to emphasize its role in solving problems in Physics. Assessment is to be done not only on the programming but also on the basis of formulating the problem. The list of recommended programs is suggestive only. Students should be encouraged to do more physics applications.

Emphasis should be given to formulate a physics problem as mathematical one and solve by computational methods. The students should be encouraged to develop and present an independent project. At least 10 programs must be attempted (taking at least two from each unit).The implementation can be either in Python/ C++/Scilab.

Unit 1 - Linear Systems :

a) Solve a system of linear equations using Gauss Elimination method with pivoting (application to electric networks).
b) Solve a system of linear equations using Gauss-Seidel method and study the convergence (application to spring mass system).
c) Determine the inverse of a square matrix using Gauss-Jordan method.
d) Solve a tridiagonal system of linear equations.
e) Study an example of ill-conditioned systematic
f) Find the LU equivalent of a matrix.
g) Determine the largest and smallest eigenvalues using Power and inverse power methods. Consider a case where power method fails.

Unit 2 - Interpolation:

a) Given a dataset (x, y) with equidistant x values, prepare the Newton's forward difference, backward difference and divided difference tables.
b) Given a dataset (x, y) corresponding to a physics problem, use Lagrange and Newton's forms of interpolating polynomials and compare. Determine the value of y at an intermediate value of x not included in the data set. This may be done with equally spaced and non-equally spaced x-values.
c) Given a tabulated data for an elementary function, approximate it by a polynomial and compare with the true function.
d) Compare the interpolating polynomial for a given dataset (following a known form e.g. exponential) with the approximation obtained by least square fitting.
e) Compare the interpolating polynomial approximating a given function in a given range obtained with uniformly spaced points and by Chebyshev points.
f) Compare the Chebyshev and Maclaurin series expansions of an exponential or sinusoidal function.

Unit 3 - Integration:

a) Use integral definition of error function to compute and plot erf(x) in a given range. Use Trapezoidal, Simpson and Gauss Legendre methods and compare the results for a small and large values of x.
b) Use the definition of erf(x) and numerically take the limit x going to infinity to get the value of Gaussian integral using Simpson method. Compare the result with the value obtained by Gauss Hermite and Gauss Lagaurre methods.
c) Verify the degree of precision of each quadrature rule.
d) Use Simpson methods to compute a double integral over a rectangular region.
e) Approximate the value of π by evaluating the integral $\int_0^\infty \frac{1}{x^2+1}\,dx$using Simpson, Gauss Hermite and Gauss Lagaurre methods.

Unit 4 - Initial Value Problems (IVP):

a) Compare the errors in Euler, RK2 and RK4 by solving a first order IVP with known solution. Reduce the step size to a point where the round off errors take over.

b) Solve a system of n first order differential equations by Euler and RK methods. Use it to solve an nth order IVP. Solve a damped free and forced harmonic oscillator problem using this.
c) Solve a physics problem like free fall with air drag or parachte problem using RK method.
d) Solve a compound spring system (3 springs) by solving a system of differential equations using Euler and RK for a given set of initial conditions.
e) Obtain the current flowing in a series LCR circuit with constant voltage for a given set of initial conditions.

Unit 5 - Boundary value problems (BVP):

a) Solve a linear BVP using shooting and finite difference method and compare the results.
b) Solve a non-linear BVP using the finite differnce and shooting method and compare the results.
c) Determine the temperature distribution along a rod made of two dissimilar materials (of different thermal conductivities) welded together when temperatures at two ends are maintained at given temperatures.
d) Design a physics problem that can be modelled by a BVP and solve it by any method.

References for laboratory work

1) Documentation at the Python home page (https://docs.python.org/3/) and the tutorials there (https://docs.python.org/3/tutorial/).
2) Documentation of NumPy and Matplotlib : https://numpy.org/doc/stable/user/ and https://matplotlib.org/stable/tutorials/
3) Computational Physics, Darren Walker, 1st Edn., Scientific International Pvt. Ltd (2015).
4) An Introduction to Computational Physics, T. Pang, Cambridge University Press (2010).
5) Computational Problems for Physics, R.H. Landau and M.J. Páez, 2018, CRC Press.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

Category II

Physical Science Courses
with Physics discipline as one of the Core Disciplines

(B. Sc. Physical Science with Physics as Major discipline)

DISCIPLINE SPECIFIC CORE COURSE – DSC 3: HEAT AND THERMODYNAMICS

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
HEAT AND THERMODYNAMICS DSC – 3	**4**	**2**	**0**	**2**	**--**

LEARNING OBJECTIVES

This course will review the basic concepts of Thermodynamics, Kinetic Theory of gases with a brief introduction to Statistical Mechanics. The primary goal is to make the student understand the applications of fundamental laws of thermodynamics to various systems and processes. This coursework will enable the students to understand the connection between the macroscopic observations of physical systems and microscopic behaviour of atoms andmolecule through a brief knowledge of statistical mechanics. The lab course deals with providing the knowledge of the concepts of Thermodynamics along with Planck's Law and Stefan Boltzmann laws related to black body radiation.

LEARNING OUTCOMES

At the end of this course, students will be able to

- gain an essence of the basic concepts of thermodynamics, the first and the second law of thermodynamics, the concept of entropy and the associated theorems, the thermodynamic potentials and their physical interpretations along with Maxwell's thermodynamic relations.
- Know the fundamentals of the kinetic theory of gases, Maxwell-Boltzman distribution law, mean free path of molecular collisions, viscosity, thermal conductivity and diffusion.
- Learn about the black body radiations, Stefan- Boltzmann's law, Rayleigh-Jean's law and Planck's law and their significances.
- gain the basic knowledge about quantum statistics: the Bose-Einstein statistics and the Fermi-Dirac statistics.
- In the laboratory course, the students are expected to: Measure of Planck's constant using black body radiation, determine Stefan's Constant, coefficient of thermal conductivity of a bad conductor and a good conductor, determine the temperature coefficient of resistance, study variation of thermo-emf across two junctions of a thermocouple with temperature etc.

SYLLABUS OF DSC – 3

THEORY COMPONENT

Unit – I - Laws of Thermodynamics (10 Hours)

Fundamental basics of Thermodynamic system and variables, Zeroth Law of Thermodynamics and temperature, First law and internal energy, various thermodynamical processes, Applications of First Law: general relation between C_P and C_V, work done during various processes, Compressibility and Expansion Coefficient, reversible and irreversible processes, Second law: Kelvin-Planck and Clausius statements, Carnot engine, Carnot cycle and theorem, basic concept of Entropy, Entropy changes in reversible and irreversible processes, Clausius inequality, Entropy-temperature diagrams.

Unit – II - Thermodynamic Potentials and Maxwell's Relations (5 Hours)

Basic concept of Thermodynamic Potentials, Internal Energy, Enthalpy, Helmholtz Free Energy, Gibb's Free Energy, derivation of Maxwell's Thermodynamic Relations and their applications in Clausius Clapeyron Equation, value of $C_P – C_v$, TdS Equations, Energy equations for ideal gases, evaluation of C_P /C_v

Unit – III - Kinetic Theory of Gases and Molecular Collisions (6 Hours)

Maxwell-Boltzmann Law of Distribution of Velocities in an ideal gas and its experimental verification, Mean, Root Mean Square and Most Probable Speeds, Mean Free Path (Zeroth order), Transport Phenomena in ideal gases: Viscosity, Thermal Conductivity and Diffusion (for vertical case)

Unit – IV - Theory of Radiation (5 Hours)

Blackbody radiation, Spectral distribution, Derivation of Planck's law, Deduction of Wien's law, Rayleigh-Jeans Law, Stefan Boltzmann Law and Wien's displacement law from Planck's law

Unit – V - Statistical Mechanics (4 Hours)

Macrostate and Microstate, phase space, Entropy and thermodynamic probability, Maxwell-Boltzmann law, qualitative description of Quantum statistics – Bose Einstein and Fermi Dirac, comparison of three statistics.

References:

Essential Readings:

1) Heat and Thermodynamics: M. W. Zemansky and R. Dittman, 1981, Tata McGraw-Hill.
2) Thermal Physics: S. C. Garg, R. M. Bansal and C. K. Ghosh, 2nd Edition, Tata McGraw-Hill.
3) Thermodynamics, Kinetic Theory and Statistical Thermodynamics: Sears and Salinger, 1988, Narosa.
4) Concepts in Thermal Physics: Blundell and Blundell, 2nd Edition, 2009, Oxford University Press.
5) Thermal Physics, A. Kumar and S. P. Taneja, 2014, R. Chand Publications.
6) A Text Book of Heat and Thermodynamics for Degree Students, J. B. Rajam, 1981, S. Chand.

Additional Readings:

1) An Introduction to Thermal Physics: D. Schroeder, 2021, Oxford University Press (earlier published by Pearsons)
2) Thermal Physics: C. Kittel and H. Kroemer, 1980, 2^{nd} Edition, W.H. Freeman
3) Heat, Thermodynamics and Statistical Physics, Brij Lal, N. Subrahmanyam and P. S. Hemne, S. Chand and Company

PRACTICAL COMPONENT

(15 Weeks with 4 hours of laboratory session per week)

At least six experiments to be done from the following:

1) To determine Mechanical Equivalent of Heat, J, by Callender and Barne‟s constant flow method.
2) To determine the Coefficient of Thermal Conductivity of Cu by Searle‟s Apparatus.
3) To determine the Coefficient of Thermal Conductivity of a bad conductor by Lee and Charlton’s disc method using steam or electrical heating.
4) Measurement of Planck’s constant using black body radiation.
5) To determine the Temperature Coefficient of Resistance by Platinum Resistance Thermometer
6) To study the variation of thermos-emf across two junctions of a thermocouple with temperature.
7) To determine Stefan’s Constant.
8) To determine the Temperature Coefficient of Resistance using Platinum Resistance Thermometer (PRT) by Callender-Griffith Bridge

References for laboratory work:

1) Advanced Practical Physics for students: B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
2) A Text Book of Practical Physics: Indu Prakash and Ramakrishna, 11^{th} Edition, Kitab Mahal
3) Advanced level Practical Physics: Nelkon and Ogborn, 4^{th} Ed, reprinted 1985, Heinemann Educational Publishers.
4) An Advanced Course in Practical Physics: D. Chattopadhyay& P. C. Rakshit, 1990, New Central Book Agency.
5) Practical Physics: G.L. Squires, 1985, Cambridge University Press.
6) B.Sc. Practical Physics: Harnam Singh, Dr P. S. Hemne, revised edition 2011, S. Chand and Co.
7) B. Sc. Practical Physics: C. L. Arora, 2001, S. Chand and Co.
8) B. Sc. Practical Physics: Geeta Sanon, R. Chand and Co.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 13a PHYSICS: BIOPHYSICS

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Biophysics DSE 13a PHYSICS	**4**	**4**	**0**	**0**	--

LEARNING OBJECTIVES

This course familiarizes the students with the basic facts and ideas of biology from a quantitative perspective. It shows them how ideas and methods of physics enrich our understanding of biological systems at diverse length and time scales. The course also gives them a flavour of the interface between biology, chemistry, physics and mathematics.

LEARNING OUTCOMES

After completing this course, students will

- Know basic facts about biological systems, including single cells, multicellular organisms and ecosystems from a quantitative perspective.
- Gain familiarity with various biological processes at different length and time scales, including molecular processes, organism level processes and evolution.
- Be able to apply the principles of physics from areas such as mechanics, electricity and magnetism, thermodynamics, statistical mechanics, and dynamical systems to understand certain living processes.
- Get exposure to complexity of life at i) the level of cell, ii) level of multi cellular organism and iii) at macroscopic system – ecosystem and biosphere.
- Gain a systems level perspective on organisms and appreciate how networks of interactions of many components give rise to complex behaviour.
- Perform mathematical and computational modelling of certain aspects of living systems.
- Get exposure to models of evolution.

SYLLABUS OF DSE 13a PHYSICS

THEORY COMPONENT

Unit – I **(4 Hours)**

Overview: The boundary, interior and exterior environment of living cells. Processes: exchange of matter and energy with environment, metabolism, maintenance, reproduction, evolution. Self-replication as a distinct property of biological systems. Time scales and spatial scales.

Unit - II **(16 Hours)**

Molecules of life: Metabolites, proteins and nucleic acids. Their sizes, types and roles in structures and processes. Transport, energy storage, membrane formation, catalysis, replication, transcription, translation, signaling. Typical populations of molecules of various types present in cells, their rates of production and turnover. Energy required to make a bacterial cell. Simplified mathematical models of transcription and translation, small genetic circuits and signaling pathways to be studied analytically and computationally.

Unit - III **(16 Hours)**
Molecular motion in cells: Random walks and applications to biology: Diffusion; models of macromolecules. Molecular motors: Transport along microtubules. Flagellar motion: bacterial chemotaxis. Mechanical, entropic and chemical forces.

Unit - IV **(16 Hours)**
The complexity of life: At the level of a cell: Metabolic, regulatory and signaling networks in cells. Dynamics of metabolic networks; the stoichiometric matrix. The implausibility of life based on a simplified probability estimate, and the origin of life problem. At the level of a multicellular organism: Numbers and types of cells in multicellular organisms. Cellular differentiation and development. Brain structure: neurons and neural networks. At the level of an ecosystem and the biosphere: Foodwebs. Feedback cycles and self-sustaining ecosystems. Allometric scaling laws.

Unit - V **(8 Hours)**
Evolution: The mechanism of evolution: variation at the molecular level, selection at the level of the organism. Models of evolution. The concept of genotype-phenotype map.

References:
Essential Readings:

1) Biological Physics: Energy, Information, Life; Philip Nelson (W H Freeman & Co, NY, 2004)
2) Cell Biology by the Numbers; Ron Milo and Rob Phillips (Garland Science, Taylor & Francis Group, NY USA and Abingdon UK, 2016)
3) Physical Biology of the Cell (2nd Edition); Rob Phillips et al (Garland Science, Taylor & Francis Group, NY USA and Abingdon UK, 2013)
4) Evolution; M. Ridley (Blackwell Publishers, 2009, 3rd edition).

Additional Readings:

1) Physics in Molecular Biology; Kim Sneppen and Giovanni Zocchi (Cambridge University Press, Cambridge UK, 2005)
2) Biophysics: Searching for Principles; William Bialek (Princeton University Press, Princeton USA, 2012).

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – 13b PHYSICS: MATHEMATICAL PHYSICS I

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
MATHEMATICAL PHYSICS I DSE – 13b Physics	4	4	0	0	--

LEARNING OBJECTIVES

The emphasis of course is to equip students with the mathematical tools required in solving problem of interest to physicists. The mathematical tools might be building blocks to understand the fundamental computational physics skills and hence enable them to solve a wide range of physics problems. Overall, to help students develop critical skills and knowledge that will prepare them not only for doing fundamental and applied research but also prepare them for a wide variety of careers

LEARNING OUTCOMES

After completing this course, student will be able to,

- Learn the functions more than one variable using the concepts of calculus.
- Solve first order differential equations and apply it to physical problems.
- Represent a periodic function by a sum of harmonics using Fourier series.
- Obtain power series solution of differential equation of 2nd order with variable coefficients using Frobenius mehod.
- Learn beta and gamma functions.
- Learn complex analysis.

SYLLABUS OF DSE 13b - PHYSICS

THEORY COMPONENT

Unit – I **(16 Hours)**

Calculus of functions of more than one variable: Partial derivatives, chain rule for partial derivatives, exact and inexact differentials. Integrating factor, with simple illustration. Constrained Maximization using Lagrange Multipliers.

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. Even and odd functions and their Fourier expansions. Application to Summing of Infinite Series

Unit – II **(10 Hours)**

Frobenius Method and Special Functions: Singular Points of Second Order Linear Differential Equations and their importance. Frobenius method and its applications to differential equations. Legendre Differential Equations and its solution. Properties of Legendre Polynomials: Rodrigues Formula, Orthogonality. Simple recurrence relations

Unit – III **(14 Hours)**

Some Special Integrals: Beta and Gamma Functions and Relation between them. Expression of Integrals in terms of Gamma Functions

Partial Differential Equations: Solutions to partial differential equations, using separation of variables: Laplace's Equation in problems of rectangular geometry. Solution of 1D wave equation

Unit – IV **(20 Hours)**

Complex Analysis: Introduction to complex variables, Functions of Complex variable, limit, continuity, Analytic functions, Cauchy-Riemann equations, singular points, Cauchy Integral Theorem, Cauchy's Integral Formula, Residues, Cauchy's residue theorem, application of contour integration in solving real integrals.

References:

Essential Readings:

1) An introduction to ordinary differential equations, E.A. Coddington, 2009, PHI learning.
2) Differential Equations, George F. Simmons, 2007, McGraw Hill.
3) Mathematical methods for Scientists and Engineers, D.A. McQuarrie, 2003, Viva Book.
4) Advanced Engineering Mathematics, D.G. Zill and W.S. Wright, 5 Ed., 2012, Jones and Bartlett Learning.
5) Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India.
6) Fourier Analysis: With Applications to Boundary Value Problems, Murray Spiegel, 2017, McGraw Hill Education.
7) Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber, F.E. Harris, 7 Ed., 2013, Elsevier.
8) Essential Mathematical Methods, K. F.Riley and M. P.Hobson, 2011, Cambridge Univ. Press.

Additional Readings:

1) Introduction to Electrodynamics, Chapter 1, David J. Griffiths, 4 Ed., 2017, Cambridge University Press.
2) The Feynman Lectures on Physics, Volume II, Feynman, Leighton and Sands, 2008, Narosa Publishing House.
3) Advanced Engineering Mathematics, D.G. Zill and W.S. Wright, 5 Ed., 2012, Jones and Bartlett Learning.
4) Mathematical Tools for Physics, James Nearing, 2010, Dover Publications.
5) Mathematical Physics, A.K. Ghatak, I. C. Goyal and S.J. Chua, Laxmi Publications Private Limited (2017).

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

Category II

Physical Science Courses (with Electronics)
with Physics and Electronics discipline as Core Disciplines

DISCIPLINE SPECIFIC CORE COURSE – PHYSICS DSC 5: HEAT AND THERMODYNAMICS

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
HEAT AND THERMODYNAMICS PHYSICS DSC 5	4	2	0	2	--

LEARNING OBJECTIVES

This course will review the basic concepts of Thermodynamics, Kinetic Theory of gases with a brief introduction to Statistical Mechanics. The primary goal is to make the student understand the applications of fundamental laws of thermodynamics to various systems and processes. This coursework will enable the students to understand the connection between the macroscopic observations of physical systems and microscopic behaviour of atoms and molecule through a brief knowledge of statistical mechanics. The lab course deals with providing the knowledge of the concepts of Thermodynamics along with Planck's Law and Stefan Boltzmann laws related to black body radiation.

LEARNING OUTCOMES

At the end of this course, students will be able to

- gain an essence of the basic concepts of thermodynamics, the first and the second law of thermodynamics, the concept of entropy and the associated theorems, the thermodynamic potentials and their physical interpretations along with Maxwell's thermodynamic relations.
- Know the fundamentals of the kinetic theory of gases, Maxwell-Boltzman distribution law, mean free path of molecular collisions, viscosity, thermal conductivity and diffusion.
- Learn about the black body radiations, Stefan- Boltzmann's law, Rayleigh-Jean's law and Planck's law and their significances.
- gain the basic knowledge about quantum statistics: the Bose-Einstein statistics and the Fermi-Dirac statistics.
- In the laboratory course, the students are expected to: Measure of Planck's constant using black body radiation, determine Stefan's Constant, coefficient of thermal conductivity of a bad conductor and a good conductor, determine the temperature coefficient of resistance, study variation of thermo-emf across two junctions of a thermocouple with temperature etc.

SYLLABUS OF PHYSICS DSC – 5

THEORY COMPONENT

Unit – I - Laws of Thermodynamics (10 Hours)

Fundamental basics of Thermodynamic system and variables, Zeroth Law of Thermodynamics and temperature, First law and internal energy, various thermodynamical processes, Applications of First Law: general relation between C_P and C_V, work done during various processes, Compressibility and Expansion Coefficient, reversible and irreversible processes, Second law: Kelvin-Planck and Clausius statements, Carnot engine, Carnot cycle and theorem, basic concept of Entropy, Entropy changes in reversible and irreversible processes, Clausius inequality, Entropy-temperature diagrams.

Unit – II - Thermodynamic Potentials and Maxwell's Relations (5 Hours)

Basic concept of Thermodynamic Potentials, Internal Energy, Enthalpy, Helmholtz Free Energy, Gibb's Free Energy, derivation of Maxwell's Thermodynamic Relations and their applications in Clausius Clapeyron Equation, value of $C_P – C_v$, TdS Equations, Energy equations for ideal gases, evaluation of C_P /C_v

Unit – III - Kinetic Theory of Gases and Molecular Collisions (6 Hours)

Maxwell-Boltzmann Law of Distribution of Velocities in an ideal gas and its experimental verification, Mean, Root Mean Square and Most Probable Speeds, Mean Free Path (Zeroth order), Transport Phenomena in ideal gases: Viscosity, Thermal Conductivity and Diffusion (for vertical case)

Unit – IV - Theory of Radiation (5 Hours)

Blackbody radiation, Spectral distribution, Derivation of Planck's law, Deduction of Wien's law, Rayleigh-Jeans Law, Stefan Boltzmann Law and Wien's displacement law from Planck's law

Unit – V - Statistical Mechanics (4 Hours)

Macrostate and Microstate, phase space, Entropy and thermodynamic probability, Maxwell-Boltzmann law, qualitative description of Quantum statistics – Bose Einstein and Fermi Dirac, comparison of three statistics.

References:

Essential Readings:

1) Heat and Thermodynamics: M. W. Zemansky and R. Dittman, 1981, Tata McGraw-Hill.
2) Thermal Physics: S. C. Garg, R. M. Bansal and C. K. Ghosh, 2nd Edition, Tata McGraw-Hill.
3) Thermodynamics, Kinetic Theory and Statistical Thermodynamics: Sears and Salinger, 1988, Narosa.
4) Concepts in Thermal Physics: Blundell and Blundell, 2nd Edition, 2009, Oxford University Press.
5) Thermal Physics, A. Kumar and S. P. Taneja, 2014, R. Chand Publications.
6) A Text Book of Heat and Thermodynamics for Degree Students, J. B. Rajam, 1981, S. Chand.

Additional Readings:

1) An Introduction to Thermal Physics: D. Schroeder, 2021, Oxford University Press (earlier published by Pearsons)
2) Thermal Physics: C. Kittel and H. Kroemer, 1980, 2nd Edition, W.H. Freeman
3) Heat, Thermodynamics and Statistical Physics, Brij Lal, N. Subrahmanyam and P. S. Hemne, S. Chand and Company

PRACTICAL COMPONENT

(15 Weeks with 4 hours of laboratory session per week)

At least six experiments to be done from the following:

1) To determine Mechanical Equivalent of Heat, J, by Callender and Barne"s constant flow method.
2) To determine the Coefficient of Thermal Conductivity of Cu by Searle"s Apparatus.
3) To determine the Coefficient of Thermal Conductivity of a bad conductor by Lee and Charlton's disc method using steam or electrical heating.
4) Measurement of Planck's constant using black body radiation.
5) To determine the Temperature Coefficient of Resistance by Platinum Resistance Thermometer
6) To study the variation of thermos-emf across two junctions of a thermocouple with temperature.
7) To determine Stefan's Constant.
8) To determine the Temperature Coefficient of Resistance using Platinum Resistance Thermometer (PRT) by Callender-Griffith Bridge

References for laboratory work:

1) Advanced Practical Physics for students: B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
2) A Text Book of Practical Physics: Indu Prakash and Ramakrishna, 11th Edition, Kitab Mahal
3) Advanced level Practical Physics: Nelkon and Ogborn, 4th Ed, reprinted 1985, Heinemann Educational Publishers.
4) An Advanced Course in Practical Physics: D. Chattopadhyay& P. C. Rakshit, 1990, New Central Book Agency.
5) Practical Physics: G.L. Squires, 1985, Cambridge University Press.
6) B.Sc. Practical Physics: Harnam Singh, Dr P. S. Hemne, revised edition 2011, S. Chand and Co.
7) B. Sc. Practical Physics: C. L. Arora, 2001, S. Chand and Co.
8) B. Sc. Practical Physics: Geeta Sanon, R. Chand and Co.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC CORE COURSE – PHYSICS DSC 6: COMMUNICATION ELECTRONICS

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
COMMUNICATION ELECTRONICS Physics DSC – 6	4	2	0	2	--

LEARNING OBJECTIVES

This paper aims to describe the concepts of electronics in communication. Communication techniques based on Analog Modulation, Analog and digital Pulse Modulation including PAM, PWM, PPM, ASK, PSK, FSK are described in detail. Communication and Navigation systems such as GPS, satellite and mobile telephony systems are introduced.

LEARNING OUTCOMES

At the end of this course, students will be able to develop following learning outcomes:

- This paper aims to describe the concepts of electronics in communication. In this course, students will receive an introduction to the principle, performance and applications of communication systems.
- Students will learn the various means and modes of communication. They will gain an understanding of fundamentals of electronic communication system and electromagnetic communication spectrum with an idea of frequency allocation for radio communication system in India.
- They will gain an insight on the use of different modulation and demodulation techniques used in analog communication
- Students will be able to analyse different parameters of analog communication techniques.
- They will learn the need of sampling and different sampling techniques where they can sample analog signal.
- Students will learn the generation and detection of a signal through pulse and digital modulation techniques and multiplexing.
- They will gain an in-depth understanding of different concepts used in a satellite communication system.
- This paper will essentially connect the text book knowledge with the most popular communication technology in real world.

SYLLABUS OF PHYSICS DSC 6

THEORY COMPONENT

Unit – I **(10 Hours)**
Electronic communication: Introduction to communication – means and modes. Power measurements (units of power). Need for modulation. Block diagram of an electronic communication system. Brief idea of frequency allocation for radio communication system in India (TRAI). Electromagnetic communication spectrum, band designations and usage. Channels and base-band signals.
Analog Modulation: Amplitude Modulation: Frequency spectrum of AM waves, average power, average voltage, modulation index, AM-modulator circuits (collector modulation), AM-demodulator (diode detector), single side band generation and detection.
Angle Modulation: Frequency and phase modulation, frequency spectrum of FM waves, intersystem comparisons (FM and AM), FM generation using VCO, FM detector (slope detector)

Unit – II **(5 Hours)**
Analog Pulse Modulation: Channel capacity, Sampling Theorem and Nyquist Criterion, Basic Principles – Pulse Amplitude Modulation (PAM), Pulse Width Modulation (PWM), Pulse Position Modulation (PPM), modulation and detection technique for PAM only, Multiplexing – Time Division Multiplexing (TDM) and Frequency Division Multiplexing (FDM).

Unit – III **(6 Hours)**
Digital Pulse Modulation: Need for digital transmission, Pulse Code Modulation (PCM), Digital Carrier Modulation Techniques, Sampling, Quantization and Encoding. Concept of Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK) and Phase Shift Keying (PSK)

Unit – IV **(6 Hours)**
Satellite Communication: Introduction, Geosynchronous satellite orbits, geostationary satellite advantages of geostationary satellites. Transponders (C - Band), Uplink and downlink, path loss, Satellite visibility, Ground and earth stations. Simplified block diagram of the earth station.

Unit – V **(3 Hours)**
Mobile Telephony System: Basic concept of mobile communication, frequency bands used in mobile communication, the concept of cell sectoring and cell splitting, SIM number, IMEI number, GPS navigation system (qualitative idea only).

References:
Essential Readings:
1) Communication Electronics, Principles and Applications, L.E. Frenzel, Tata McGraw-Hill.
2) Communication Systems: Analog and Digital, R.P. Singh and S.D Sapre, Tata McGraw-Hill.
3) Analog and Digital Communications, H. Hsu, Schaum's Outline Series, Tata McGraw-Hill.
4) Electronic Communications Systems: Fundamentals Through Advanced, Wayne Tomasi, Fifth Edition, Pearson.

5) Communication Systems, S. Haykin, Wiley India

Additional Readings:

1) Electronic Communication, L. Temes and M. Schultz, Schaum's Outline Series, Tata McGraw- Hill.
2) Electronic Communication Systems, G. Kennedy and B. Davis, Tata McGraw-Hill
3) Analog and Digital Communication Systems, M.J. Roden, Prentice Hall of India.

PRACTICAL COMPONENT

(15 Weeks with 4 hours of laboratory session per week)

Every student must perform at least 06 experiments.

1) To study AM – Generation and Detection circuit
2) To study FM – Generation and Detection circuit
3) To study Time Division Multiplexing (TDM)
4) To study Pulse Amplitude Modulation (PAM)
5) To study Pulse Width Modulation (PWM)
6) To study Pulse Position Modulation (PPM)
7) To study Amplitude Shift Keying (ASK)
8) To study Frequency Shift Keying (FSK)
9) To study Phase Shift Keying (PSK)

References (for Laboratory Work):

1) Introduction to Analog and Digital Communication – by M. A. Bhagyaveni, R. Kalidoss and K. S. Vishvaksenan, River Publishers Series in Communications
2) Communication Systems – by Michael Moher Simon Haykin, Wiley
3) Wireless Communication – by Goldsmith Andrea, Cambridge University Press
4) Digital Communications: Fundamentals & Applications – Bernard Sklar and Pabitra Kumar Ray, Pearson Education India

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 1: BIOPHYSICS

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Biophysics DSE 1	**4**	**4**	**0**	**0**	--

LEARNING OBJECTIVES

This course familiarizes the students with the basic facts and ideas of biology from a quantitative perspective. It shows them how ideas and methods of physics enrich our understanding of biological systems at diverse length and time scales. The course also gives them a flavour of the interface between biology, chemistry, physics and mathematics.

LEARNING OUTCOMES

After completing this course, students will

- Know basic facts about biological systems, including single cells, multicellular organisms and ecosystems from a quantitative perspective.
- Gain familiarity with various biological processes at different length and time scales, including molecular processes, organism level processes and evolution.
- Be able to apply the principles of physics from areas such as mechanics, electricity and magnetism, thermodynamics, statistical mechanics, and dynamical systems to understand certain living processes.
- Get exposure to complexity of life at i) the level of cell, ii) level of multi cellular organism and iii) at macroscopic system – ecosystem and biosphere.
- Gain a systems level perspective on organisms and appreciate how networks of interactions of many components give rise to complex behaviour.
- Perform mathematical and computational modelling of certain aspects of living systems.
- Get exposure to models of evolution.

SYLLABUS OF DSE 1

THEORY COMPONENT

Unit – I **(4 Hours)**

Overview: The boundary, interior and exterior environment of living cells. Processes: exchange of matter and energy with environment, metabolism, maintenance, reproduction, evolution. Self-replication as a distinct property of biological systems. Time scales and spatial scales.

Unit - II **(16 Hours)**

Molecules of life: Metabolites, proteins and nucleic acids. Their sizes, types and roles in structures and processes. Transport, energy storage, membrane formation, catalysis, replication, transcription, translation, signaling. Typical populations of molecules of various types present in cells, their rates of production and turnover. Energy required to make a bacterial cell. Simplified mathematical models of transcription and translation, small genetic circuits and signaling pathways to be studied analytically and computationally.

Unit - III **(16 Hours)**
Molecular motion in cells: Random walks and applications to biology: Diffusion; models of macromolecules. Molecular motors: Transport along microtubules. Flagellar motion: bacterial chemotaxis. Mechanical, entropic and chemical forces.

Unit - IV **(16 Hours)**
The complexity of life: At the level of a cell: Metabolic, regulatory and signaling networks in cells. Dynamics of metabolic networks; the stoichiometric matrix. The implausibility of life based on a simplified probability estimate, and the origin of life problem. At the level of a multicellular organism: Numbers and types of cells in multicellular organisms. Cellular differentiation and development. Brain structure: neurons and neural networks. At the level of an ecosystem and the biosphere: Foodwebs. Feedback cycles and self-sustaining ecosystems. Allometric scaling laws.

Unit - V **(8 Hours)**
Evolution: The mechanism of evolution: variation at the molecular level, selection at the level of the organism. Models of evolution. The concept of genotype-phenotype map.

References:
Essential Readings:

1) Biological Physics: Energy, Information, Life; Philip Nelson (W H Freeman & Co, NY, 2004)
2) Cell Biology by the Numbers; Ron Milo and Rob Phillips (Garland Science, Taylor & Francis Group, NY USA and Abingdon UK, 2016)
3) Physical Biology of the Cell (2nd Edition); Rob Phillips et al (Garland Science, Taylor & Francis Group, NY USA and Abingdon UK, 2013)
4) Evolution; M. Ridley (Blackwell Publishers, 2009, 3rd edition).

Additional Readings:

1) Physics in Molecular Biology; Kim Sneppen and Giovanni Zocchi (Cambridge University Press, Cambridge UK, 2005)
2) Biophysics: Searching for Principles; William Bialek (Princeton University Press, Princeton USA, 2012).

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

DISCIPLINE SPECIFIC ELECTIVE COURSE – PHYSICS DSE 2: MATHEMATICAL PHYSICS I

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
MATHEMATICAL PHYSICS I Physics DSE 2	4	4	0	0	--

LEARNING OBJECTIVES

The emphasis of course is to equip students with the mathematical tools required in solving problem of interest to physicists. The mathematical tools might be building blocks to understand the fundamental computational physics skills and hence enable them to solve a wide range of physics problems. Overall, to help students develop critical skills and knowledge that will prepare them not only for doing fundamental and applied research but also prepare them for a wide variety of careers

LEARNING OUTCOMES

After completing this course, student will be able to,

- Learn the functions more than one variable using the concepts of calculus.
- Solve first order differential equations and apply it to physical problems.
- Represent a periodic function by a sum of harmonics using Fourier series.
- Obtain power series solution of differential equation of 2^{nd} order with variable coefficients using Frobenius mehod.
- Learn beta and gamma functions.
- Learn complex analysis.

SYLLABUS OF PHYSICS DSE 2

THEORY COMPONENT

Unit – I **(16 Hours)**

Calculus of functions of more than one variable: Partial derivatives, chain rule for partial derivatives, exact and inexact differentials. Integrating factor, with simple illustration. Constrained Maximization using Lagrange Multipliers.

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. Even and odd functions and their Fourier expansions. Application to Summing of Infinite Series

Unit – II **(10 Hours)**

Frobenius Method and Special Functions: Singular Points of Second Order Linear Differential Equations and their importance. Frobenius method and its applications to differential equations. Legendre Differential Equations and its solution. Properties of Legendre Polynomials: Rodrigues Formula, Orthogonality. Simple recurrence relations

Unit – III **(14 Hours)**

Some Special Integrals: Beta and Gamma Functions and Relation between them. Expression of Integrals in terms of Gamma Functions

Partial Differential Equations: Solutions to partial differential equations, using separation of variables: Laplace's Equation in problems of rectangular geometry. Solution of 1D wave equation

Unit – IV **(20 Hours)**

Complex Analysis: Introduction to complex variables, Functions of Complex variable, limit, continuity, Analytic functions, Cauchy-Riemann equations, singular points, Cauchy Integral Theorem, Cauchy's Integral Formula, Residues, Cauchy's residue theorem, application of contour integration in solving real integrals.

References:

Essential Readings:

1) An introduction to ordinary differential equations, E.A. Coddington, 2009, PHI learning.
2) Differential Equations, George F. Simmons, 2007, McGraw Hill.
3) Mathematical methods for Scientists and Engineers, D.A. McQuarrie, 2003, Viva Book.
4) Advanced Engineering Mathematics, D.G. Zill and W.S. Wright, 5 Ed., 2012, Jones and Bartlett Learning.
5) Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India.
6) Fourier Analysis: With Applications to Boundary Value Problems, Murray Spiegel, 2017, McGraw Hill Education.
7) Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber, F.E. Harris, 7 Ed., 2013, Elsevier.
8) Essential Mathematical Methods, K. F.Riley and M. P.Hobson, 2011, Cambridge Univ. Press.

Additional Readings:

1) Introduction to Electrodynamics, Chapter 1, David J. Griffiths, 4 Ed., 2017, Cambridge University Press.
2) The Feynman Lectures on Physics, Volume II, Feynman, Leighton and Sands, 2008, Narosa Publishing House.
3) Advanced Engineering Mathematics, D.G. Zill and W.S. Wright, 5 Ed., 2012, Jones and Bartlett Learning.
4) Mathematical Tools for Physics, James Nearing, 2010, Dover Publications.
5) Mathematical Physics, A.K. Ghatak, I. C. Goyal and S.J. Chua, Laxmi Publications Private Limited (2017).

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

COMMON POOL OF GENERIC ELECTIVES (GE) COURSES

GENERIC ELECTIVE (GE – 4): INTRODUCTION TO ELECTRONICS

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course	Department offering the course
		Lecture	Tutorial	Practical		
INTRODUCTION TO ELECTRONICS GE – 4	4	2	0	2	NIL	Physics and Astrophysics

LEARNING OBJECTIVES

This paper aims to introduce fundamentals of electronics to students not majoring in physics. Basics of Analog and Digital Electronics are envisioned to be introduced with emphasis on applications of diodes, transistor (BJT), operational amplifier, 555 timer, number systems, basic gates and digital circuits.

LEARNING OUTCOMES

At the end of this course, students will be able to imbibe the following learning outcomes:

- This paper aims to describe the concepts of basic electronics in real-life. In this course, students will receive an introduction to the principle, performance and applications of basic electronic components.
- The students will gain an insight on the existence of analog and digital signals and their necessity. Specifically they would know the difference between active and passive electronic components including filters.
- Students will learn about diodes and its uses in rectification (analog) and switching properties thereof (digital). They will gain an insight into working principle of Photodiodes, Solar Cells, LED and Zener Diode as Voltage Regulator.
- They will gain an understanding of construction and working principle of bipolar junction transistors (BJTs). Specifically, they would understand the fundamentals of amplification.
- Students will be able to seamlessly understand and work on different numbers systems including binary, octal, hexadecimal besides decimal.
- They will learn about the existence of digital gates besides their need in electronic decision making thus laying the foundation for basic artificial intelligence.
- Students will learn the fundamentals of operation amplifier and their regular application including those used to to sum, subtract and compare two or more signals.
- They will gain an in-depth understanding of working of Cathode Ray Oscilloscope which effectively acts as an electronic stethoscope for analysis of electronic signal in any laboratory.
- This paper will essentially connect the text book knowledge with the most common electronic components available that influence design of technology in a real world.
- The project component included in the practical section is envisaged to impart much

needed hands-on skill sets to the student. Therein he/she gets an experience in correctly choosing components required to build an electronic circuit, identifying the procurement source (online/offline) besides gaining valuable experience in trouble-shooting

SYLLABUS OF GE - 4

THEORY COMPONENT

Unit – I **(4 Hours)**

Analog and digital signals, Active and passive electronic components, RC integrator and differentiator (use as low pass and high pass filter): Qualitative analysis and frequency response.

Unit – II **(6 Hours)**

I-V characteristics of a diode and it's applications as rectifier (Half and full wave rectifier configurations), Clipper and Clamper circuits (Qualitative Analysis only). Principle and working of Photodiodes, Solar Cells, LED and Zener Diode as Voltage Regulator.

Unit – III **(4 Hours)**

Input and output characteristics of a bipolar junction transistor (BJT) in CB and CE configurations, identifying active, cut-off and saturation regions. Transistor parameters alpha and beta, and relation between them. Application of BJT as a switch and an amplifier in CE configuration (Graphical Analysis)

Unit – IV **(6 Hours)**

Review of basic and Universal Logic Gates, Binary to decimal and Decimal to binary conversion, binary addition and subtraction using 2's complement, Half and Full Adder, Half and Full Subtractor using NAND Gates.

Unit – V **(6 Hours)**

Operational Amplifier (Black Box Approach): Pinout diagram of IC 741; Characteristics of Op-amp (Voltage Gain, offset voltage, slew rate, CMRR, Bandwidth, Input Impedance and Output Impedance). Open loop configuration and its application as a comparator and zero crossing detector. Closed Loop Configuration and its Applications as Inverting and Non-inverting Amplifier (Voltage gain using concept of virtual ground), Summing Amplifier and Subtractor

Unit – VI **(4 Hours)**

Block diagram of CRO, Voltage and frequency measurement. Pinout diagram of IC 555 and its application as Astable Multivibrator.

References:

Essential Readings:

1) Electronic Devices, Thomas L Floyd; Pearsons Education
2) Op Amps and Linear Integrated Circuits, Ramakant A Gaekwad, Pearson Education
3) Microelectronic circuits, A. S. Sedra, K. C. Smith, A.N. Chandorkar, Oxford University Press.
4) Electronic Principles, A. Malvino, D. J. Bates, 7th Edition, 2018, Tata Mc-Graw Hill Education.

5) Electronic Devices and circuit theory, R. L. Boylestad & L. D. Nashelsky, Pearson Learning
6) Digital Principles and Applications, Donald P Leach, Albert Paul Malvino and Goutam Saha, Pearson Education, Tata Mc-Graw Hill.

Additional Readings:

1) Electronic Fundamental and Applications, John D Ryder; PHI Learning
2) Electronic Devices and Circuits, J. Millman and C. C. Halkias, Tata Mc-Graw Hill.

PRACTICAL COMPONENT

(15 Weeks with 4 hours of laboratory session per week)

Every student must perform either "04 Experiments and 01 Project" or "At least six experiments"

1) Voltage and frequency measurement using CRO
2) Study of RC circuits as an Integrator and Differentiator
3) IV characteristics for pn junction diode and Zener diode
4) Study of Zener diode as voltage regulator circuit
5) Study of transistor characteristics in CE configuration
6) Half Adder and Full Adder using NAND gates
7) Half Subtractor and Full Subtractor using NAND gates
8) Design Astable Multivibrator using IC 555
9) Study the Frequency Response of Op Amp in Inverting and Non Inverting configurations.
10) Study of zero crossing detector using Op amp IC 741
11) Addition of two dc voltages using OP Amp in inverting and non-inverting configurations.

References (for Laboratory Work):

1) An Analog Electronics Companion: Basic Circuit Design for Engineers and Scientists – by Scott Hamilton, Cambridge University Press
2) Practical Electronics – by Ralph Morrison, Wiley
3) Practical Electronic Design for Experimenters (ELECTRONICS) – by Louis E. Frenzel, McGraw Hill Education
4) Practical Electronics for Inventors – by Paul Scherz and Simon Monk, McGraw Hill
5) Analog Electronics with Op-amps: A Source Book of Practical Circuits (Electronics Texts for Engineers and Scientists) – by Anthony Peyton and Vincent Walsh, Cambridge University Press

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

GENERIC ELECTIVE (GE – 5): SOLID STATE PHYSICS

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course	Department offering the course
		Lecture	Tutorial	Practical		
SOLID STATE PHYSICS GE – 5	4	3	1	0	Knowledge of basic physics	Physics and Astrophysics

LEARNING OBJECTIVES

This course introduces the basic concepts and principles required to understand the various properties exhibited by condensed matter, especially solids. It enables the students to appreciate how the interesting and wonderful properties exhibited by matter depend upon its atomic and molecular constituents. It also communicates the importance of solid state physics in modern society. Emphasis should be given on the applications and uses of solids.

LEARNING OUTCOMES

On successful completion of the module students should be able to,

- Elucidate the concept of lattice, basis and symmetry in crystals. Learn to appreciate structure and symmetry of solids.
- Understand the elementary lattice dynamics and its influence on the properties of materials.
- Describe the main features of the physics of electrons in solids: origin of energy bands.
- Introduction to dia-, para-, ferri and ferro-magnetic properties of solids and their applications.
- Introduction to dielectric properties exhibited by solids and the concept of polarizability.
- Introduction to superconductivity.

SYLLABUS OF GE - 5

THEORY COMPONENT

UNIT – I **(21 Hours)**

Review of Atomic Structure and bonding in solids: Classification of matter as solid, liquid and gas: salient features and properties, Qualitative discussion on Rutherford Model and Bohr model of atom, qualitative idea about discrete energy levels, wave-mechanical concept of the atom, forces between atoms, Ionic bonding, covalent bonding, metallic bonding, Hydrogen bonding and Van der Waals bonding, Properties of solids exhibiting different bonding.

Crystal structure: Periodicity in crystals: lattice points and space lattice, translational, rotational and reflection symmetry elements, lattice with a basis and crystal structure, unit cells and lattice parameters, Bravais lattices (in 2D and 3D) and crystal systems SC, BCC and FCC lattices, conventional and primitive unit cell, Wigner Seitz unit cell, amorphous and crystalline materials. Planes, Miller Indices, directions, density of atoms in different planes, interplanar spacing, concept of Reciprocal Lattice, Brillouin Zones (2 D lattice).

Atomic Packing and Imperfections in crystals: Packing of spheres in 2D and 3D, hexagonal close packing, packing fraction of SC, FCC, and BCC. Point defects and line defects and their consequences on the crystal properties
X-rays: Their generation and properties, Bragg's law and Laue Condition, single crystal method and powder diffraction method, simple problems related to X-Ray diffraction in SC, BCC, FCC.

UNIT – II **(4 Hours)**
Elementary Lattice Dynamics: Lattice vibrations and phonons: linear monoatomic and diatomic chains, acoustic and optical phonons, qualitative description of the phonon spectrum in solids.

UNIT – III **(10 Hours)**
Electrical properties of metals: Free electron theory of metals (Drude model), its success and drawbacks, concept of relaxation time, collision time and mean free path, electrical conductivity, mobility and Ohm's law, thermal conductivity of metals, Wiedemann-Franz-Lorentz law.
Band Theory: The Kronig-Penney model (Qualitative idea), Band Gap, direct and indirect bandgap, concept of effective mass, Hall Effect (Metal and Semiconductor).
Optical properties of solids: (Qualitative) Absorption process, transmission and reflectance in solids. Discussion on photoconductivity, photoluminescence.

UNIT – IV **(3 Hours)**
Magnetic Properties of solids: Dia-, Para-, Ferri- and Ferro- magnetic Materials, definition in terms of susceptibility.Weiss's Theory of FerromagnetismandFerromagnetic Domains (qualitative treatment only),B-H curve, soft and hard material and their applications(discussion only) as cores in generators, transformers and electromagnets, energy lossin Hysteresis curve.

UNIT – V **(4 Hours)**
Dielectric Properties of solids: Dipole moment, polarization,local electric field in solids. Depolarization field, electric susceptibility, various sources of polarizability,piezo-, pyro- and ferroelectric materials and their applications(discussion only) as transducers, pickups, sensors, actuators, delay lines.

UNIT – VI **(3 Hours)**
Superconductivity: (Qualitative treatment only) Experimental Results. Critical Temperature. Critical magnetic field.Meissner effect. Type I and type II Superconductors, applications of superconductors. Discussion on applications in MRI, particle collider, power transmission, magnetic levitation etc.

References:
Essential Readings:

1) Solid State Physics, M. A. Wahab, 2015, 3rd Ed,Narosa Publications.
2) Solid State Physics, S. O. Pillai, New Age International Publishers
3) Introduction to Solid State Physics, Charles Kittel, 8thEd., 2004, Wiley India Pvt. Ltd.
4) Elements of Solid State Physics, J. P. Srivastava, 2ndEd., 2006, Prentice-Hall of India.
5) Solid State Physics, A. J. Dekker, 2008, Macmillan Education.

Additional Readings:

1) Introduction to Solids, Leonid V. Azaroff, 2004, Tata Mc-Graw Hill.
2) Solid State Physics, N.W. Ashcroft and N.D. Mermin, 1976, Cengage Learning.
3) Elementary Solid State Physics, M.Ali Omar, 2006, Pearson
4) Solid State Physics, Rita John, 2014, McGraw Hill
5) Superconductivity: A Very short Introduction – Stephen J Blundell - Audiobook

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

GENERIC ELECTIVE (GE – 7): BIOLOGICAL PHYSICS

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course	Department offering the course
		Lecture	Tutorial	Practical		
BIOLOGICAL PHYSICS GE – 7	4	3	1	0	--	Physics and Astrophysics

LEARNING OBJECTIVES

This course familiarizes the students with the basic facts and ideas of biology from a quantitative perspective. It shows them how ideas and methods of physics enrich our understanding of biological systems at diverse length and time scales. The course also gives them a flavour of the interface between biology, chemistry, physics and mathematics.

LEARNING OUTCOMES

After completing this course, students will

- Know basic facts about biological systems, including single cells, multicellular organisms and ecosystems from a quantitative perspective.
- Gain familiarity with various biological processes at different length and time scales, including molecular processes, organism level processes and evolution.
- Appreciate how fundamental principles of physics can be applied to gain an understanding of biological systems.
- Get exposure to complexity of life at i) the level of cell, ii) level of multi cellular organism and iii) at macroscopic system – ecosystem and biosphere.
- Gain a systems level perspective on organisms and appreciate how networks of interactions of many components give rise to complex behaviour.
- Perform mathematical modelling of certain aspects of living systems.
- Get exposure to models of evolution.

SYLLABUS OF GE 7

THEORY COMPONENT

Unit – I **(4 Hours)**

Overview: The boundary, interior and exterior environment of living cells. Processes: exchange of matter and energy with environment, metabolism, maintenance, reproduction, evolution. Self-replication as a distinct property of biological systems. Time scales and spatial scales.

Unit - II **(12 Hours)**

Molecules of life: Metabolites, proteins and nucleic acids. Their sizes, types and roles in structures and processes. Transport, energy storage, membrane formation, catalysis, replication, transcription, translation, signaling. Typical populations of molecules of various types present in cells, their rates of production and turnover. Energy required to make a bacterial cell. Simplified mathematical models of transcription and translation.

Unit - III **(12 Hours)**

Molecular motion in cells: Random walks and applications to biology: Diffusion; models of macromolecules. Molecular motors: Transport along microtubules. Flagellar motion: bacterial chemotaxis.

Unit - IV **(12 Hours)**

The complexity of life: At the level of a cell: Intracellular biochemical networks. Dynamics of metabolic networks; the stoichiometric matrix. The implausibility of life based on a simplified probability estimate, and the origin of life problem. At the level of a multicellular organism: Numbers and types of cells in multicellular organisms. Cellular differentiation and development. Brain structure: neurons and neural networks. At the level of an ecosystem and the biosphere: Foodwebs. Feedback cycles and self-sustaining ecosystems. Allometric scaling laws.

Unit - V **(5 Hours)**

Evolution: The mechanism of evolution: variation at the molecular level, selection at the level of the organism. Models of evolution.

References:

Essential Readings:

1) Biological Physics: Energy, Information, Life; Philip Nelson (W H Freeman & Co, NY, 2004)
2) Cell Biology by the Numbers; Ron Milo and Rob Phillips (Garland Science, Taylor & Francis Group, NY USA and Abingdon UK, 2016)
3) Physical Biology of the Cell (2nd Edition); Rob Phillips et al (Garland Science, Taylor & Francis Group, NY USA and Abingdon UK, 2013)
4) Evolution; M. Ridley (Blackwell Publishers, 2009, 3rd edition).

Additional Readings:

1) Physics in Molecular Biology; Kim Sneppen and Giovanni Zocchi (Cambridge University Press, Cambridge UK, 2005)
2) Biophysics: Searching for Principles; William Bialek (Princeton University Press, Princeton USA, 2012).

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

GENERIC ELECTIVE (GE – 8):

NUMERICAL ANALYSIS AND COMPUTATIONAL PHYSICS

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course	Department offering the course
		Lecture	Tutorial	Practical		
NUMERICAL ANALYSIS AND COMPUTATIONAL PHYSICS GE – 8	4	2	0	2	Differential calculus, Integration and ordinary differential calculus at the class 12 level.	Physics and Astrophysics

LEARNING OBJECTIVES

The emphasis of course is to equip students with the mathematical tools required in solving problem of interest to physicists. To expose students to fundamental computational physics skills and hence enable them to solve a wide range of physics problems.

LEARNING OUTCOMES

After completing this course, student will be able to,

- Develop numerical methods to understand errors and solution of Algebraic and Transcendental equations.
- Understand interpolation, least square fitting, Numerical differentiation, Numerical integration and solution of ordinary differential equations.
- In the laboratory course, the students will learn to,
    - apply appropriate numerical method to solve selected physics problems using user defined and inbuilt functions.
    - solve non-linear equations
    - perform least square fitting of the data taken in physics lab by user defined functions.
    - Interpolate a data by polynomial approximations
    - numerically integrate a function and
    - solve first order initial value problems numerically.

SYLLABUS OF GE - 8

THEORY COMPONENT

Unit – I **(8 Hours)**

Errors and iterative Methods: Truncation and Round-off Errors. Floating Point Computation, Overflow and underflow. Single and Double Precision Arithmetic, Iterative Methods. Review of Taylor’s Theorem and Mean value Theorem (No proofs).

Solutions of Algebraic and Transcendental Equations: Bisection method, Secant Method, Newton Raphson method. Comparison and error estimation

Unit – II **(10 Hours)**
Interpolation: Concept of Interpolation, Lagrange Form of interpolating polynomial, Newton's Forward and Backward Differences, Newton's Forward and Backward Interpolation Formulas.
Regression: Algorithm for Least square fitting of a straight line, Fitting a Power function, and Exponential Function using conversion to linear relation by transforming the variables.

Unit – III **(7 Hours)**
Numerical Differentiation: Approximating the derivative of a function given in the form of discrete data, Numerical Computation of First and second order derivative of a function given in closed form (using Taylor's expansion) , errors in Numerical Differentiation.
Numerical Integration: Newton Cotes Quadrature methods for evaluation of definite integrals numerically, Trapezoidal Rule, Simpson's 1/3 and 3/8 Rules. Derivation of composite formulae for these methods and discussion of error estimation.

Unit – IV **(5 Hours)**
Solution of Ordinary Differential Equations: First Order ODE's: solution of Initial Value problems: (1) Euler's Method and (2) Runge Kutta methods

References:
Essential Readings:

1) Elementary Numerical Analysis, K. E. Atkinson, 3rd Edn., Wiley India Edition (2007)
2) Introduction to Numerical Analysis, S. S. Sastry, 5th Edn. PHI Learning Pvt. Ltd.(2012)
3) Computational Physics, Darren Walker, 1st Edn., Scientific International Pvt. Ltd (2015).
4) Applied numerical analysis, Cutis F. Gerald and P. O. Wheatley, Pearson Education, India (2007).

Additional Readings:

1) An Introduction to Computational Physics, T. Pang, Cambridge University Press (2010).
2) Numerical Recipes: The art of scientific computing, William H. Press, Saul A. Teukolsky and William Vetterling, Cambridge University Press; 3rd edition (2007)
3) Computational Problems for Physics, R.H. Landau and M.J. Páez, CRC Press (2018).

PRACTICAL COMPONENT

(15 Weeks with 4 hours of laboratory session per week)

The aim of this lab is not just to teach computer programming and numerical analysis but to emphasize its role in solving problems in Physics.

- The course will consist of practical sessions and lectures on Python.
- Assessment is to be done not only on the programming but also on the basis of formulating the problem.
- The list of recommended programs is suggestive only. Students should be encouraged to do more physics applications. Emphasis should be given to formulate a physics problem as mathematical one and solve by computational methods.

- At least 6 programs must be attempted (taking at least one from each unit).

Unit I

Basic Elements of Python: The Python interpreter, the print statement, comments, Python as simple calculator, objects and expressions, variables (numeric, character and sequence types) and assignments, mathematical operators. Strings, Lists, Tuples and Dictionaries, type conversions, input statement, list methods. List mutability, formatting in the print statement
Control Structures: Conditional operations, *if, if-else, if-elif-else, while* and *for* Loops, indentation, break and continue, List comprehension. Simple programs for practice like solving quadratic equations, temperature conversion etc.
Functions: Inbuilt functions, user-defined functions, local and global variables, passing functions, modules, importing modules, math module, making new modules. Writing functions to perform simple operations like finding largest of three numbers, listing prime numbers, etc. Generating pseudo random numbers

Recommended List of Programs
(a) Make a function that takes a number *N* as input and returns the value of factorial of *N*. Use this function to print the number of ways a set of *m* red and *n* blue balls can be arranged.
(b) Generate random numbers (integers and floats) in a given range and calculate area and volume of regular shapes with random dimensions.
(c) Generate data for coordinates of a projectile and plot the trajectory. Determine the range, maximum height and time of flight for a projectile motion.

Unit II

NumPy Fundamentals: Importing *Numpy*, Difference between List and NumPy array, Adding, removing and sorting elements, creating arrays using *ones(), zeros(), random(), arange(), linspace()*. Basic array operations (*sum, max, min, mean, variance*), 2-d arrays, matrix operations, reshaping and transposing arrays, savetxt() and loadtxt().
Plotting with Matplotlib: *matplotlib.pyplot* functions, Plotting of functions given in closed form as well as in the form of discrete data and making histograms.

Recommended List of Programs
(a) Given a function in closed form y=f(x), generate numpy arrays for x and y and plot y as a function of x with appropriate scale and legend.
(b) Generate data for coordinates of a projectile and plot the trajectory.
(c) Given the expressions in closed form, plot the displacement-time and velocity-time graph for the un-damped, under damped critically damped and over damped oscillator.

Unit III

Root Finding
a) Determine the depth up to which a spherical homogeneous object of given radius and density will sink into a fluid of given density.
b) Solve transcendental equations like $\alpha = \tan(\alpha)$.
c) To approximate nth root of a number up to a given number of significant digits.

Unit IV

Least Square fitting
Make function for least square fitting, use it for fitting given data (*x,y*) and estimate the parameters *a, b* as well as uncertainties in the parameters for the following cases:

a) Linear ($y = ax + b$)
b) Power law ($y = ax^b$)
c) Exponential ($y = ae^{bx}$)

Interpolation:
(a) Write program to determine the unique polynomial of a degree n that agrees with a given set of $(n+1)$ data points (x_i, y_i) and use this polynomial to find the value of y at a value of x not included in the data.
(b) Generate a tabulated data containing a given number of values $(x_i, f(x_i))$ of a function f(x) and use it to interpolate at a value of x not used in table.

Unit V
Numerical Differentiation
a) Given displacement at equidistant time values, calculate velocity and acceleration and plot them.
b) Compute the left, right and central approximations for derivative of a function given in closed form. Plot both the function and derivative (forward, backward and central derivatives) on the same graph. Plot the error as a function of step size on a log-log graph , study the behaviour of the plot as step size decreases and hence discuss the effect of round off error.

Numerical Integration:
a) Given acceleration at equidistant time values, calculate position and velocity and plot them.
b) Use integral definition of ln(x) to compute and plot ln(x) in a given range. Use trapezoidal and Simpson methods and compare the results.
c) Verify the rate of convergence of the composite Trapezoidal and Simpson methods by approximating the value of a given definite integral.

References
1) Documentation at the Python home page (https://docs.python.org/3/) and the tutorials there (https://docs.python.org/3/tutorial/).
2) Documentation of NumPy and Matplotlib : https://numpy.org/doc/stable/user/ and https://matplotlib.org/stable/tutorials/
3) Computational Physics, Darren Walker, 1st Edn., Scientific International Pvt. Ltd (2015).
4) Introduction to Numerical Analysis, S. S. Sastry, 5th Edn., PHI Learning Pvt. Ltd (2012).
5) Elementary Numerical Analysis, K. E. Atkinson, 3rd Edn., Wiley India Edition(2007)
6) Applied numerical analysis, Cutis F. Gerald and P. O. Wheatley, Pearson Education, India (2007).

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

GENERIC ELECTIVE (GE – 9): APPLIED DYNAMICS

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course	Department offering the course
		Lecture	Tutorial	Practical		
APPLIED DYNAMICS GE – 9	4	3	1	0	--	Physics and Astrophysics

LEARNING OBJECTIVES

This course introduces the main topics of low-dimensional nonlinear systems, with applications to a wide variety of disciplines, including physics, engineering, mathematics, chemistry, and biology. This course begins with the first order dynamical system and the idea of phase space, flows and trajectories and ends with the elementary fluid dynamics. The nature of the subject demands that the tutorials should include only computational problems.

LEARNING OUTCOMES

Upon successful course completion, a student will be able to:

- Demonstrate understanding of the concepts that underlay the study of dynamical systems.
- Learn various forms of dynamics and different routes to chaos.
- Understand basic Physics of fluids and its dynamics

SYLLABUS OF GE 9

THEORY COMPONENT

Unit – I **(22 Hours)**

Introduction to Dynamical systems: Definition of a continuous first order dynamical system. The idea of phase space, flows and trajectories. Concept of stability and un-stability. Simple mechanical systems as first order dynamical systems: simple and damped harmonic oscillator. Fixed points, attractors, stability of fixed points, basin of attraction, notion of qualitative analysis of dynamical systems. Examples of dynamical systems – Population models e.g. exponential growth and decay, logistic growth, predator-prey dynamics.

Unit – II **(16 Hours)**

Introduction to Chaos: Bifurcations: Saddle-Node bifurcation, Transcritical bifurcation, Pitchfork bifurcation and Hopf bifurcation. Chaos in nonlinear equations: Logistic map and Lorenz equations. Sensitivity to initial states. Parameter dependence: steady, periodic and chaotic states. Cobweb iteration. Simple examples from physics, chemistry, engineering and lifesciences.

Unit – III **(7 Hours)**

Elementary Fluid Dynamics: Basic physics of fluids: The continuum hypothesis-concept of fluid element or fluid parcel; Definition of a fluid- shear stress; Fluid properties- viscosity, thermal conductivity, mass diffusivity and equation of state.

References:

Essential Readings:

1) Nonlinear Dynamics and Chaos, S. H. Strogatz, Westview Press, 2nd edition, 2014
2) Understanding Nonlinear Dynamics, Daniel Kaplan and Leon Glass, Springer New York, 1995.
3) Nonlinear Dynamics: Integrability, Chaos and Patterns, M. Lakshmanan and S. Rajasekar, Springer, 2003.
4) An Introduction to Fluid Dynamics, G..K. Batchelor, Cambridge University Press, 2002.
5) Fluid Mechanics, 2nd Edition, L. D. Landau and E. M. Lifshitz, Pergamon Press, Oxford, 1987.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.

INDEX
DEPARTMENT OF PHYSICS AND ASTROPHYSICS
Semester-IV

B. SC. (HONOURS) PHYSICS

DISCIPLINE SPECIFIC CORE COURSE – DSC -10: MODERN PHYSICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Modern Physics DSC – 10	**4**	**3**	**0**	**1**	Appeared in Semester 3	DSC Light and Matter of this course or its equivalent

LEARNING OBJECTIVES

This course introduces modern development in Physics. Starting from Planck's law, it develops the idea of probability interpretation and then discusses the formulation of Schrodinger equation and its applications to step potential and rectangular potential problems. This paper aims to provide knowledge about atomic physics, hydrogen atoms and X-rays. This paper covers the in depth knowledge of lasers, its principle and working. It also introduces concepts of nuclear physics and accelerators.

LEARNING OUTCOMES

After getting exposure to this course, the following topics would be learnt.

- Main aspects of the inadequacies of classical mechanics as well as understanding of the historical development of quantum mechanics. Heisenberg's Uncertainty principle and its applications, photoelectric effect and Compton scattering.
- The Schrodinger equation in 1-dimension, wave function, probability and probability current densities, normalization, conditions for physical acceptability of wave functions, position and momentum operators and their expectation values,Commutator of position and momentum operators.
- Time independent Schrodinger equation, derivation by separation of variables, wave packets, particle in a box problem, energy levels. Reflection and transmission across a step and rectangular potential barrier.
- Modification in Bohr's quantum model: Sommerfeld theory of elliptical orbits
- Hydrogen atom energy levels and spectra emission and absorption spectra.
- X-rays: their production and spectra: continuous and characteristic X-rays, Moseley Law.
- Lasers and their working principle, spontaneous and stimulated emissions and absorption, Einstein's A and B coefficients, Metastable states, components of a laser and lasing action in He-Ne lasers and free electron laser.
- Basic properties of nuclei, nuclear binding energy, semi-empirical mass formula, nuclear force and meson theory. Radioactivity.
- Types of Accelerators, Van-de Graaff generator linear accelerator, cyclotron.

SYLLABUS OF DSC – 10

THEORY COMPONENT

Unit – I **(9 Hours)**

Origin of Quantum Theory: Black body radiation and failure of classical theory, Planck's quantum hypothesis, Planck's radiation law, quantitative treatment of photo-electric effect and Compton scattering, Heisenberg's uncertainty principle, Gamma ray microscope thought experiment, position - momentum uncertainty, consequences of uncertainty principle.

Unit – II **(9 Hours)**

The Schrodinger Equation: The Schrodinger equation in one dimension, statistical interpretation of wave function, probability and probability current densities. Normalization, conditions for physical acceptability of wave functions with examples, position and momentum operators and their expectation values. Commutator of position and momentum operators

Unit – III **(9Hours)**

Time Independent Schrodinger Equation: Demonstration of separation of variable method for time independent Schrodinger equation: Free particle wave function, wave packets, application to energy eigen values and stationary states for particle in a box problem. Reflection and transmission across a step and rectangular potential barrier

Unit - IV **(9Hours)**

Atomic Physics: Beyond the Bohr's Quantum Model: Sommerfeld theory of elliptical orbits; Hydrogen atom energy levels and spectra, emission and absorption spectra; Correspondence principle; X-rays: Method of production, Continuous and Characteristic X-rays, Moseley's law.

Lasers: Lifetime of excited states, natural and Doppler width of spectral lines, emission (spontaneous and stimulated) and absorption processes, Einstein's A and B coefficients, principle of detailed balancing, metastable states, components of a laser and lasing action, working principle of a 4 level laser, e.g. He-Ne lasers; qualitative idea of X-ray free electron lasers.

Unit - V **(9Hours)**

Basic Properties of Nuclei: Introduction (notation, a basic idea about nuclear size, mass, angular momentum, spin, parity, isospin), N-Z graph, nuclear binding energy, semi-empirical mass formula, and basic idea about the nuclear force and meson theory.

Radioactivity: Law of radioactivity and secular equilibrium.

Accelerators: Accelerator facility available in India: Van-de Graaff generator (Tandem accelerator), linear accelerator, cyclotron(principle, construction, working, advantages and disadvantages), discovery of new elements of the periodic table

References:

Essential Readings:

1) Concepts of Modern Physics, A. Beiser, 2002, McGraw-Hill.
2) Modern Physics, R. A. Serway, C. J. Moses and C. A. Moyer, 2012, Thomson Brooks Cole, Cengage.
3) Schaum's Outline of Modern Physics, R. Gautreau and W. Savin, 2020, McGraw Hill LLC

4) Modern Physics for Scientists and Engineers, S. T. Thornton Rex, 4th edition, 2013, Cengage Learning.
5) Introduction to Modern Physics, F.K. Richtmyer, E.H. Kennard and J. N. Cooper, 2002, Tata McGraw Hill.
6) Physics for scientists and Engineers with Modern Physics, Jewett and Serway, 2010.
7) Learning Modern Physics, G. Kaur and G.R. Pickrell, 2014, McGraw Hill.
8) Modern Physics, R. Murugeshan, S Chand & Co. Ltd.
9) Schaum's Outline of Beginning Physics II | Waves, electromagnetism, Optics and Modern Physics, Alvin Halpern, Erich Erlbach, McGraw Hill.
10) Theory and Problems of Modern Physics, Schaum's outline, R. Gautreau and W. Savin, 2nd edition, Tata McGraw-Hill Publishing Co. Ltd.
11) Quantum Physics, Berkeley Physics, Vol.4. E. H. Wichman, 1971, Tata McGraw-Hill
12) Quantum Mechanics: Theory and Applications, A. Ghatak and S. Lokanathan, 2004, Macmillan Publishers India Limited.
13) Introduction to Quantum Mechanics, D. J. Griffith, 2005, Pearson Education.
14) Concepts of nuclear physics, B. Cohen, 2003, McGraw-Hill Education.
15) Atomic Physics, Ghoshal, 2019, S. Chand Publishing House.
16) Atomic Physics, J. B. Rajam& foreword by Louis De Broglie, 2010, (S. Chand & Co.
17) Nuclear Physics, S. N. Ghoshal, S. Chand Publishers.
18) Physics of Atoms and Molecules, B. H. Bransden and C. J. Jochain, 2nd edition, Pearson
19) Atomic and Molecular Physics, Rajkumar, RBSA Publishers.
20) Atoms, Molecules and Photons, W. Demtroder, 2nd edition, 2010, Springer.
21) Introducing Nuclear Physics, K. S. Krane, 2008, Wiley India.

Additional Readings:

1) Basic Atomic & Molecular Spectroscopy, J. M. Hollas (Royal Society of Chemistry)
2) Molecular Spectra and Molecular Structure, G. Herzberg.
3) Basic Ideas and Concepts in Nuclear Physics: An Introductory Approach (Series in Fundamental and Applied Nuclear Physics), K. Heyde (Institute of Physics Publishing Third Edition.
4) Nuclear Physics: Principles and applications, J. Lilley, 2006, Wiley.
5) Schaum's Outline of Modern Physics, 1999, McGraw-Hill Education.
6) Atomic and molecular Physics, R. Kumar, 2013, Campus Book Int.
7) The Fundamentals of Atomic and Molecular Physics (Undergraduate Lecture Notes in Physics), 2013, Springer.
8) Six Ideas that Shaped Physics: Particles Behave like Waves, T. A. Moore, 2003, McGraw Hill.
9) Thirty years that shook physics: The story of quantum theory, G. Gamow, Garden City, NY: Doubleday, 1966.

PRACTICAL COMPONENT

(15 Weeks with 2 hours of laboratory session per week)

Mandatory activity:

- Sessions on the review of experimental data analysis, sources of error and their estimation in detail, writing of scientific laboratory reports including proper reporting of errors.
- Application to the specific experiments done in the lab
- Familiarization with Schuster`s focusing; determination of angle of prism.

At least five experiments to be performed from the following list

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 material of filament of directly heated vacuum diode.
4) To determine the Planck's constant using LEDs of at least 4 different colours.
5) To determine the wavelength of the H-alpha emission line of Hydrogen atoms.
6) To determine the ionization potential of mercury.
7) To determine the value of e/m by (a) Magnetic focusing or (b) Bar magnet.
8) To show the tunneling effect in tunnel diodes using I-V characteristics.
9) One innovative experiment designed by the teacher relevant to the syllabus.

References for laboratory work:

1) Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
2) A Text Book of Practical Physics, I. Prakash and Ramakrishna, 11th edition, 2011, KitabMahal.
3) Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th edition, reprinted, 1985, Heinemann Educational Publishers.
4) A Laboratory Manual of Physics for Undergraduate Classes, D. P. Khandelwal, 1985, Vani Publisher.
5) B.Sc. Practical Physics, H. Singh, S. Chand & Co Ltd.
6) B.Sc. Practical Physics, G. Sanon, R.Chand and Co.

DISCIPLINE SPECIFIC CORE COURSE – DSC - 11: SOLID STATE PHYSICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Solid State Physics DSC – 11	**4**	**3**	**0**	**1**	Appeared in Semester 3	Basic understanding of thermal physics, electricity and magnetism

LEARNING OBJECTIVES

This course introduces the basic concepts and principles required to understand the various properties exhibited by condensed matter, especially solids. It enables the students to appreciate how the interesting and wonderful properties exhibited by matter depend upon the arrangement of its atomic and molecular constituents. The gained knowledge helps to solve problems in solid state physics using relevant mathematical tools. It also communicates the importance of solid state physics in modern society.

LEARNING OUTCOMES

On successful completion of the module students should be able to,

- Elucidate the concept of lattice, crystals and symmetry operations
- Understand elementary lattice dynamics and its influence on the properties of materials
- Describe the origin of energy bands, and their influence on electronic behaviour
- Explain the origin of dia-, para-, and ferro-magnetic properties of solids
- Explain the origin of the dielectric properties exhibited by solids and the concept of polarizability
- Understand the basics of superconductivity
- In the laboratory students will carry out experiments based on the theory that they have learned to measure the magnetic susceptibility, dielectric constant, trace hysteresis loop. They will also employ to four probe methods to measure electrical conductivity and the hall set up to determine the hall coefficient of a semiconductor

SYLLABUS OF DSC - 11

THEORY COMPONENT

Unit – I - Crystal Structure (10 Hours)

Classification of solids as amorphous and crystalline materials,basic understanding of bonding in crystals, closed packed structure and packing fractions,lattice translation vectors,lattice with a basis,types of lattices,unit cell, symmetry elements,crystal planes and Miller indices,reciprocal lattice and Ewald'sconstruction (geometrical),Brillouin Zones, Diffraction of X-rays: single crystal and powder method. Bragg's Law

Unit – II - Elementary band theory **(6 Hours)**
Brief discussion on free electron model, success and failure of free electron model, Kronig-Penney model, band gap, direct and indirect bandgap, effective mass, concept of mobility, Hall effect (Semiconductor).

Unit – III - Elementary Lattice Dynamics **(10 Hours)**
Lattice Vibrations and Phonons: Linear monoatomic and diatomic chains,acoustic and optical phonons,Dulong and Petit's Law, Einstein and Debye theories of specific heat of solids. T^3 law

Unit – IV - Magnetic Properties of Matter **(9 Hours)**
Dia-, Para-, Ferri- and Ferromagnetic Materials, Classical Langevin Theory of dia– and para-magnetism, Weiss's Theory of Ferromagnetism and Ferromagnetic Domains, Curie's law, B-H Curve,hysteresis and energy loss, soft and hard material

Unit – V - Dielectric Properties of Materials **(7 Hours)**
Polarization,local electric field in solids,depolarization field,electric susceptibility,polarizability,ClausiusMossottiequation,classical theory of electronic polarizability, AC electronic polarizability,normal and anomalous dispersion,complex dielectric constant,basic idea of ferroelectricity and PE Hysteresis loop.

Unit – VI – Superconductivity **(3 Hours)**
Experimental results,critical temperature,critical magnetic field,Meissner effect, Type I and type II superconductors

References:

Essential Readings:

1) Introduction to Solid State Physics, Charles Kittel, 8th edition, 2004, Wiley India Pvt. Ltd.
2) Elements of Solid State Physics, J. P. Srivastava, 2nd edition, 2006, Prentice-Hall of India.
3) Introduction to Solids, Leonid V. Azaroff, 2004, Tata Mc-Graw Hill.
4) Solid State Physics, N. W. Ashcroft and N. D. Mermin, 1976, Cengage Learning.
5) Solid-state Physics, H. Ibach and H. Luth, 2009, Springer

Additional Readings:

1) Elementary Solid State Physics, M. Ali Omar, 2006, Pearson
2) Solid State Physics, R. John, 2014, McGraw Hill
3) Solid State Physics, M. A. Wahab, 2011, Narosa Publications

PRACTICAL COMPONENT

(15 Weeks with 2 hours of laboratory session per week)

- Sessions on the construction and use of specific measurement instruments and experimental apparatus used in the solid state physics laboratory, including necessary precautions.
- Sessions on the review of experimental data analysis, sources of error and their estimation in detail, writing of scientific laboratory reports including proper reporting of errors.
- Application to the specific experiments done in the laboratory.

At least four experiments to be performed from the following list

1) Measurement of susceptibility of paramagnetic solution (Quinck'stube method).
2) To measure the magnetic susceptibility of solids.
3) To study the dielectric constant of a material/s (solid/liquid) as a function of temperature and frequency.
4) To determine the complex dielectric constant and plasma frequency of a metal using Surface Plasmon Resonance (SPR) technique.
5) To determine the refractive index of a dielectric material using SPR technique.
6) To study the PE Hysteresis loop of a ferroelectric crystal.
7) To draw the BH curve of iron (Fe) using solenoid anddetermine the energy loss from hysteresis loop.
8) To measure the resistivity of a semiconductor (Ge) with temperature (up to 150^oC) by four-probe method and determine its band gap.
9) To determine the Hall coefficient of a semiconductor sample.
10) Analysis of X-ray diffraction data in terms of unit cell parameters and estimation of particle size.
11) To study magnetoresistance in a semiconductor with magnetic field

References for laboratory work:

1) Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.
2) A Text Book of Practical Physics, I. Prakashand Ramakrishna, 11^{th} edition, 2011, KitabMahal
3) Elements of Solid State Physics, J. P. Srivastava, 2^{nd} edition, 2006, Prentice-Hall of India
4) Practical Physics, G. L. Squires, 4^{th} edition, 2015, Cambridge University Press.
5) Practical Physics, C. L.Arora,19^{th} edition, 2015,S. Chand

DISCIPLINE SPECIFIC CORE COURSE – DSC - 12: ANALOG ELECTRONICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Analog Electronics DSC – 12	**4**	**2**	**0**	**2**	Appeared in Semester 3	--

LEARNING OBJECTIVES

This course introduces the concept of semiconductor devices and their analog applications. It also emphasizes on understanding of amplifiers, oscillators, operational amplifier and their applications.

LEARNING OUTCOMES

At the end of this course, the following concepts will be learnt.

- To learn about diodes and its uses in rectification
- To gain an insight into working principle of photodiodes, solar cells, LED and zenerdiode as voltage regulator
- To gain an understanding of construction and working principle of bipolar junction transistors (BJTs), characteristics of different configurations, biasing and analysis of transistor amplifier
- To be able to design and understand use of different types of oscillators
- To learn the fundamentals of operation amplifiers and understand their operations to compare, add, or subtract two or more signals and to differentiate or integrate signals etc.

In the laboratory course, the students will be able to study characteristics of various diodes and BJT. They will be able to design amplifiers, and oscillators. Also different applications using Op-Amp will be designed.

SYLLABUS OF DSC - 12

THEORY COMPONENT

Unit – I - Two-terminal devices and their applications **(5 Hours)**

IV characteristics of a diode and its application as rectifier (half-wave and full wave rectifier), IV characteristics of a zener diode and its use as voltage regulator, principle, structure and characteristics of (1) LED, (2) Photodiode and (3) Solar Cell

Unit – II - Bipolar junction transistors **(4 Hours)**

n-p-n and p-n-p transistors, IV characteristics of CB and CE configurations,active, cut-off and saturation regions, current gains α and β, relations between α and β, physical mechanism of current flow

Unit – III – Amplifiers and sinusoidal oscillators **(11 Hours)**

Load line analysis of transistor, DC load line and Q-point,fixed bias and voltage divider bias,

transistor as 2-port network, h-parameter equivalent circuit of a transistor, analysis of a single-stage CE amplifier using hybrid model (input and output impedance,current and voltage gain)
Sinusoidal Oscillators: General idea of positive and negative feedback,Barkhausen'scriterion for self-sustained oscillations, RC phase shift oscillator, determination of frequency, Hartley and Colpitts oscillators

Unit – IV - Operational Amplifiers (Black Box approach) (10 Hours)
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 Op-Amps: (1) Inverting and non-inverting amplifiers, (2) Adder, (3) Subtractor, (4) Differentiator, (5) Integrator, (6) Comparator and Zero crossing detector (7) Wein bridge oscillator

References:
Essential Readings:

1) Integrated Electronics, J. Millman and C.C. Halkias, 1991, Tata Mc-Graw Hill
2) Electronics: Fundamentals and Applications, J. D. Ryder, 2004, Prentice Hall
3) Linear Integrated Circuit, R. A. Gayakwad, 4thedition, 2000, Prentice Hall
4) Microelectronic circuits, A.S. Sedra, K.C. Smith and A.N. Chandorkar, 6th edition, 2014, Oxford University Press.
5) Semiconductor Devices: Physics and Technology, S.M. Sze, 2nd edition, 2002, Wiley India
6) Electronic Principles, A. Malvino, D.J. Bates, 7th edition, 2018, Tata Mc-Graw Hill Education.
7) Electronic Devices and circuit Theory, R.L. Boylestadand L.D. Nashelsky, 2009, Pearson

Additional Readings:

1) Learning Electronic Devices and circuits, S.Salivahananand N.S.Kumar, 3rd edition, 2012, Tata Mc-Graw Hill
2) Microelectronic Circuits, M.H. Rashid, 2nd edition, Cengage Learning
3) Microelectronic Devices and Circuits, D. A.Bell, 5th edition,2015, Oxford University Press
4) Basic Electronics: Principles and Applications, C. Saha, A. Halder and D. Ganguli, 1stedition, 2018, Cambridge University Press
5) Solid State Electronic Devices, B.G.Streetmanand S.K.Banerjee, 6th edition,2009, PHI

PRACTICAL COMPONENT

(15 Weeks with 4 hours of laboratory session per week)

- Session on the construction and use of specific analogue devices and experimental apparatuses used in the lab, including necessary precautions
- Sessions on the review of experimental data analysis, sources of error and their estimation in detail, writing of scientific laboratory reports including proper reporting of errors.
- Application to the specific experiments done in the lab.

At least six experiments to be performed from the following list

1) To study the V-I characteristics of a Zener diode and its use as voltage regulator.

2) Study of V-I and power curves of solar cells, and find maximum power point and efficiency.
3) Tostudy the characteristics of a Bipolar Junction Transistor in CE configuration.
4) To design a CE transistor amplifier of a given gain (mid-gain) using voltage divider bias.
5) To design a Wien bridge oscillator for given frequency using an op-amp.
6) To design an inverting amplifier using Op-amp (741, 351) for dc voltage of given gain
7) To design inverting amplifier using Op-amp (741, 351) and study its frequency response
8) To design non-inverting amplifier using Op-amp (741, 351) and study frequency response
9) To add two dc voltages using Op-amp in inverting and non-inverting mode
10) To study the zero-crossing detector and comparator
11) To investigate the use of an op-amp as an integrator
12) To investigate the use of an op-amp as a differentiator.

References for laboratory work:

1) Basic Electronics: A text lab manual, P. B. Zbar, A. P. Malvino and M. A. Miller, 1994, Mc- Graw Hill
2) Student Manual for The Art of Electronics, T. C. Hayes and P. Horowitz

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 3: ADVANCED MATHEMATICAL PHYSICS I

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Advanced Mathematical Physics I DSE – 3	**4**	**4**	**0**	**0**	Appeared in Semester 3	DSC courses of Mathematical Physics I and Mathematical Physics III

LEARNING OBJECTIVES

The objective of the course is to impart the concept of calculus of variation and generalized mathematical constructs in terms of algebraic structures mainly vector spaces. Both concepts are extremely useful in physics, engineering, machine learning, economics and even life sciences and social sciences. While linear algebra studies linear vector spaces, linear transformations, and the matrices, calculus of variation is an important mathematical tool in optimization. This course is intended to provide a solid foundation in both topics as used by physicists and has direct applications in classical and quantum mechanics.

LEARNING OUTCOMES

After completing this course, students will be able to,

- Apply the techniques of calculus of variation to real world problems.
- Solve Euler-Lagrange equations for simple cases.
- Understand algebraic structures in n-dimension and basic properties of the linear vector spaces.
- Understand the concept of dual spaces and inner product spaces.
- Represent linear transformations as matrices and understand basic properties of matrices.
- Determine the eigenvalues and eigenvectors of matrices and diagonalise the matrices.
- Determine orthogonal basis for a vector space using Gram-Schmidt procedure.

SYLLABUS OF DSE - 3

THEORY COMPONENT

Unit – I **(18 Hours)**

Calculus of Variation: Functionals and extrema, Euler's equation for (i) one independent and one dependent variable, (ii) several dependent variables and (iii) several independent variables; Variable end-point problems; Application to problems (e.g. geodesics, catenary, minimum area of soap film, brachistochrone, Fermat's principle, Laplace equation etc.); Generalised coordinates and concept of Lagrangian; Hamilton's principle, Euler-Lagrange's equations of motion and its applications to physics problems (e.g. simple pendulum, one dimensional harmonic oscillator and other problems).

Unit – II **(12 Hours)**

Vector Spaces as Algebraic Structures: Definition and examples of groups, rings, fields and vector spaces;real and complex fields, use of ket notation $|\alpha>$ for vectors; Subspaces, linear combination of vectors, linear dependence and independence of vectors, span of a subset of vectors, bases and dimension of vector space, direct sum of spaces, representation of vectors as column matrix with R^n as example.

Inner Product Spaces: Inner product of vectors ($<\alpha|\beta>$) and norm of a vector, Euclidean spaces and unitary spaces, Cauchy-Schwartz inequality, concept of length and distance, metric spaces. Hilbert Space (definition only);linear functional, dual space, dual basis ($<\alpha|$ notation);Orthogonality of vectors, orthonormal basis, Gram-Schmidt procedure to construct an orthonormal basis.

Unit – III **(18 Hours)**

Linear Transformation: Linear mappings and examples, homomorphism and isomorphism of vector space, rank and nullity of a linear mapping, range space and Kernel (null space) of a linear mapping, non-singular transformations.

Matrices as Representations: Matrix representation of linear transformations, composition of linear transformations and matrix multiplication, linear algebra; Algebra of matrices, determinant and trace of matrix and their properties;Non-singular matrices;Rank of a matrix and invertibility of matrices;direct sum and direct product of matrices.

Change of basis transformation, similar matrices;transpose and adjoint of a linear transformation, self-adjoint operators;symmetric and Hermitian matrices;preservation of norms by orthogonal and unitary transformations.

Unit – IV **(12 Hours)**

Eigen-values and Eigenvectors: Eigen-values and eigen vectors of a transformation and corresponding matrix representation;Cayley-Hamilton theorem (statement only), its applications like inverse and powers of a matrix;Eigensystems of Hermitian and unitary matrices;Diagonalization of matrices; Normal matrices; Simultaneous diagonalizability of two matrices.

Use of matrices in solving coupled linear first order ordinary differential equations with constant coefficients; Minimal polynomial, functions of a matrix.

References:

Essential Readings:

1) Mathematical Methods for Physicists, G.Arfken, H. Weber and F. E. Harris, 7th edition, 2012, Elsevier
2) Applied Mathematics for Engineers and Physicists, L. A. Pipes and L. R. Harvill, 1970, McGraw-Hill Inc
3) Calculus of Variations, I. M. Gelfand and S. V. Fomin, 2000, Dover Publications
4) Introduction to Matrices and Linear Transformations, D. T. Finkbeiner, 2011, Dover Publications
5) Schaum's Outline of Theory and Problems of Linear Algebra, S.Lipschutz and M. Lipson, 2017, McGraw Hill Education
6) Linear Algebra, S. H. Friedberg, A. J. Insel, and L. E. Spence, 2022, Pearson Education

Additional Readings:

1) Elementary Linear Algebra with Supplemental Applications, H. Anton and C.Rorres, 2016, Wiley Student Edition
2) A Physicist's Introduction to Algebraic Structures: Vector Spaces, Groups, Topological

Spaces and More, P. B. Pal, 2019, Cambridge University Press
3) Matrices and Tensors in Physics: A.W. Joshi, 2017, New Age International Pvt. Ltd.
4) An Introduction to Linear Algebra and Tensors, M. A.Akivis, V. V. Goldberg, Richard and Silverman, 2012, Dover Publications
5) Linear Algebra and Applications, D. C. Lay, 2002, Pearson Education India
6) Vector Spaces and Matrices in Physics, M.C. Jain, 2000, Narosa
7) Mathematical Methods for Physics and Engineering, K. F. Riley and M. P. Hobson, 2018, Cambridge University Press

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 4: PHYSICS OF DEVICES

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Physics of Devices DSE – 4	**4**	**2**	**0**	**2**	Appeared in Semester 3	Knowledge of basic electronics concepts.

LEARNING OBJECTIVES

This paper is based on advanced electronics which covers the devices such as UJT, JFET, MOSFET, CMOS etc. Process of IC fabrication is discussed in detail.

LEARNING OUTCOMES

At the end of this course, students will be able to,

- Develop the basic knowledge of semiconductor device physics and electronic circuits along with the practical technological considerations and applications.
- Understand the operation of devices such as UJT, JFET, MOS, various bias circuits of MOSFET, basics of CMOS and charge coupled devices.
- Learn to analyse MOSFET circuits and develop an understanding of MOSFET I-V characteristics and the allowed frequency limits.
- Learn the IC fabrication technology involving the process of diffusion, implantation, oxidation and etching with an emphasis on photolithography and electron-lithography
- Apply concepts for the regulation of power supply by developing an understanding of various kinds of RC filters classified on the basis of allowed range of frequencies.
- Learn to use semiconductordiode as a clipper and clamper circuit

SYLLABUS OF DSE - 4

THEORY COMPONENT

Unit – I **(7 Hours)**

Semiconductors (P and N type), Energy band diagram, Barrier formation in pn junction diode, Derivation of barrier potential and barrier width, storage and depletion capacitances, current flow mechanism in forward and reverse bias junction, current components in a transistor, tunnel diode, metal-semiconductor contacts, Schottky junction and Ohmic junction

Unit – II **(6 Hours)**

Diode as clipper and clamper circuits, RC Filters: Passive-Low pass and High pass filters, Active (1st order Butterworth)-Low Pass, High Pass, Band Pass, and band reject Filters.

Unit – III **(11 Hours)**

Characteristic and small-signal equivalent circuits of UJT and JFET, introduction to metal oxide semiconductor (MOS) device/MOSFET, MOSFET - their frequency limits,enhancement and depletion mode MOSFETS, basic idea of CMOS and charge coupled devices, importance of power devices: power diode, SCR. Construction and I-V characteristics of DIAC and TRIAC.

Unit – IV **(4 Hours)**
(Basic idea) Basic process flow for IC fabrication,diffusion and implantation of dopants,passivation/oxidation technique for Si,contacts and metallization technique,basic idea of thermal evaporation and sputtering techniques, basic idea ofphotolithography, electron-lithography, SSI, MSI, LSI, VLSI and USI.

Unit – V **(2 Hours)**
Basic idea about sensors (gas/fire) and piezoelectric transducer

References:
Essential Readings:

1) Physics of Semiconductor Devices, S.M.Sze and K.K.Ng, 3rd edition 2008, John Wiley and Sons
2) Electronic Devices and Circuits, A. Mottershead, 1998, PHI Learning Pvt. Ltd.
3) Electronic communication systems, G. Kennedy, 1999, Tata McGraw Hill.
4) Integrated Electronics, J. Millman and C.C. Halkias, 1991, Tata Mc-Graw Hill.
5) Electronics: Fundamentals and Applications, J.D. Ryder, 2004, Prentice Hall.
6) Solid State Electronic Devices, B. G. Streetman and S. K. Banerjee, 7th edition
7) Power Electronics, M. D. Singh and K. B. Khanchandani, 2006, Tata Mc-Graw Hill

Additional Readings:

1) Op-Amps and Linear Integrated Circuits, R.A.Gayakwad, 4th edition, 2000, PHI Learning Pvt. Ltd
2) Introduction to Measurements and Instrumentation, A.K.Ghosh, 4th edition, 2017, PHI Learning
3) Semiconductor Physics and Devices, D.A. Neamen, 4th edition, 2011, Tata McGraw Hill

PRACTICAL COMPONENT

(15 Weeks with 4 hours of laboratory session per week)

At least six experiments to be performed from the following list

1) To design the active low pass and high pass filters of given specification.
2) To design the active filter (wide band pass and band reject) of given specification.
3) To study the output and transfer characteristics of a JFET.
4) To design a common source JFET amplifier and study its frequency response.
5) To study the output characteristics of a MOSFET.
6) To study the characteristics of a UJT and design a simple relaxation oscillator.
7) To study diode as clipper circuit.
8) To study diode as a clamper circuit.
9) Pattern the given structure on silicon wafer by wet chemical etching.

Suggested extra experiment:
1) Deposition of metallic thin films using thermal evaporation technique.

2) Preparation of a pn junction and study its IV characteristics.

References for laboratory work:

1) Advanced PC based instrumentation; Concepts and Practice, N. Mathivanan, 2007, Prentice-Hall of India
2) Basic Electronics: A text lab manual, P.B.Zbar, A.P.Malvino, M.A.Miller,1994, Mc-Graw Hill
3) Introduction to PSPICE using ORCAD for circuits and Electronics, M.H.Rashid,2003, PHI Learning.

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 5: PHYSICS OF EARTH

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Physics of Earth DSE – 5	**4**	**4**	**0**	**0**	Appeared in Semester 3	--

LEARNING OBJECTIVES

This course familiarizes the students with the origin of earth in the solar system and various processes occurring in atmosphere, oceans and earth's internal structure.

LEARNING OUTCOMES

At the end of this course student will be able to,

- Have an overview of structure of the earth as well as various dynamical processes occurring on it.
- Develop an understanding of evolution of the earth.
- Apply physical principles of elasticity and elastic wave propagation to understand modern global seismology as a probe of the Earth's internal structure.
- Understand the origin of magnetic field, geodynamics of earthquakes and the description of seismic sources; a simple but fundamental theory of thermal convection; the distinctive rheological behaviour of the upper mantle and its top.
- Explore various roles played by water cycle, carbon cycle, nitrogen cycles in maintaining steady state of earth leading to better understanding of the contemporary dilemmas (climate change, bio diversity loss, population growth, etc.) disturbing the Earth.
- Develop the problem solving skills by adding numerical and simulations to clarify thefundamental concepts.

SYLLABUS OF DSE - 5

THEORY COMPONENT

Unit – I **(10 Hours)**

The Earth and the Universe:

a) General characteristics and origin of the Universe. The Big Bang Theory. Estimation of age of the Universe and Hubble constant. Formation of Galaxies. Types of galaxies, Milky Way galaxy, Nebular hypothesis, Solar system, The Terrestrial and Jovian planets (Sizes, Acceleration due to gravity, Obliquity, Flatness, Eccentricity, Density, Temperature, Pressure, Atmosphere, Moons, Exceptions in trends). Titius-Bode law. Asteroid belt. Asteroids: origin types and examples, Meteorites.

b) Earth in the Solar system, origin, size, shape, mass, density, rotational and revolution parameters and its age. Earth's orbit and spin, the Moon's orbit and spin.

c) Energy and particle fluxes incident on the Earth.

Unit – II **(15 Hours)**

Structure of Earth:

a) The Solid Earth: topography (Maps, Techniques, Forms of Topographic data).
b) Internal structure: Core, mental, magnetic field. Origin of the Magnetic field. Convection in Earth's core and production of its magnetic field. Dynamo Theory, calculation of magnetic fields, Causes of variation of Magnetic Field and Palaeomagnetism.
c) The Hydrosphere: The oceans, their extent, depth, volume, chemical composition. Ocean circulations. Oceanic current system and effect of Coriolis forces.
d) The Cryosphere: Polar caps and ice sheets. Mountain glaciers, permafrost.

Unit – III **(15 Hours)**

Dynamical Processes:

a) The Solid Earth: Concept of plate tectonics; types of plate movements, hotspots; sea-floor spreading and continental drift.
b) Geodynamic elements of Earth: Mid Oceanic Ridges, trenches, transform faults and island arcs. Continents, mountains and rift valleys.
c) Earthquake and earthquake belts. Types and properties of Seismic waves, Richter scale, geophones.
d) Volcanoes: types, products and distribution.
e) Concepts of eustasy, air-sea interaction; wave erosion and beach processes. Tides. Tsunamis.

Unit – IV **(12 Hours)**

The Atmosphere

a) The Atmosphere: Features of different layers, variation of temperature with altitude; Dry, moist and environmental lapse rate, variation of density and pressure with altitude, Types of clouds and formation.
b) The Atmosphere: Atmospheric circulation. Causes of Atmospheric circulation, Formation of three cells, Easterlies and Westerlies, and ICTZ, Weather and climatic changes. Earth's heat budget. Cyclones and anti-cyclones, tropical storms, hurricanes and tornadoes.
c) Climate: Earth's temperature and greenhouse effect. Paleoclimate and recent climate changes. The Indian monsoon system.

Unit – V **(8 Hours)**

Disturbing the Earth – Contemporary dilemmas

a) Human population growth.
b) Hydrosphere: Fresh water depletion.
c) Geosphere: Chemical effluents, nuclear waste.
d) Biosphere: Biodiversity loss. Deforestation. Robustness and fragility of ecosystems. Water cycle, Carbon cycle. The role of cycles in maintaining a steady state.
e) Air Pollution: Types of air pollutants, Effects on atmosphere and living organisms. Ozone Hole.

References:

Essential Readings:

1) Planetary Surface Processes, H. J.Melosh, 2011, Cambridge University Press.
2) Holme's Principles of Physical Geology, 1992, Chapman &Hall.
3) Planet Earth, Cosmology, Geology and the Evolution of Life and Environment, C. Emiliani, 1992, Cambridge University Press.

4) Physics of the Earth, F. D. Stacey, P. M. Davis, 2008, Cambridge University Press.
5) Environmental Physics: Sustainable Energy and Climate Change, E. Boecker and R.V. Grondelle, 3rd edition, 2011, Wiley, UK
6) Atmospheric Remote Sensing (Principles and Applications, Editors – S. Tiwari and A. K. Singh, Chapter-1 (Composition and thermal structure of the Earth's atmosphere, by S. K. Dhaka and V. Kumar), 1st edition, Elsevier

Additional Readings:

1) The Blue Planet: An Introduction to Earth System Science, B. J. Skinner, S. C. Portere, 1994, John Wiley & Sons.
2) Consider a Spherical Cow: A course in environmental problem solving, J. Harte, University Science Books.
3) Fundamentals of Geophysics, W.Lowrie, 1997, Cambridge University Press.
4) The Solid Earth: An Introduction to Global Geophysics, C. M. R. Fowler, 1990, Cambridge University Press.
5) Climate Change: A Very Short Introduction, M. Maslin, 3rd edition, 2014, Oxford University Press.
6) The Atmosphere: A Very Short Introduction, P. I. Palmer, 2017, Oxford University Press.
7) IGNOU Study material: PHE 15 Astronomy and Astrophysics Block 2

Category II

Physical Science Courses
with Physics discipline as one of the Core Disciplines

(B. Sc. Physical Science with Physics as Major discipline)

DISCIPLINE SPECIFIC CORE COURSE – PHYSICS DSC 4: WAVES AND OPTICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Waves and Optics PHYSICS DSC – 4	4	2	0	2	Appeared in Semester 3	--

LEARNING OBJECTIVES

This is a core course in Physics curriculum that begins with explaining ideas of superposition of harmonic oscillations leading to physics of travelling and standing waves. The course also provides an in depth understanding of wave phenomena of light, namely, interference and diffraction with emphasis on practical applications of the same.

LEARNING OUTCOMES

On successfully completing the requirements of this course, the students will have the skill and knowledge to,

- Understand simple harmonic oscillation and superposition principle.
- Understand superposition of a range of collinear and mutually perpendicular simple harmonic motions and their applications.
- Understand concept of normal modes in stationary waves: their frequencies and configurations.
- Understand interference as superposition of waves from coherent sources derived from same parent source.
- Demonstrate understanding of interference experiments: Young's double slit, Fresnel's biprism, Llyod'smirror, Newton's rings
- Demonstrate basic concepts of diffraction: Superposition of wavelets diffracted from apertures
- Understand Fraunhoffer diffraction from apertures: single slit, double slit, grating
- Demonstrate fundamental understanding of Fresnel diffraction: Half period zones, diffraction of different apertures
- Laboratory course is designed to understand the principles of measurement and skills in experimental designs.

SYLLABUS OF PHYSICS DSC – 4

THEORY COMPONENT

Unit – I **(11 Hours)**

Superposition ofcollinear harmonic oscillations: Simple harmonic motion (SHM);linearity and superposition principle;superposition of two collinear oscillations having (1) equal frequencies and (2) different frequencies (beats).

Superposition of two perpendicular harmonic oscillations: Graphical and analytical methods.

Lissajous figures with equal and unequal frequencies and their uses
Superposition of two harmonic Waves: Standing (stationary) waves in a string;normal modes of stretched strings

Unit – II **(8 Hours)**
Interference: Division of amplitude and division of wavefront; Young's double slit experiment: width and shape of fringes; Fresnel's biprism; Lloyd's mirror;Phase change on reflection: Stokes' treatment; Interference in thin films: parallel and wedge-shaped films. Fringes of equal inclination (Haidinger fringes); Fringes of equal thickness (Fizeau Fringes); Newton's rings: Measurement of wavelength and refractive index

Unit – III **(11 Hours)**
Diffraction:
Fraunhofer diffraction: Single slit,double slit,diffraction grating
Fresnel diffraction: Fresnel's assumptions. Fresnel's half-period zones for plane wave. Explanation of rectilinear propagation of light; Fresnel's diffraction pattern of a straight edge, a slit and a wire using half-period zone analysis

References:
Essential Readings:
1) Vibrations and Waves, A.P. French, 1st edition, 2003, CRC press.
2) The Physics of Waves and Oscillations, N.K. Bajaj, 1998, Tata McGraw Hill.
3) Waves: Berkeley Physics Course, vol. 3, Francis Crawford, 2007, Tata McGraw-Hill.
4) Fundamental of Optics, A. Kumar, H.R. Gulati and D.R. Khanna, 2011, R. Chand Publications.
5) Optics, A. Ghatak, 6th edition, 2017, McGraw-Hill Education, New Delhi
6) The Physics of Vibrations and Waves, H. J. Pain, 2013, John Wiley and Sons.

Additional Readings:
1) Principles of Optics, M. Born and E. Wolf, 7th edition, 1999, Pergamon Press.
2) Optics, E. Hecht, 4th edition, 2014, Pearson Education.
3) Fundamentals of Optics, F.A. Jenkins and H.E. White, 1981, McGraw-Hill

PRACTICAL COMPONENT

(15 Weeks with 4 hours of laboratory session per week)

At least 7 experiments to be performed from the following list

1) To determine the frequency of an electric tuning fork by Melde's experiment and verify λ^2–T law.
2) To study Lissajous figures.
3) Familiarization with Schuster`s focusing and determination of angle of prism.
4) To determine refractive index of the material of a prism using sodium light.
5) To determine the dispersive power and Cauchy's constants of the material of a prism using mercury light.
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.

References for laboratory work:

1) Advanced Practical Physics for students, B.L.Flint and H.T.Worsnop, 1971, Asia Publishing House
2) A Text Book of Practical Physics, I.Prakash and Ramakrishna, 11th edition, 2011,KitabMahal
3) Advanced level Physics Practicals, M. Nelson and J. M. Ogborn, 4th edition, reprinted 1985, Heinemann Educational Publishers
4) A Laboratory Manual of Physics for undergraduate classes, D.P.Khandelwal,1985, Vani Pub.
5) B.Sc. Practical Physics, G.Sanon, 2019, R.Chand & Co

DISCIPLINE SPECIFIC ELECTIVE COURSE – PHYSICS DSE 14a: INTRODUCTION TO NUMERICAL METHODS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Introduction to Numerical Methods PHYSICSDSE 14a	4	2	0	2	Appeared in Semester 3	Elementary calculus

LEARNING OBJECTIVES

The main objective of this course is to introduce the students to the field of numerical analysis enabling them to solve a wide range of physics problems. The skills developed during the course will prepare them not only for doing fundamental and applied research but also for a wide variety of careers.

LEARNING OUTCOMES

After completing this course, student will be able to,

- Analyse a physics problem, establish the mathematical model and determine the appropriate numerical techniques to solve it.
- Derive numerical methods for various mathematical tasks such as root finding, interpolation, least squares fitting, numerical differentiation, numerical integration, and solution of initial value problems.
- Analyse and evaluate the accuracy of the numerical methods learned.

In the laboratory course, the students will learn to implement these numerical methods in Python and develop codes to solve various physics problems and interpret the results.

SYLLABUS OF PHYSICS DSE – 14a
THEORY COMPONENT

Unit – I **(7 Hours)**

Approximation and errors in computing: Introduction to numerical computation, Taylor's expansion and mean value theorem; Floating point computation, overflow and underflow; IEEE single and double precision format; Rounding and truncation error, absolute and relative error, error propagation.

Solutions of algebraic and transcendental equations: Basic idea of iteration method, Bisection method, Secant method, Newton Raphson method;comparison of order of convergence.

Unit – II **(7 hours)**

Interpolation: Interpolation and Lagrange polynomial, divided differences, Newton divided-difference form of the interpolating polynomial with equally spaced nodes. Theoretical error in interpolation.

Least Squares Approximation: Least squares linear regression, Least squares regression for exponential and power functions by taking logarithm.

Unit - III **(8 Hours)**

Numerical Differentiation: Using finite difference to approximate derivatives of first and second order using Taylor series and error in this approximation.

Numerical Integration: Newton Cotes quadrature methods;derivation of Trapezoidal and Simpson (1/3 and 3/8) rules from Lagrange interpolating polynomial;error and degree of precision of a quadrature formula;composite formulae for trapezoidal and Simpson methods; Gauss Legendre quadrature method.

Unit - IV **(8 Hours)**

Initial Value Problems: Solution of initial value problems by Euler, modified Euler and RungeKutta (RK2, RK4) methods;local and global errors, comparison of errors in the Euler and RK methods,system of first order differential equations. Solving higher order initial value problems by converting them into a system of first order equations.

References:

Essential Readings:

1) Introduction to Numerical Analysis, S. S. Sastry, 5th edition, 2012, PHI Learning Pvt. Ltd.
2) Elementary Numerical Analysis, K. E. Atkinson, 3rd edition, 2007, Wiley India Edition.
3) Numerical methods for scientific and engineering computation, M. K. Jain, S. R. K. Iyenger and R. K. Jain, 2012, New Age Publishers
4) A Friendly Introduction to Numerical Analysis, B.Bradie, 2007, Pearson India

Additional Readings:

1) Numerical Recipes: The art of scientific computing, W. H. Press, S. A. Teukolsky and W. Vetterling, 3rd edition, 2007, Cambridge University Press
2) Numerical Methods for Scientists and Engineers, R. W. Hamming, 1987, Dover Publications
3) Applied numerical analysis, C. F. Gerald and P. O. Wheatley, 2007, Pearson Education
4) Numerical Analysis, R. L. Burden and J. D.Faires, 2011, Brooks/Cole, Cengage Learning
5) Numerical Methods, V.N. Vedamurthy and N.Ch. S.N. Iyengar, 2011, Vikas Publishing House

PRACTICAL COMPONENT

(15 Weeks with 4 hours of laboratory session per week)

The aim of this Lab is not just to teach computer programming and numerical analysis but toemphasize its role in solving problems in Physics.

- Assessment is to be done not only on the programming but also on the basis of formulating the problem.
- The list of recommended programs is suggestive only. Students should be encouraged to do more physics applications. Emphasis should be given to formulate a physics problem as mathematical one and solve by computational methods.
- The students should be encouraged to develop and present an independent project.
- **At least 12 programs must be attempted (taking two from each unit). The implementation is to be done in Python. Use of scipy inbuilt functions may be encouraged**

Unit 1

Basic Elements of Python: The Python interpreter, the print statement, comments, Python as simple calculator, objects and expressions, variables (numeric, character and sequence types) and assignments, mathematical operators. Strings, Lists, Tuples and Dictionaries, type conversions, input statement, list methods. List mutability, formatting in the print statement.

Control Structures: Conditional operations, ***if, if-else, if-elif-else, while*** and ***for*** Loops, indentation, break and continue, List comprehension. Simple programs for practice like solving quadratic equations, temperature conversion etc.

Functions: Inbuilt functions, user-defined functions, local and global variables, passing functions, modules, importing modules, math module, making new modules. Writing functions to perform simple operations like finding largest of three numbers, listing prime numbers, etc. Use of inbuilt functions to generate pseudo random numbers.

Recommended List of Programs

a) Make a function that takes a number *N* as input and returns the value of factorial of *N*. Use this function to print the number of ways a set of *m* red and *n* blue balls can be arranged.
b) Generate random numbers (integers and floats) in a given range and calculate area and volume of regular shapes with random dimensions.
c) Write functions to convert Cartesian coordinates of a given point to cylindrical and spherical polar coordinates or vice versa.
d) Solve quadratic equations for the three cases of distinct real, double real and complex conjugate roots.

Unit 2

NumPy Fundamentals: Importing *Numpy*, Difference between List and NumPy array, Adding, removing and sorting elements, creating arrays using *ones(), zeros(), random(), arange(), linspace()*. Basic array operations (*sum, max, min, mean, variance*), 2-d arrays, matrix operations, reshaping and transposing arrays, savetxt() and loadtxt().

Plotting with Matplotlib:*matplotlib.pyplot* functions, plotting of functions given in closed form as well as in the form of discrete data and making histograms

Recommended List of Programs

(a) To generate data for coordinates of a projectile and plot the trajectory. Determine the range, maximum height and time of flight for a projectile motion.
(b) To plot the displacement-time and velocity-time graph for the undamped, under damped critically damped and over damped oscillator using *matplotlib* (using given formulae).
(c) To generate array of N random numbers drawn from a given distribution (uniform, binomial, poisson and gaussian) and draw histogram using *matplotlib* for increasing N to verify the distribution.
(d) To approximate the elementary functions (e.g. exp(x), sin(x), cos(x), ln(1+x), etc.) by a finite number of terms of Taylor's series and discuss the truncation error. To plot the function as well the nth partial sum of its series for various values of *n* on the same graph and visualise the convergence of series.

Unit 3

Root Finding: Implement the algorithms for Bisection, Secant and Newton Raphson methods or their combinations to,

(a) Determine the depth up to which a spherical homogeneous object of given radius and density will sink into a fluid of given density.

(b) Solve transcendental equations like α = tan(α).
(c) Approximate nth root of a number up to a given number of significant digits.

Unit 4
Interpolation and Least Square Fitting:

a) Given a dataset (x, y) with equidistant x values, prepare the Newton's divided difference table. Generate a tabulated data for an elementary function, approximate it by a polynomial and compare with the true function.
b) Given a dataset (x, y) corresponding to a physics problem, use Lagrange and Newton's forms of interpolating polynomials and compare. Determine the value of y at an intermediate value of x not included in the data set. This may be done with equally spaced and non-equally spaced x-values.
c) Make Python function for least square fitting, use it for fitting given data (*x,y*) and estimate the parameters a, b as well as uncertainties in the parameters for the following cases :

i. Linear($y = ax + b$)
ii. Power law($y = ax^b$) and
iii. Exponential($y = ae^{bx}$)

The real data taken in physics lab may be used here.

d) Compare the interpolating polynomial for a given dataset (following a known form e.g. exponential) with the approximation obtained by least square fitting.

Unit 5
Differentiation and Integration:

a) To compute the left, right and central approximations for derivative of a functiongiven in closed form. Plot both the function and derivative on the same graph. Plot (using *matplotlib)* the error as a function of step size on a log-log graph, study the behaviour of the plot as step size decreases and hence discuss the effect of round off error.
b) Use integral definition of error function to compute and plot erf(x) in a given range. Use Trapezoidal, Simpson and Gauss Legendre methods and compare the results for small and large values of x.
c) Verify the degree of precision of each quadrature rule.
d) Approximate the value of π by evaluating the integral$\int_0^\infty \frac{1}{x^2+1} dx$using Simpson and Gauss Legendre method. More integrals may be evaluated.

Unit 6
Initial Value Problems (IVP):

a) Compare the errors in Euler, RK2 and RK4 by solving a first order IVP with known solution. Reduce the step size to a point where the round off errors takes over.
b) Radioactive decay: With a given number of initial nuclei and decay constant plot the number of nuclei left as a function of time and determine the half life
c) Solve a system of two first order differential equations by Euler, RK2 and RK4 methods. Use it to solve an nth order IVP. Solve a damped free and forced harmonic oscillator problem using this.
d) Solve a physics problem like free fall with air drag or parachute problem using RK method.
e) Obtain the current flowing in a series LCR circuit with constant voltage for a given set of initial conditions.

References for laboratory work:

1) Documentation at the Python home page (https://docs.python.org/3/) and the tutorials there (https://docs.python.org/3/tutorial/).
2) Documentation of NumPy and Matplotlib: https://numpy.org/doc/stable/user/ and https://matplotlib.org/stable/tutorials/
3) Computational Physics, D. Walker, 1st edition, 2015, Scientific International Pvt. Ltd
4) An Introduction to Computational Physics, T. Pang, 2010, Cambridge University Press
5) Python Programming and Numerical Methods - A Guide for Engineers and Scientists, Q. Kong, T.Siauw, A. M. Bayen, 2021, Academic Press

DISCIPLINE SPECIFIC ELECTIVE COURSE – PHYSICS DSE 14b: ANALOG ELECTRONICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Analog Electronics PHYSICS DSE – 14b	4	2	0	2	Appeared in Semester 3	--

LEARNING OBJECTIVES

This course introduces the concept of semiconductor devices and their analog applications. It also emphasizes on understanding of amplifiers, oscillators, operational amplifier and their applications.

LEARNING OUTCOMES

At the end of this course, the following concepts will be learnt.

- To learn about diodes and its uses in rectification
- To gain an insight into working principle of photodiodes, solar cells, LED and zenerdiode as voltage regulator
- To gain an understanding of construction and working principle of bipolar junction transistors (BJTs), characteristics of different configurations, biasing and analysis of transistor amplifier
- To be able to design and understand use of different types of oscillators
- To learn the fundamentals of operation amplifiers and understand their operations to compare, add, or subtract two or more signals and to differentiate or integrate signals etc.

In the laboratory course, the students will be able to study characteristics of various diodes and BJT. They will be able to design amplifiers, and oscillators. Also different applications using Op-Amp will be designed.

SYLLABUS OF Physics DSE–14b

THEORY COMPONENT

Unit – I - Two-terminal devices and their applications (5 Hours)

IV characteristics of a diode and its application as rectifier (half-wave and full wave rectifier), IV characteristics of a zener diode and its use as voltage regulator, principle, structure and characteristics of (1) LED, (2) Photodiode and (3) Solar Cell

Unit – II - Bipolar junction transistors (4 Hours)

n-p-n and p-n-p transistors, IV characteristics of CB and CE configurations,active, cut-off and saturation regions, current gains α and β, relations between α and β, physical mechanism of current flow

Unit – III – Amplifiers and sinusoidal oscillators (11 Hours)

Load line analysis of transistor, DC load line and Q-point,fixed bias and voltage divider bias, transistor as 2-port network, h-parameter equivalent circuit of a transistor, analysis of a

single-stage CE amplifier using hybrid model (input and output impedance,current and voltage gain)
Sinusoidal Oscillators: General idea of positive and negative feedback,Barkhausen'scriterion for self-sustained oscillations, RC phase shift oscillator, determination of frequency, Hartley and Colpitts oscillators

Unit – IV - Operational Amplifiers (Black Box approach) (10 Hours)
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 Op-Amps: (1) Inverting and non-inverting amplifiers, (2) Adder, (3) Subtractor, (4) Differentiator, (5) Integrator, (6) Comparator and Zero crossing detector (7) Wein bridge oscillator

References:
Essential Readings:

1) Integrated Electronics, J. Millman and C.C. Halkias, 1991, Tata Mc-Graw Hill
2) Electronics: Fundamentals and Applications, J. D. Ryder, 2004, Prentice Hall
3) Linear Integrated Circuit, R. A. Gayakwad, 4thedition, 2000, Prentice Hall
4) Microelectronic circuits, A.S. Sedra, K.C. Smith and A.N. Chandorkar, 6th edition, 2014, Oxford University Press.
5) Semiconductor Devices: Physics and Technology, S.M. Sze, 2nd edition, 2002, Wiley India
6) Electronic Principles, A. Malvino, D.J. Bates, 7th edition, 2018, Tata Mc-Graw Hill Education.
7) Electronic Devices and circuit Theory, R.L. Boylestadand L.D. Nashelsky, 2009, Pearson

Additional Readings:

1) Learning Electronic Devices and circuits, S.Salivahananand N.S.Kumar, 3rd edition, 2012, Tata Mc-Graw Hill
2) Microelectronic Circuits, M.H. Rashid, 2nd edition, Cengage Learning
3) Microelectronic Devices and Circuits, D. A.Bell, 5th edition,2015, Oxford University Press
4) Basic Electronics: Principles and Applications, C. Saha, A. Halder and D. Ganguli, 1stedition, 2018, Cambridge University Press
5) Solid State Electronic Devices, B.G.Streetmanand S.K.Banerjee, 6th edition,2009, PHI

PRACTICAL COMPONENT

(15 Weeks with 4 hours of laboratory session per week)

- Session on the construction and use of specific analogue devices and experimental apparatuses used in the lab, including necessary precautions
- Sessions on the review of experimental data analysis, sources of error and their estimation in detail, writing of scientific laboratory reports including proper reporting of errors.
- Application to the specific experiments done in the lab.

At least six experiments to be performed from the following list

1) To study the V-I characteristics of a Zener diode and its use as voltage regulator.
2) Study of V-I and power curves of solar cells, and find maximum power point and

efficiency.

3) Tostudy the characteristics of a Bipolar Junction Transistor in CE configuration.
4) To design a CE transistor amplifier of a given gain (mid-gain) using voltage divider bias.
5) To design a Wien bridge oscillator for given frequency using an op-amp.
6) To design an inverting amplifier using Op-amp (741, 351) for dc voltage of given gain
7) To design inverting amplifier using Op-amp (741, 351) and study its frequency response
8) To design non-inverting amplifier using Op-amp (741, 351) and study frequency response
9) To add two dc voltages using Op-amp in inverting and non-inverting mode
10) To study the zero-crossing detector and comparator
11) To investigate the use of an op-amp as an integrator
12) To investigate the use of an op-amp as a differentiator.

References for laboratory work:

1) Basic Electronics: A text lab manual, P. B. Zbar, A. P. Malvino and M. A. Miller, 1994, Mc- Graw Hill
2) Student Manual for The Art of Electronics, T. C. Hayes and P. Horowitz

DISCIPLINE SPECIFIC ELECTIVE COURSE – PHYSICS DSE 14c: PHYSICS OF EARTH

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Physics of Earth PHYSICS DSE – 14c	4	4	0	0	Appeared in Semester 3	--

LEARNING OBJECTIVES

This course familiarizes the students with the origin of earth in the solar system and various processes occurring in atmosphere, oceans and earth's internal structure.

LEARNING OUTCOMES

At the end of this course student will be able to,

- Have an overview of structure of the earth as well as various dynamical processes occurring on it.
- Develop an understanding of evolution of the earth.
- Apply physical principles of elasticity and elastic wave propagation to understand modern global seismology as a probe of the Earth's internal structure.
- Understand the origin of magnetic field, geodynamics of earthquakes and the description of seismic sources; a simple but fundamental theory of thermal convection; the distinctive rheological behaviour of the upper mantle and its top.
- Explore various roles played by water cycle, carbon cycle, nitrogen cycles in maintaining steady state of earth leading to better understanding of the contemporary dilemmas (climate change, bio diversity loss, population growth, etc.) disturbing the Earth
- Develop the problem solving skills by adding numerical and simulations to clarify the fundamental concepts.

SYLLABUS OF DSE–14c

THEORY COMPONENT

Unit – I **(10 Hours)**

The Earth and the Universe:

a) General characteristics and origin of the Universe. The Big Bang Theory. Estimation of age of the Universe and Hubble constant. Formation of Galaxies. Types of galaxies, Milky Way galaxy, Nebular hypothesis, Solar system, The Terrestrial and Jovian planets (Sizes, Acceleration due to gravity, Obliquity, Flatness, Eccentricity, Density, Temperature, Pressure, Atmosphere, Moons, Exceptions in trends). Titius-Bode law. Asteroid belt. Asteroids: origin types and examples, Meteorites.

b) Earth in the Solar system, origin, size, shape, mass, density, rotational and revolution parameters and its age. Earth's orbit and spin, the Moon's orbit and spin.

c) Energy and particle fluxes incident on the Earth.

Unit – II **(15 Hours)**

Structure of Earth:

a) The Solid Earth: topography (Maps, Techniques, Forms of Topographic data).
b) Internal structure: Core, mental, magnetic field. Origin of the Magnetic field. Convection in Earth's core and production of its magnetic field. Dynamo Theory, calculation of magnetic fields, Causes of variation of Magnetic Field and Palaeomagnetism.
c) The Hydrosphere: The oceans, their extent, depth, volume, chemical composition. Ocean circulations. Oceanic current system and effect of Coriolis forces.
d) The Cryosphere: Polar caps and ice sheets. Mountain glaciers, permafrost.

Unit – III **(15 Hours)**

Dynamical Processes:

a) The Solid Earth: Concept of plate tectonics; types of plate movements, hotspots; sea-floor spreading and continental drift.
b) Geodynamic elements of Earth: Mid Oceanic Ridges, trenches, transform faults and island arcs. Continents, mountains and rift valleys.
c) Earthquake and earthquake belts. Types and properties of Seismic waves, Richter scale, geophones.
d) Volcanoes: types, products and distribution.
e) Concepts of eustasy, air-sea interaction; wave erosion and beach processes. Tides. Tsunamis.

Unit – IV **(12 Hours)**

The Atmosphere

a) The Atmosphere: Features of different layers, variation of temperature with altitude; Dry, moist and environmental lapse rate, variation of density and pressure with altitude, Types of clouds and formation.
b) The Atmosphere: Atmospheric circulation. Causes of Atmospheric circulation, Formation of three cells, Easterlies and Westerlies, and ICTZ, Weather and climatic changes. Earth's heat budget. Cyclones and anti-cyclones, tropical storms, hurricanes and tornadoes.
c) Climate: Earth's temperature and greenhouse effect. Paleoclimate and recent climate changes. The Indian monsoon system.

Unit – V **(8 Hours)**

Disturbing the Earth – Contemporary dilemmas

a) Human population growth.
b) Hydrosphere: Fresh water depletion.
c) Geosphere: Chemical effluents, nuclear waste.
d) Biosphere: Biodiversity loss. Deforestation. Robustness and fragility of ecosystems. Water cycle, Carbon cycle. The role of cycles in maintaining a steady state.
e) Air Pollution: Types of air pollutants, Effects on atmosphere and living organisms. Ozone Hole.

References:

Essential Readings:

1) Planetary Surface Processes, H. J.Melosh, 2011, Cambridge University Press.
2) Holme's Principles of Physical Geology, 1992, Chapman &Hall.
3) Planet Earth, Cosmology, Geology and the Evolution of Life and Environment, C. Emiliani, 1992, Cambridge University Press.
4) Physics of the Earth, F. D. Stacey, P. M. Davis, 2008, Cambridge University Press.

5) Environmental Physics: Sustainable Energy and Climate Change, E. Boecker and R.V. Grondelle, 3rd edition, 2011, Wiley, UK
6) Atmospheric Remote Sensing (Principles and Applications, Editors – S. Tiwari and A. K. Singh, Chapter-1 (Composition and thermal structure of the Earth's atmosphere, by S. K. Dhaka and V. Kumar), 1st edition, Elsevier

Additional Readings:

1) The Blue Planet: An Introduction to Earth System Science, B. J. Skinner, S. C. Portere, 1994, John Wiley & Sons.
2) Consider a Spherical Cow: A course in environmental problem solving, J. Harte, University Science Books.
3) Fundamentals of Geophysics, W.Lowrie, 1997, Cambridge University Press.
4) The Solid Earth: An Introduction to Global Geophysics, C. M. R. Fowler, 1990, Cambridge University Press.
5) Climate Change: A Very Short Introduction, M. Maslin, 3rd edition, 2014, Oxford University Press.
6) The Atmosphere: A Very Short Introduction, P. I. Palmer, 2017, Oxford University Press.
7) IGNOU Study material: PHE 15 Astronomy and Astrophysics Block

Category II

Physical Science Courses (with Electronics)
with Physics and Electronics discipline as Core Disciplines

DISCIPLINE SPECIFIC CORE COURSE – PHYSICS DSC 7: WAVES AND OPTICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Waves and Optics PHYSICS DSC 7	4	2	0	2	Appeared in Semester 3	--

LEARNING OBJECTIVES

This is a core course in Physics curriculum that begins with explaining ideas of superposition of harmonic oscillations leading to physics of travelling and standing waves. The course also provides an in depth understanding of wave phenomena of light, namely, interference and diffraction with emphasis on practical applications of the same.

LEARNING OUTCOMES

On successfully completing the requirements of this course, the students will have the skill and knowledge to,

- Understand simple harmonic oscillation and superposition principle.
- Understand superposition of a range of collinear and mutually perpendicular simple harmonic motions and their applications.
- Understand concept of normal modes in stationary waves: their frequencies and configurations.
- Understand interference as superposition of waves from coherent sources derived from same parent source.
- Demonstrate understanding of interference experiments: Young's double slit, Fresnel's biprism, Llyod'smirror, Newton's rings
- Demonstrate basic concepts of diffraction: Superposition of wavelets diffracted from apertures
- Understand Fraunhofferdiffraction from apertures: single slit, double Slit, grating
- Demonstrate fundamental understanding of Fresnel diffraction: Half period zones, diffraction of different apertures
- Laboratorycourse is designed to understand the principles of measurement and skills in experimental designs.

SYLLABUS OF PHYSICS DSC – 7

THEORY COMPONENT

Unit – I **(11 Hours)**

Superposition ofcollinear harmonic oscillations: Simple harmonic motion (SHM);linearity and superposition principle;superposition of two collinear oscillations having (1) equal frequencies and (2) different frequencies (beats).

Superposition of two perpendicular harmonic oscillations: Graphical and analytical methods. Lissajous figures with equal and unequal frequencies and their uses

Superposition of two harmonic Waves: Standing (stationary) waves in a string;normal modes of stretched strings

Unit – II **(8 Hours)**

Interference: Division of amplitude and division of wavefront; Young's double slit experiment: width and shape of fringes; Fresnel's biprism; Lloyd's mirror; Phase change on reflection: Stokes' treatment; Interference in thin films: parallel and wedge-shaped films. Fringes of equal inclination (Haidinger fringes); Fringes of equal thickness (Fizeau Fringes); Newton's rings: Measurement of wavelength and refractive index

Unit – III **(11 Hours)**

Diffraction:

Fraunhofer diffraction: Single slit,double slit,diffraction grating

Fresnel diffraction: Fresnel's assumptions. Fresnel's half-period zones for plane wave. Explanation of rectilinear propagation of light; Fresnel's diffraction pattern of a straight edge, a slit and a wire using half-period zone analysis

References:

Essential Readings:

1) Vibrations and Waves, A.P. French, 1st edition, 2003, CRC press.
2) The Physics of Waves and Oscillations, N.K. Bajaj, 1998, Tata McGraw Hill.
3) Waves: Berkeley Physics Course, vol. 3, Francis Crawford, 2007, Tata McGraw-Hill.
4) Fundamental of Optics, A. Kumar, H.R. Gulati and D.R. Khanna, 2011, R. Chand Publications.
5) Optics, A. Ghatak, 6th edition, 2017, McGraw-Hill Education, New Delhi
6) The Physics of Vibrations and Waves, H. J. Pain, 2013, John Wiley and Sons.

Additional Readings:

1) Principles of Optics, M. Born and E. Wolf, 7th edition, 1999, Pergamon Press.
2) Optics, E. Hecht, 4th edition, 2014, Pearson Education.
3) Fundamentals of Optics, F.A. Jenkins and H.E. White, 1981, McGraw-Hill

PRACTICAL COMPONENT

(15 Weeks with 4 hours of laboratory session per week)

At least 7 experiments to be performed from the following list

1) To determine the frequency of an electric tuning fork by Melde's experiment and verify λ^2–T law.
2) To study Lissajous figures.
3) Familiarization with Schuster`s focusing and determination of angle of prism.
4) To determine refractive index of the material of a prism using sodium light.
5) To determine the dispersive power and Cauchy's constants of the material of a prism using mercury light.
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.

References for laboratory work:

1) Advanced Practical Physics for students, B.L.Flint and H.T.Worsnop, 1971, Asia Publishing House
2) A Text Book of Practical Physics, I.Prakash and Ramakrishna, 11th edition, 2011,KitabMahal
3) Advanced level Physics Practicals, M. Nelson and J. M. Ogborn, 4th edition, reprinted 1985, Heinemann Educational Publishers
4) A Laboratory Manual of Physics for undergraduate classes, D.P.Khandelwal,1985, Vani Pub.
5) B.Sc. Practical Physics, G.Sanon, 2019, R.Chand & Co

DISCIPLINE SPECIFIC CORE COURSE – PHYSICS DSC 8: MICROPROCESSOR AND MICROCONTROLLER

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Microprocessor and Microcontroller PHYSICS DSC – 8	**4**	**2**	**0**	**2**	Appeared in Semester 3	--

LEARNING OBJECTIVES

This paper introduces the basic concepts of microprocessor and microcontrollers to the undergraduate students. Basic architecture and buildings blocks of a microprocessor and microcontrollers will be discussed in detail. Pin out diagram and the assembly language programming is discussed for both of them. The course is supported by a lab where students will apply the learned concepts and write simple programs to strengthen their classroom learning.

LEARNING OUTCOMES

Upon completion of this course, students will be able to,

- Describe the basic difference between a microprocessor and microcontroller and a general computing system.
- Explain the basic architecture and pin out diagram of 8085 microprocessor and 8051 microcontroller.
- Explain the difference between machine code, mnemonics, assembly language (low level) and high level language.
- Explain the concept of memory, different types of memory available in a system. The concept of memory map and how addresses are assigned to each memory element and peripherals.
- Classify instructions 1-, 2- or 3-byte instructions and into arithmetic, logical types etc.
- Describe the different addressing modes available to perform the same task.
- Write simple programs for 8085 microprocessor and 8051 microcontroller.

SYLLABUS OF PHYSICS DSC - 8

THEORY COMPONENT

Unit – I - Microcomputer organization (4 Hours)

Basic organization of a microcomputer/ microprocessor based system, computer memory, memory classification (RAM and ROM), memory organization andaddressing, memory interfacing, memory map

Unit – II - 8085 Microprocessor architecture (4 Hours)

Main features of 8085, pin-out diagram of 8085, data and address buses, registers, ALU, stack pointer, program counter

Unit – III - 8085 Programming (7 Hours)

Instruction classification (data transfer, arithmetic, logical, branch, and control instructions), general discussion on 1 byte, 2 bytes and 3 bytes instructions, subroutines, instruction cycle, timing diagram of MOV and MVI, hardware and software interrupts (general discussion).

Unit – IV - 8051 microcontroller (8 Hours)

Microcontroller vs microprocessor, block diagram of 8051 microcontroller, 8051 assembly language programming, program counter and ROM memory map, data types and directives, flag bits and program status word (PSW) register, register banks and stack, jump, loop and call instructions

Unit – V - 8051 I/O port programming (3 Hours)

Pin out diagram of 8051 microcontroller, introduction of I/O port and their general features, I/O port programming in 8051 (using assembly language)

Unit – VI - 8051 Programming (4 Hours)

8051 addressing modes and accessing memory locations using various addressing modes, arithmetic and logic instructions

References:

Essential Readings:

1) Microprocessor Architecture Programming and applications with 8085, R. S. Goankar, 2002, Prentice Hall.
2) Microprocessors and Microcontrollers, K. Kant, 2ndedition, 2016. PHI learning Pvt. Ltd.
3) The 8051 Microcontroller, Ayala, Cengage learning, 3rdedition.
4) The 8051 Microcontroller and Embedded Systems Using Assembly and C, M. A. Mazidi, J. G. Mazidi, and R. D. McKinlay, 2nd edition, 2007, Pearson Education India.
5) Microprocessor and Microcontrollers, N. Senthil Kumar, 2010, Oxford University Press.
6) 8051 Microcontroller, S. Shah, 2010, Oxford University Press.

Additional Readings:

1) Embedded Systems: Design and Applications, S.F. Barrett, 2008, Pearson Education India.
2) Introduction to embedded system, K.V. Shibu, 1stedition, 2009, McGraw Hill.
3) Embedded Microcomputer systems: Real time interfacing, J.W. Valvano, 2011, Cengage Learning.

PRACTICAL COMPONENT

(15 Weeks with 4 hours of laboratory session per week)

There are two options here:

A. Every Student must perform at least 06 experiments each from Section-A and Section-B

Or

B. Every Student must perform at least 04 experiments each from Section-A and Section-B and a suitable project based on Arduino.

Section-A: Programs using 8085 Microprocessor

1) Addition and subtraction of two 8 bits numbers using direct addressing mode

2) Addition and subtraction of two 8 bits numbers using indirect addressing mode
3) Addition and subtraction of two 16 bits numbers using direct addressing mode
4) Addition and subtraction of two 16 bits numbers using indirect addressing mode
5) Multiplication by repeated addition.
6) Division by repeated subtraction.
7) Handling of 16-bit Numbers.
8) Use of CALL and RETURN Instruction.
9) Block data handling.
10) Parity checking in an 8-bit and 16 bit number.

Section-B: Experiments using 8051 microcontroller:

1) To find that the given numbers is prime or not.
2) To find the factorial of a number.
3) Write a program to make the two numbers equal by increasing the smallest number and decreasing the largest number.
4) Use one of the four ports of 8051 for O/P interfaced to eight LED's. Simulate binary counter (8 bit) on LED's.
5) Program to glow the first four LEDs then next four using TIMER application.
6) Program to rotate the contents of the accumulator first right and then left.
7) Program to run a countdown from 9-0 in the seven segment LED display.
8) To interface seven segment LED display with 8051 microcontroller and display 'HELP' in the seven segment LED display.
9) To toggle '1234' as '1324' in the seven segments LED display.
10) Interface stepper motor with 8051 and write a program to move the motor through a given angle in clock wise or counter clockwise direction.
11) Application of embedded systems: Temperature measurement & display on LCD

References for laboratory work:

1) Microprocessor Architecture Programming and applications with 8085, R. S. Goankar, 2002, Prentice Hall.
2) Embedded Systems: Architecture, Programming and Design, R. Kamal, 2008, Tata McGraw Hill.
3) The 8051 Microcontroller and Embedded Systems Using Assembly and C, M.A. Mazidi, J.G. Mazidi, and R.D. McKinlay, 2nd edition, 2007, Pearson Education India.
4) 8051 microcontrollers, S. Shah, 2010, Oxford University Press.
5) Embedded Microcomputer systems: Real time interfacing, J.W. Valvano, 2011, Cengage Learning

DISCIPLINE SPECIFIC ELECTIVE COURSE – PHYSICS DSE 11: INTRODUCTION TO NUMERICAL METHODS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Introduction to Numerical Methods PHYSICS DSE 11	**4**	**2**	**0**	**2**	Appeared in Semester 3	Elementary calculus

LEARNING OBJECTIVES

The main objective of this course is to introduce the students to the field of numerical analysis enabling them to solve a wide range of physics problems. The skills developed during the course will prepare them not only for doing fundamental and applied research but also for a wide variety of careers.

LEARNING OUTCOMES

After completing this course, student will be able to,

- Analyse a physics problem, establish the mathematical model and determine the appropriate numerical techniques to solve it.
- Derive numerical methods for various mathematical tasks such as root finding, interpolation, least squares fitting, numerical differentiation, numerical integration, and solution of initial value problems.
- Analyse and evaluate the accuracy of the numerical methods learned.

In the laboratory course, the students will learn to implement these numerical methods in Python and develop codes to solve various physics problems and interpret the results.

SYLLABUS OF PHYSICS DSE – 11

THEORY COMPONENT

Unit – I **(7 Hours)**

Approximation and errors in computing: Introduction to numerical computation, Taylor's expansion and mean value theorem; Floating point computation, overflow and underflow; IEEE single and double precision format; Rounding and truncation error, absolute and relative error, error propagation.

Solutions of algebraic and transcendental equations: Basic idea of iteration method, Bisection method, Secant method, Newton Raphson method;comparison of order of convergence.

Unit – II **(7 hours)**

Interpolation: Interpolation and Lagrange polynomial, divided differences, Newton divided-difference form of the interpolating polynomial with equally spaced nodes. Theoretical error in interpolation.

Least Squares Approximation: Least squares linear regression, Least squares regression for exponential and power functions by taking logarithm.

Unit - III **(8 Hours)**

Numerical Differentiation: Using finite difference to approximate derivatives of first and second order using Taylor series and error in this approximation.

Numerical Integration: Newton Cotes quadrature methods;derivation of Trapezoidal and Simpson (1/3 and 3/8) rules from Lagrange interpolating polynomial;error and degree of precision of a quadrature formula;composite formulae for trapezoidal and Simpson methods; Gauss Legendre quadrature method.

Unit - IV **(8 Hours)**

Initial Value Problems: Solution of initial value problems by Euler, modified Euler and RungeKutta (RK2, RK4) methods;local and global errors, comparison of errors in the Euler and RK methods,system of first order differential equations. Solving higher order initial value problems by converting them into a system of first order equations.

References:

Essential Readings:

1) Introduction to Numerical Analysis, S. S. Sastry, 5th edition, 2012, PHI Learning Pvt. Ltd.
2) Elementary Numerical Analysis, K. E. Atkinson, 3rd edition, 2007, Wiley India Edition.
3) Numerical methods for scientific and engineering computation, M. K. Jain, S. R. K. Iyenger and R. K. Jain, 2012, New Age Publishers
4) A Friendly Introduction to Numerical Analysis, B.Bradie, 2007, Pearson India

Additional Readings:

1) Numerical Recipes: The art of scientific computing, W. H. Press, S. A. Teukolsky and W. Vetterling, 3rd edition, 2007, Cambridge University Press
2) Numerical Methods for Scientists and Engineers, R. W. Hamming, 1987, Dover Publications
3) Applied numerical analysis, C. F. Gerald and P. O. Wheatley, 2007, Pearson Education
4) Numerical Analysis, R. L. Burden and J. D.Faires, 2011, Brooks/Cole, Cengage Learning
5) Numerical Methods, V.N. Vedamurthy and N.Ch. S.N. Iyengar, 2011, Vikas Publishing House

PRACTICAL COMPONENT

(15 Weeks with 4 hours of laboratory session per week)

The aim of this Lab is not just to teach computer programming and numerical analysis but toemphasize its role in solving problems in Physics.

- Assessment is to be done not only on the programming but also on the basis of formulating the problem.
- The list of recommended programs is suggestive only. Students should be encouraged to do more physics applications. Emphasis should be given to formulate a physics problem as mathematical one and solve by computational methods.
- The students should be encouraged to develop and present an independent project.
- **At least 12 programs must be attempted (taking two from each unit). The implementation is to be done in Python. Use of scipy inbuilt functions may be encouraged.**

Unit 1

Basic Elements of Python: The Python interpreter, the print statement, comments, Python as simple calculator, objects and expressions, variables (numeric, character and sequence types) and assignments, mathematical operators. Strings, Lists, Tuples and Dictionaries, type conversions, input statement, list methods. List mutability, formatting in the print statement.

Control Structures: Conditional operations, ***if, if-else, if-elif-else, while*** and ***for*** Loops, indentation, break and continue, List comprehension. Simple programs for practice like solving quadratic equations, temperature conversion etc.

Functions: Inbuilt functions, user-defined functions, local and global variables, passing functions, modules, importing modules, math module, making new modules. Writing functions to perform simple operations like finding largest of three numbers, listing prime numbers, etc. Use of inbuilt functions to generate pseudo random numbers.

<u>Recommended List of Programs</u>

a) Make a function that takes a number *N* as input and returns the value of factorial of *N*. Use this function to print the number of ways a set of *m* red and *n* blue balls can be arranged.
b) Generate random numbers (integers and floats) in a given range and calculate area and volume of regular shapes with random dimensions.
c) Write functions to convert Cartesian coordinates of a given point to cylindrical and spherical polar coordinates or vice versa.
d) Solve quadratic equations for the three cases of distinct real, double real and complex conjugate roots.

Unit 2

NumPy Fundamentals: Importing *Numpy*, Difference between List and NumPy array, Adding, removing and sorting elements, creating arrays using *ones(), zeros(), random(), arange(), linspace()*. Basic array operations (*sum, max, min, mean, variance*), 2-d arrays, matrix operations, reshaping and transposing arrays, savetxt() and loadtxt().

Plotting with Matplotlib:*matplotlib.pyplot* functions, plotting of functions given in closed form as well as in the form of discrete data and making histograms

<u>Recommended List of Programs</u>

(a) To generate data for coordinates of a projectile and plot the trajectory. Determine the range, maximum height and time of flight for a projectile motion.
(b) To plot the displacement-time and velocity-time graph for the undamped, under damped critically damped and over damped oscillator using *matplotlib* (using given formulae).
(c) To generate array of N random numbers drawn from a given distribution (uniform, binomial, poisson and gaussian) and draw histogram using *matplotlib* for increasing N to verify the distribution.
(d) To approximate the elementary functions (e.g. exp(x), sin(x), cos(x), ln(1+x), etc.) by a finite number of terms of Taylor's series and discuss the truncation error. To plot the function as well the nth partial sum of its series for various values of *n* on the same graph and visualise the convergence of series.

Unit 3

Root Finding: Implement the algorithms for Bisection, Secant and Newton Raphson methods or their combinations to,

(a) Determine the depth up to which a spherical homogeneous object of given radius and density will sink into a fluid of given density.

(b) Solve transcendental equations like $\alpha = \tan(\alpha)$.
(c) Approximate nth root of a number up to a given number of significant digits.

Unit 4
Interpolation and Least Square Fitting:

a) Given a dataset (x, y) with equidistant x values, prepare the Newton's divided difference table. Generate a tabulated data for an elementary function, approximate it by a polynomial and compare with the true function.
b) Given a dataset (x, y) corresponding to a physics problem, use Lagrange and Newton's forms of interpolating polynomials and compare. Determine the value of y at an intermediate value of x not included in the data set. This may be done with equally spaced and non-equally spaced x-values.
c) Make Python function for least square fitting, use it for fitting given data (*x,y*) and estimate the parameters a, b as well as uncertainties in the parameters for the following cases :
   i. Linear$(y = ax + b)$
   ii. Power law$(y = ax^b)$ and
   iii. Exponential$(y = ae^{bx})$
   The real data taken in physics lab may be used here.
d) Compare the interpolating polynomial for a given dataset (following a known form e.g. exponential) with the approximation obtained by least square fitting.

Unit 5
Differentiation and Integration:

a) To compute the left, right and central approximations for derivative of a functiongiven in closed form. Plot both the function and derivative on the same graph. Plot (using *matplotlib)* the error as a function of step size on a log-log graph, study the behaviour of the plot as step size decreases and hence discuss the effect of round off error.
b) Use integral definition of error function to compute and plot erf(x) in a given range. Use Trapezoidal, Simpson and Gauss Legendre methods and compare the results for small and large values of x.
c) Verify the degree of precision of each quadrature rule.
d) Approximate the value of π by evaluating the integral$\int_0^\infty \frac{1}{x^2+1} dx$using Simpson and Gauss Legendre method. More integrals may be evaluated.

Unit 6
Initial Value Problems (IVP):

a) Compare the errors in Euler, RK2 and RK4 by solving a first order IVP with known solution. Reduce the step size to a point where the round off errors takes over.
b) Radioactive decay: With a given number of initial nuclei and decay constant plot the number of nuclei left as a function of time and determine the half life
c) Solve a system of two first order differential equations by Euler, RK2 and RK4 methods. Use it to solve an nth order IVP. Solve a damped free and forced harmonic oscillator problem using this.
d) Solve a physics problem like free fall with air drag or parachute problem using RK method.
e) Obtain the current flowing in a series LCR circuit with constant voltage for a given set of initial conditions.

References for laboratory work:

1) Documentation at the Python home page (https://docs.python.org/3/) and the tutorials there (https://docs.python.org/3/tutorial/).
2) Documentation of NumPy and Matplotlib: https://numpy.org/doc/stable/user/ and https://matplotlib.org/stable/tutorials/
3) Computational Physics, D. Walker, 1st edition, 2015, Scientific International Pvt. Ltd
4) An Introduction to Computational Physics, T. Pang, 2010, Cambridge University Press
5) Python Programming and Numerical Methods - A Guide for Engineers and Scientists, Q. Kong, T.Siauw, A. M. Bayen, 2021, Academic Press

DISCIPLINE SPECIFIC ELECTIVE COURSE – PHYSICS DSE 12: PHYSICS OF EARTH

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Physics of Earth Physics DSE 12	**4**	**4**	**0**	**0**	Appeared in Semester 3	--

LEARNING OBJECTIVES

This course familiarizes the students with the origin of earth in the solar system and various processes occurring in atmosphere, oceans and earth's internal structure.

LEARNING OUTCOMES

At the end of this course student will be able to,

- Have an overview of structure of the earth as well as various dynamical processes occurring on it.
- Develop an understanding of evolution of the earth.
- Apply physical principles of elasticity and elastic wave propagation to understand modern global seismology as a probe of the Earth's internal structure.
- Understand the origin of magnetic field, geodynamics of earthquakes and the description of seismic sources; a simple but fundamental theory of thermal convection; the distinctive rheological behaviour of the upper mantle and its top.
- Explore various roles played by water cycle, carbon cycle, nitrogen cycles in maintaining steady state of earth leading to better understanding of the contemporary dilemmas (climate change, bio diversity loss, population growth, etc.) disturbing the Earth
- Develop the problem solving skills by adding numerical and simulations to clarify the fundamental concepts.

SYLLABUS OF DSE–12

THEORY COMPONENT

Unit – I **(10 Hours)**

The Earth and the Universe:

a) General characteristics and origin of the Universe. The Big Bang Theory. Estimation of age of the Universe and Hubble constant. Formation of Galaxies. Types of galaxies, Milky Way galaxy, Nebular hypothesis, Solar system, The Terrestrial and Jovian planets (Sizes, Acceleration due to gravity, Obliquity, Flatness, Eccentricity, Density, Temperature, Pressure, Atmosphere, Moons, Exceptions in trends). Titius-Bode law. Asteroid belt. Asteroids: origin types and examples, Meteorites.

b) Earth in the Solar system, origin, size, shape, mass, density, rotational and revolution parameters and its age. Earth's orbit and spin, the Moon's orbit and spin.

c) Energy and particle fluxes incident on the Earth.

Unit – II **(15 Hours)**

Structure of Earth:

a) The Solid Earth: topography (Maps, Techniques, Forms of Topographic data).
b) Internal structure: Core, mental, magnetic field. Origin of the Magnetic field. Convection in Earth's core and production of its magnetic field. Dynamo Theory, calculation of magnetic fields, Causes of variation of Magnetic Field and Palaeomagnetism.
c) The Hydrosphere: The oceans, their extent, depth, volume, chemical composition. Ocean circulations. Oceanic current system and effect of Coriolis forces.
d) The Cryosphere: Polar caps and ice sheets. Mountain glaciers, permafrost.

Unit – III **(15 Hours)**

Dynamical Processes:

a) The Solid Earth: Concept of plate tectonics; types of plate movements, hotspots; sea-floor spreading and continental drift.
b) Geodynamic elements of Earth: Mid Oceanic Ridges, trenches, transform faults and island arcs. Continents, mountains and rift valleys.
c) Earthquake and earthquake belts. Types and properties of Seismic waves, Richter scale, geophones.
d) Volcanoes: types, products and distribution.
e) Concepts of eustasy, air-sea interaction; wave erosion and beach processes. Tides. Tsunamis.

Unit – IV **(12 Hours)**

The Atmosphere

a) The Atmosphere: Features of different layers, variation of temperature with altitude; Dry, moist and environmental lapse rate, variation of density and pressure with altitude, Types of clouds and formation.
b) The Atmosphere: Atmospheric circulation. Causes of Atmospheric circulation, Formation of three cells, Easterlies and Westerlies, and ICTZ, Weather and climatic changes. Earth's heat budget. Cyclones and anti-cyclones, tropical storms, hurricanes and tornadoes.
c) Climate: Earth's temperature and greenhouse effect. Paleoclimate and recent climate changes. The Indian monsoon system.

Unit – V **(8 Hours)**

Disturbing the Earth – Contemporary dilemmas

a) Human population growth.
b) Hydrosphere: Fresh water depletion.
c) Geosphere: Chemical effluents, nuclear waste.
d) Biosphere: Biodiversity loss. Deforestation. Robustness and fragility of ecosystems. Water cycle, Carbon cycle. The role of cycles in maintaining a steady state.
e) Air Pollution: Types of air pollutants, Effects on atmosphere and living organisms. Ozone Hole.

References:

Essential Readings:

1) Planetary Surface Processes, H. J.Melosh, 2011, Cambridge University Press.
2) Holme's Principles of Physical Geology, 1992, Chapman &Hall.
3) Planet Earth, Cosmology, Geology and the Evolution of Life and Environment, C. Emiliani, 1992, Cambridge University Press.
4) Physics of the Earth, F. D. Stacey, P. M. Davis, 2008, Cambridge University Press.

5) Environmental Physics: Sustainable Energy and Climate Change, E. Boecker and R.V. Grondelle, 3rd edition, 2011, Wiley, UK
6) Atmospheric Remote Sensing (Principles and Applications, Editors – S. Tiwari and A. K. Singh, Chapter-1 (Composition and thermal structure of the Earth's atmosphere, by S. K. Dhaka and V. Kumar), 1st edition, Elsevier

Additional Readings:

1) The Blue Planet: An Introduction to Earth System Science, B. J. Skinner, S. C. Portere, 1994, John Wiley & Sons.
2) Consider a Spherical Cow: A course in environmental problem solving, J. Harte, University Science Books.
3) Fundamentals of Geophysics, W.Lowrie, 1997, Cambridge University Press.
4) The Solid Earth: An Introduction to Global Geophysics, C. M. R. Fowler, 1990, Cambridge University Press.
5) Climate Change: A Very Short Introduction, M. Maslin, 3rd edition, 2014, Oxford University Press.
6) The Atmosphere: A Very Short Introduction, P. I. Palmer, 2017, Oxford University Press.
7) IGNOU Study material: PHE 15 Astronomy and Astrophysics Block

COMMON POOL OF GENERIC ELECTIVES (GE) COURSES

GENERIC ELECTIVE (GE – 15): QUANTUM MECHANICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course	Department offering the course
		Lecture	Tutorial	Practical			
Quantum Mechanics GE – 15	4	3	1	0	Appeared in previous Semester	GE Modern Physics of this course or its equivalent	Physics and Astrophysics

LEARNING OBJECTIVES

The development of quantum mechanics has revolutionized the human life. In this course, the students will be exposed to the probabilistic concepts of basic non-relativistic quantum mechanics and its applications to understand the sub atomic world.

LEARNING OUTCOMES

After completing this course, the students will be able to,

- Learn the methods to solve time-dependent and time-independent Schrödinger equation.
- Characteristics of an acceptable wave function for any sub atomic particle in various potentials.
- Applications of the Schrodinger equation to different cases of potentials namely infinite and finite potential well, step potential, rectangular potential barrier, harmonic oscillator potential.
- Solve the Schrodinger equation in 3-D.
- Understand the spectrum and eigenfunctions for hydrogen atom

SYLLABUS OF GE - 15

THEORY COMPONENT

Unit – I **(10 Hours)**

Review of Schrodinger wave equation, applicability of operator, eigenvalues, eigenfunction, normalisation, expectation value to various kinds of potential, Superposition Principle, linearity of Schrodinger equation, General solution as a linear combination of discrete stationary states, Observables as operators,Commutator of position and momentum operators,Ehrenfest's theorem. Applicability to various kinds of wave functions

Unit – II **(15 Hours)**

General discussion of bound states in an arbitrary potential: Continuity of wave function, boundary conditions and emergence of discrete energy levels. Application to energy eigen states for a particle in a finite square potential well, reflection and transmission across step potential and rectangular potential barrier. Fourier transforms and momentum space wavefunction, time evolution of Gaussian wave packets, Uncertainty principle

Unit – III **(10 Hours)**

Harmonic oscillator: Energy eigen values and eigen states of a 1-D harmonic oscillator using algebraic method (ladder operators) and using Hermite polynomials. Zero point energy and uncertainty principle.Applications to various kinds of wavefunctions

Unit – IV **(10 Hours)**

Schrödinger Equation in three dimensions: Probability and probability densities in 3D. Schrödinger equation in spherical polar coordinates, its solution for Hydrogen atom solution using separation of angular and radial variables, Angular momentum operator, quantum numbers and spherical harmonics. Radial wavefunctions from Frobenius method, Orbital angular momentum quantum numbers l and ml, s, p, d shells

References:

Essential Readings:

1) Quantum Mechanics: Theory and Applications, A.Ghatak and S. Lokanathan,6th edition, 2019, Laxmi Publications, New Delhi.
2) Introduction to Quantum Mechanics, D.J. Griffith, 2nd edition, 2005, Pearson Education.
3) A Text book of Quantum Mechanics, P.M. Mathews and K. Venkatesan, 2nd edition,2010, McGraw Hill.
4) Quantum Mechanics, B. H. Bransden and C. J. Joachain, 2nd edition, 2000, Prentice Hall
5) Quantum Mechanics: Concepts and Applications, 2nd edition, N.Zettili, A John Wiley and Sons, Ltd., Publication
6) Atomic Physics, S. N. Ghoshal, 2010, S. Chand and Company

Additional Readings:

1) Quantum Mechanics for Scientists & Engineers, D.A.B. Miller, 2008, Cambridge University Press.
2) Introduction to Quantum Mechanics, R. H. Dicke and J. P. Wittke, 1966, Addison-Wesley Publications
3) Quantum Mechanics, L. I. Schiff, 3rd edition, 2010, Tata McGraw Hill.
4) Quantum Mechanics, R.Eisberg and R.Resnick, 2nd edition, 2002, Wiley
5) Quantum Mechanics, B. C. Reed, 2008, Jones and Bartlett Learning.
6) Quantum Mechanics, W. Greiner, 4th edition, 2001, Springer.
7) Introductory Quantum Mechanics, R. L. Liboff, 4th edition, 2003, Addison Wesley

GENERIC ELECTIVE (GE – 16) INTRODUCTION TO EMBEDDED SYSTEM

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course	Department offering the course
		Lecture	Tutorial	Practical			
Introduction to Embedded System Design GE – 16	4	2	0	2	Appeared in previous semester	NIL	Physics and Astrophysics

LEARNING OBJECTIVES

This paper aims to introduce the basic concepts or fundamentals of embedded system design to students not majoring in physics. The course covers the comprehensive introduction to embedded systems, their role and application areas in our daily life. Basic elements needed to design a typical embedded system are discussed to provide the students a broader perspective. Specific applications of embedded systems which are a part of our daily life were discussed. In the end Arduino Uno is introduced.

LEARNING OUTCOMES

Upon completion of this course, students will be able to,

- Learn about an embedded system and how it is different than a general purpose computing system like computer or laptop etc.
- The student should be able to identify various embedded systems available around us in our daily life.
- Classify embedded systems based on generation, complexity and performance, major applications areas etc.
- Explain the domains and areas of applications of embedded systems. The students should be able to get a broader perspective of different embedded systems available in industry, telecom, photography, homes, automobile, aviation and ship industry etc.
- Explain the roles and uses of various components like microcontroller, memory, sensors and actuators, interface types etc. of embedded systems.
- Know the basic characteristics and quality attributes that any typical embedded system must possess.
- This paper is designed in such a way that the students will be able to connect the textbook knowledge with basic design and working of the various embedded systems present in our daily life. By the end of this course the student will have a fairly good idea of embedded systems and the gained knowledge will be helpful in predicting the possible design and working of an unknown system. Arduino Uno is introduced so that students can learn how to use different sensors to control different processes.

SYLLABUS OF GE - 16

THEORY COMPONENT

UNIT – I - Introduction to Embedded Systems (3 Hours)

Embedded systems, historical background, difference between an embedded systems and general computing systems, classification of embedded systems based on generation, complexity and performance, major applications areas, purpose of embedded systems like in data collection/storage/representation, data communication, data/signal processing, monitoring, control, application specific user interface.

Unit – II - Elements of Embedded System (6 Hours)

Core of the embedded system: General purpose and domain specific processors like microprocessors, microcontrollers and digital signal processors, application specific integrated circuits (ASICs), programmable logic devices (PLDs), commercial off-the-shelf components (COTS), reduced instruction set computing (RISC) and complex instruction set computing (CISC), Harvard vs Von-Neumann architecture, different types of memory (RAM, ROM, Storage etc) their classification and different versions,reset circuit, oscillator unit

Unit – III - Peripheral devices, sensors and actuators (6 Hours)

General discussion on light emitting dodes (LEDs), 7-segment LED display, piezobuzzer, push button switch, keypad or keyboard (discuss design using push button switches), relay (single pole single throw), LDR, thermistor, IR sensor, ultrasonic sensor, opto-coupler, DC motors, servo motor, stepper motor (unipolar and bipolar)

Unit – IV - Communication Interface (2 Hours)

Serial and parallel interface, universal serial bus (USB), Infra-red data transfer, bluetooth (BT), Wi-Fi, general packet radio Service (GPRS), 3G, 4G, LTE

Unit – V - Characteristics and quality attributes of an embedded systems (3 Hours)

Characteristics: Application and domain specific,reactive and real time,operation under harsh environments,distributed or stand alone,size and weight,power consumption

Operationaland non-operational attributes: response time,throughput, reliability, maintainability, security, safety, testability and debug-ability, evolvability, portability, cost and revenue

Unit – VI - Applications of Embedded Systems (4 Hours)

General discussion on the design and working of washing machine, refrigerator, microwave oven, automobiles, mobile phones, hearing aid device, electrocardiogram (ECG), AC or TV remote control system, smart watch, digital camera and laser printers etc.

Unit – VII - Introduction to Arduino (6 Hours)

Pin diagram and description of Arduino UNO, basic programming and applications

References:

Essential Readings:

1) Introduction to embedded system, K.V. Shibu, 1st edition, 2009, McGraw Hill
2) Embedded Systems: Architecture, Programming and Design, R. Kamal, 2008, Tata McGraw Hill
3) Embedded Systems and Robots, S.Ghoshal, 2009, Cengage Learning.
4) Embedded Microcomputer systems: Real time interfacing, J. W. Valvano, 2011, Cengage Learning
5) Embedded System, B. K. Rao, 2011, PHI Learning Pvt. Ltd.
6) Programming Arduino: Getting Started with Sketches, S. Monk, 2nd edition, McGraw Hill

7) Arduino: Getting Started With Arduino and Basic Programming with Projects by E. Leclerc

Additional Readings:

1) The 8051 Microcontroller and Embedded Systems Using Assembly and C, M. A. Mazidi, J. G. Mazidi and R. D. McKinlay, 2nd edition, 2007, Pearson Education
2) Microprocessors and Microcontrollers, K. Kant, 2nd edition, 2016, PHI learning Pvt. Ltd.
3) The 8051 Microcontroller, Ayala, 3rdedition, Cengage learning

PRACTICAL COMPONENT

(15 Weeks with 4 hours of laboratory session per week)

- Every student must perform at least six experiments from the following list
- Mandatory exercise for all students: Familiarization with power supply, function generator, CRO/DSO, multimeter, bread board etc. Measure the frequency and amplitude (pp or rms) of a given signal using CRO/DSO. (The purpose is to acquaint the students with these instruments so that they can have a basic understanding of these instruments).

ARDUINO based Experiments:

1) Flashing LEDs ON/OFF after a given delay.
2) Design a simple transmitter and receiver circuit using IR LED and a detector and use it for obstacle detection.
3) Interface a simple relay circuit to switch ON and OFF a dc motor/LED.
4) Interface DC motor to Arduin Uno and rotate it clockwise and anticlockwise.
5) Interface Servo motor to Arduin Uno and rotate it clockwise and anticlockwise for a given angle.
6) Interface an ADC and read the output of the LDR sensor. Display the value on the serial monitor.
7) To design an alarm system using an Ultrasonic sensor.
8) To design a counter/Motion sensor alarm using IR Led and Detector
9) To design a circuit to control ON/OFF of LED light using LDR.
10) To design a circuit to control ON/OFF of a process using a thermistor.
11) To design a thermistor based thermometer.
12) Control the speed of the DC motor using LDR.

References for laboratory work:

1) Arduino Programming: 3 books in 1 - The Ultimate Beginners, Intermediate and Expert Guide to Master Arduino Programming, R. Turner
2) Arduino: Getting Started With Arduino and Basic Programming with Projects, E. Leclerc
3) Basic Electronics: A text lab manual, P. B. Zbar, A. P. Malvino, M. A. Miller, 1994, McGraw Hill.
4) Electronic Devices and circuit theory, R.L. Boylestadand L.D. Nashelsky, 2009, Pearson
5) Electronics: Fundamentals and Applications, J.D. Ryder, 2004, Prentice Hall.
6) Modern Electronic Instrumentation and Measurement Tech., Helfrick and Cooper,1990, PHI Learning.

GENERIC ELECTIVE (GE – 17) NANO PHYSICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course	Department offering the course
		Lecture	Tutorial	Practical			
Nano Physics GE – 17	4	2	0	2	Appeared in previous semester	NIL	Physics and Astrophysics

LEARNING OBJECTIVES

The syllabus introduces the basic concepts of nanomaterials, their synthesis, properties exhibited by them and finally few applications. Various nanomaterial synthesis/growth methods and characterizations techniques are discussed to explore the field in detail. The effect of dimensional confinement of charge carries on the electrical, optical and structural properties will be discussed. Interesting experiments which shape this filed like conductance quantization in 2DEG (Integer Quantum Hall Effect) and coulomb blockade are introduced. The concept of micro- and nano-electro mechanical systems (MEMS and NEMS) and important applications areas of nanomaterials are discussed.

LEARNING OUTCOMES

On successful completion of the course students should be able to,

- Explain the difference between nanomaterials and bulk materials and their property difference.
- Explain various methods for the synthesis/growth of nanomaterials.
- Explain the role of confinement on the density of state function and so on the various properties exhibited by nanomaterials compared to bulk materials.
- Explain the concept of quasi-particles such as excitons and how they influence the optical properties.
- Explain the direct and indirect bandgap semiconductors, radiative and non-radiative processes and the concept of luminescence.
- Explain the structure of 2DEG system and its importance in quantum transport experiments, like integer quantum Hall effect and conductance quantization.
- Explain the conductance quantization in 1D structure and its difference from the 2DEG system.
- Explain the necessary and sufficient conditions required to observe coulomb blockade, single electron transistor and the scope of these devices.
- Explain how MEMS and NEMS devices are produced and their applications.

SYLLABUS OF GE - 17

THEORY COMPONENT

Unit – I – Introduction **(3 Hours)**

Basic introduction to nano-science and technology - Implications on nanoscience on fields like Physics, Chemistry, Biology and Engineering, Classifications of nanostructured materials as quantum dots (0D), nanowires (1D), Thin films (2D) and Multilayered materials or super lattices; introduction to properties like mechanical, electronic, optical, magnetic and thermal properties and how they change at nano scale dimensions to motivate students (qualitative only).

Unit – II - Nanoscale Systems (8 Hours)

Brief review of Schrodinger equation and its applications in- Infinite potential well, potential step and potential box problems, band structure and density of states of 3D and 2D systems in detail and qualitatively for 1D and 0D, confinement of charges in nanostructures their consequences on electronic and optical properties.

Unit – III - Properties of Nano Scale systems (10 Hours)

Time and length scales (diffusion, elastic and inelastic lengths etc.) of electrons in nanostructured materials, Carrier transport in nanostructures: diffusive and ballistic transport

2D naomaterials: Conductance quantization in 2DEG in GaAs and integer quantum hall effect (semi-classical treatment)

1D nanomaterials: Conductance quantization in 1D structures using split gate in 2DEG system (Qualitative)

0D nanomaterials: Charging effect, Coulomb Blockade effect, Single Electron Transfer (SET) device

Basic understanding of excitons in semiconductors and their consequence on optical properties of the material

Unit – IV - Synthesis of Nanomaterials (Qualitative) (5 Hours)

Top down and Bottom up approach, Ball milling, Spin Coating

Vacuum deposition: Physical vapor deposition (PVD): Thermal evaporation, Sputtering, Chemical vapor deposition (CVD).

Preparation of colloidal solutions of Metals, Metal Oxide nanoparticles

Unit – V - Applications (Qualitative) (4 Hours)

Micro Electromechanical Systems (MEMS), Nano-electromechanical Systems (NEMS), Applications of nanomaterials as probes in medical diagnostics and targeted drug delivery, sunscreen, lotions, and paints and other examples to give broader perspective of applications of nanomaterials

References:

Essential Readings:

1) Introduction to Nanotechnology, C. P. Poole and Jr. Frank J. Owens, 1st edition, 2003, Wiley India Pvt. Ltd.
2) Nanotechnology: Principles and Practices, S. K. Kulkarni, 2nd edition, 2011, Capital Publishing Company
3) Introduction to Nanoscience and Technology, K. K. Chattopadhyay and A. N. Banerjee, 2009, PHI Learning Private Limited
4) Introduction to Nanoelectronics, V. V. Mitin, V. A. Kochelap and M. A. Stroscio, 2011, Cambridge University Press
5) Nanotechnology for Dummies, R. Booker and E. Boysen, 2005, Wiley Publishing Inc.
6) Introductory Nanoscience, M. Kuno, 2012, Garland science Taylor and Francis Group
7) Electronic transport in mesoscopic systems, S. Datta, 1997, Cambridge University Press.
8) Fundamentals of molecular spectroscopy, C. N. Banwell and E. M. McCash, 4th edition,

McGrawHill

Additional Readings:

1) Quantum Transport in semiconductor nanostructures, C. Beenakker and H. Van Houten, 1991, available at arXiv: cond-mat/0412664) Open Source
2) Ph.D. thesis, S. Cronewett, 2001, Available as Arxiv
3) Solid State Physics, J. R. Hall and H. E. Hall, 2^{nd}edition, 2014, Wiley

PRACTICAL COMPONENT

(15 Weeks with 4 hours of laboratory session per week)

At least six experiments to be performed from the following list

1) Synthesis of metal (e.g. Au/Ag)nanoparticles by chemical route and study its optical absorption properties.
2) Synthesis of semiconductor (CdS/ZnO/TiO_2/Fe_2O_3etc) nanoparticles and study its XRD and optical absorption properties as a function of ageing time.
3) Surface Plasmon study of metal nanoparticles as a function of size by UV-Visible spectrophotometer.
4) Analysis of XRD pattern of given nanomaterial and estimate lattice parameters and particle size.
5) To study the effect of the size nanoparticles on its color.
6) To prepare composite of CNTs with other materials and study their optical absorption/Transmission properties.
7) Growth of metallicthin filmsusing thermal evaporation technique.
8) Prepare a ceramic disc of a given compound and study its XRD/I-V characteristics/ measure its dielectric constant or any other property.
9) Fabricate a thin film of nanoparticles by spin coating (or chemical route) andstudy its XRD and transmittance spectra in UV-Visible region.
10) Prepare thin film capacitor and measure capacitance as a function oftemperature or frequency.
11) Fabricate a pnjunction diode by diffusing Al over the surface of N-type Si/Geand study itsV-I characteristic.
12) Fabricate thin films (polymer, metal oxide) using electro-deposition
13) To study variation of resistivity or sheet resistance with temperature of the fabricated thin films using four probe method.

References for laboratory work:

1) Introduction to Nanotechnology, C.P. Poole and Jr. Frank J. Owens, 1^{st} edition, 2003, Wiley India Pvt. Ltd.
2) Nanotechnology: Principles and Practices, S.K. Kulkarni, 2^{nd} edition, 2011, Capital Publishing Company
3) Introduction to Nanoscience and Technology, K. K. Chattopadhyay and A. N. Banerjee, 2009, PHI Learning Private Limited
4) Nanotechnology for Dummies, R. Booker and E. Boysen, 2005, Wiley Publishing Inc.

GENERIC ELECTIVE (GE – 18): PHYSICS OF DETECTORS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course	Department offering the course
		Lecture	Tutorial	Practical			
Physics of Detectors GE – 18	4	3	1	0	Appeared in previous Semester	GE Modern Physics of this course or its equivalent	Physics and Astrophysics

LEARNING OBJECTIVES

A detector is necessary for every physical measurement, and experimental physicists must be proficient in detector physics. The course will provide an overview of radiation and particle detectors, as well as how to use them in various experimental physics settings and application fields. The course covers the theory of detectors, their design and operation including electronic readoutsystems and signal processing. The fundamental physics processes for detecting radiation and particles are covered in the course, which include the photoelectric effect, Compton scattering, pair creation, excitation, ionization, bremsstrahlung, Cherenkov radiation, nuclear reactions, and secondary emissions.

LEARNING OUTCOMES

After completion of this course, studentsare expected to be able to,

- Understand the different types underlying fundamental physical processes for the detection of radiation and particles
- Acquire knowledge of design principles and characteristics of different types of detector
- Acquire knowledge of electronic readout systems and signal processing
- Assess the applicability of different types of detectors and detector systems in various fields of physics and applied sciences.

SYLLABUS OF GE - 18

THEORY COMPONENT

Unit – I **(12 Hours)**

Interaction of Radiation with matter: Interaction of radiation with matter (e.m. charged particles); detection of charged particles in magnetic field and measurement of charge to mass ratio; energy loss due to ionization (Bethe-Block formula), energy loss of electrons, Cerenkov radiation;gamma ray interaction through matter (photoelectric effect, Compton scattering, pair production); Dependence of electron and photon energy spectrum on materials (increasing Z); neutron interaction with matter

Unit – II **(8 Hours)**

Introduction to detectors: Basic principle of detector operation and its modes of operation, pulse height spectra, various detector performance parameters: response time, energy resolution, fano factor, efficiency: intrinsic and extrinsic, dead time.

Unit – III **(16 Hours)**

Detectors:

Gas detectors: Detector gases, gas detector characteristics, different types of detectors: gas filled ionization detectors (ionization chamber), bubble and cloud chambers, proportional counters, multi wire proportional counters (MWPC), Geiger Mueller (GM) counters and avalanche counters, gaseous multiplication detector.

Scintillation detectors: General characteristics, organic scintillators (anthraceneandplastic), inorganic crystals (NaI(Tl), CsI(Tl)), Charge Coupled Devices (CCD)

Photomultipliers: Basic construction and operation, time response and resolution, noise, gain stability;scintillation counter operation

Semiconductor detectors: Doped semiconductors, np semiconductor junction, depletion depth, detector characteristics of semiconductors. silicon and germanium detectors

Neutron detectors (gas-filled, scintillation, and semiconducting): slow and fast neutron detectors

Bolometric detectors: Working principle, characteristics and use of infrared detectors

Unit - IV **(5 Hours)**

Electronics, signal processing and techniques for data acquisition and analysis: Basic idea of analog and digital signal processing, noise and its types;instrumentation standards for nuclear instruments: NIM, ECL; TTL standards

Data acquisition system: VME and Digital pulse processing system.

Unit - V **(4 Hours)**

Application of detectors: for particle physics experiments, for nuclear physics, for astrophysics and cosmology, medical physics and imaging, by giving two examples each.

References:

Essential Readings:

1) Radiation detection and measurement, G. F. Knoll, 2010, John Wiley and Sons
2) Principles of radiation interaction in matter and detection, C. Leroy and P.G. Rancoita, 3rd edition, 2011, World Scientific
3) Techniques for Nuclear and Particle Physics experiments, W. R. Leo, 1994, Springer
4) Nuclear Radiation Detectors, S. S. Kapoor and V. S. Ramamurthy, 1st edition, John Wiley and Sons.
5) Physics and Engineering of Radiation Detection, S. N. Ahmed, 2007, Academic Press Elsevier
6) Semiconductor detectors: New developments, E. Gatti and P. Rehak, 2002, Springer

Additional Readings:

1) Radiation Detection for Nuclear Physics Methods and industrial applications, D. Jenkins
2) Advanced Nuclear Radiation Detectors Materials, processing, properties and applications, A. K.Batra, IOP Publishing
3) Measurement and Detection of Radiation, N.Tsoulfanidiset al., 4th edition, T and F CRC
4) Principles of nuclear radiation detection, G. G. Eichholz and J. W. Poston, CRC
5) Introduction to Nuclear Radiation Detectors: 2, Laboratory Instrumentation and Techniques, P. Ouseph, Springer
6) Detectors for Particle Radiation, K.Kleinknecht, Cambridge
7) Particle Detectors, C.Grupen, Cambridge
8) Handbook of Particle Detection and Imaging, C.Grupen and I. Buvat

GENERIC ELECTIVE (GE – 19): NUCLEAR AND PARTICLE PHYSICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course	Department offering the course
		Lecture	Tutorial	Practical			
Nuclear and Particle Physics GE – 19	4	3	1	0	Appeared in previous Semester	NIL	Physics and Astrophysics

LEARNING OBJECTIVES

This course imparts the understanding of the sub atomic particles and their properties; introduces various nuclear phenomena and their applications, interactions of basic building blocks of matter through fundamental forces, the inherent discrete symmetries of particles and complements each and every topic with applications and problems.

LEARNING OUTCOMES

After completion of this course, studentsare expected to have an understanding of,

- Nuclear charge and mass density, size, magnetic and electric moments
- Theoretical principles and experimental evidences towards modelling the nucleus
- Kinematics of nuclear reactions and decays
- Energy loss of radiation during propagation in medium
- Principles of nuclear detection technique
- Classification of fundamental forces based on their range, time-scale and mediator mass.
- Scattering cross-sections of 2 to 2 processes and their inherent symmetries.
- Angular and energy distributions for three body decay process.
- Discrete symmetries of nature and associated conservation laws
- Colour triplet quarks and anti-quarks as constituents of observed colour singlet baryons and mesons.

SYLLABUS OF GE 19

THEORY COMPONENT

Unit – I **(5 Hours)**

General properties of nuclei: Constituents of nucleus and their Intrinsic properties: quantitative facts about mass, radii, charge density, matter density, binding energy, N/Z plot, angular momentum, parity, magnetic moment, electric moments.

Unit – II **(5 Hours)**

Nuclear models: Liquid drop model approach, semi empirical mass formula and significance of its various terms, condition of nuclear stability, evidence for nuclear shell structure and the basic assumptions of shell model, magic numbers.

Unit – III **(7 Hours)**

Radioactivity decay: Decay rate and equilibrium (secular and transient)
(a) Alpha decay: basics of α-decay processes, Gamow factor, Geiger Nuttall law, α-decay spectroscopy, decay Chains.
(b) β-decay: energy kinematics for β-decay, β-spectrum, positron emission, electron capture, neutrino hypothesis.
(c) Gamma decay: Gamma ray emission from the excited state of the nucleus and kinematics, internal conversion.

Unit – IV **(5 Hours)**
Nuclear reactions: Kinematics of reactions, Q-value, reaction rate, reaction cross section, Concept of compound and direct reaction, Coulomb scattering (Rutherford scattering).

Unit – V **(8 Hours)**
Interaction of nuclear radiation with matter: Energy loss due to ionization (Bethe-Block formula), energy loss of electrons, Cerenkov radiation; Gamma ray interaction through matter Detector for nuclear radiations: Basics of types of detectors: gas detectors, scintillation detector, semiconductor detector(principle, schematics of construction and working)

Unit – VI **(15 Hours)**
Particle Physics: Overview of particle spectrum and their interactions in the Standard Model;range, time-scale and relative strength of interactions;interactions at a distance mediated by virtual particles (Exchange Force)
Kinematics for 2 -> 2 scattering processes and crossing symmetries of scattering amplitudes; angular and energy distributions of decaying particles in 1-> 3 decay processes (muon decay/beta decay); identification of invisibles (neutrinos) from energy and transverse momentum distributions
Lepton and Baryon quantum numbers;isospin, strangeness and hypercharge; Gell-Mann-Nishijima formula;parity and charge conjugation of a particle state; time reversal and general CPT theorem
Valence quark model of Murray Gell-Mann and Yuval Ne'eman, current and constituent masses of quarks, flavor symmetry isospin triplets, baryon octet, decuplet and meson octet; existence of Δ^{++} baryon as a clue for necessity of colour quantum number;evidence for colour triplet quarks from e^+e^- annihilation experiment;confinement of quarks, antiquarks and gluons in hadrons
High energy scattering experiments at linear and circular colliders, inelastic collisions at hadron colliders;elastic and inelastic neutrino-nucleus scattering experiments

References:
Essential Readings:
(A) For Nuclear Physics
1) Basic ideas and concepts in nuclear physics: An introductory approach, K. Heyde, 3rd edition, 1999, IOP Publication
2) Introductory Nuclear Physics, K. S.Krane, 2008, Wiley-India Publication
3) Nuclear Physics, S. N.Ghoshal, 1st edition, 2010, S. Chand Publication
4) Nuclear Physics: Principles and applications, J. Lilley, 2006, Wiley Publication
5) Concepts of Nuclear Physics, B. L. Cohen, 1974, Tata McGraw Hill Publication
6) Radiation detection and measurement, G. F. Knoll, 2010, John Wiley and Sons

(B) For Particle Physics
1) Modern Particle Physics, M. Thompson, 2013, Cambridge University Press

2) Particles and Nuclei: An Introduction to the Physical Concepts, B.Povh, K.Rith, C.Scholz, F.Zetsche and W.Rodejohann, 2015, Springer-Verlag
3) An Introductory Course of Particle Physics, P. B. Pal, 2015, CRC Press
4) Introduction to High Energy Physics, D. H. Perkins, 4th edition, 2000, Cambridge University Press
5) Introduction to elementary particles, D. J. Griffiths, 2008, Wiley
6) Quarks and Leptons, F. Halzen and A. D. Martin, 1984, John Wiley

Additional Readings:

References for Tutorial

1) Problems and Solutions in Nuclear and Particle Physics, S.Petreta, 2019, Springer
2) Schaum's Outline of Modern Physics, 1999, McGraw-Hill
3) Schaum's Outline of College Physics, E. Hecht, 11th edition, 2009, McGraw Hill
4) Problems and Solutions on Atomic, Nuclear and Particle Physics, Yung-Kuo Lim, 2000, World Scientific
5) Nuclear Physics "Problem-based Approach"including MATLAB, H. M. Aggarwal, 2016, PHI Learning Pvt. Ltd

GENERIC ELECTIVE (GE – 20): ATOMIC AND MOLECULAR PHYSICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course	Department offering the course
		Lecture	Tutorial	Practical			
Atomic and Molecular Physics GE – 20	4	3	1	0	Appeared in previous Semester	GE Modern Physics and GE Quantum Mechanics of this course or their equivalent	Physics and Astrophysics

LEARNING OBJECTIVES

This course introduces the basic concepts of atomic, molecular and nuclear physics to an undergraduate student. Advanced mathematics is avoided and the results of quantum mechanics are attempts to explain, or even to predict, the experimental observations of spectroscopy. The student will be able to visualize an atom or molecule as a physical entity rather than a series of mathematical equations.

LEARNING OUTCOMES

On successful completion of the module students should be able to elucidate the following main features.

- Stern-Gerlachexperiment, electron spin, spin magnetic moments
- Space quantization and Zeeman effect
- Spectral notations for atomic and molecular states and corresponding term symbols
- Understanding of atomic spectra and molecular spectra
- Basic principle of Raman spectroscopy and Franck Condon principle
- To complete scientific potential lies on the way we are able to interpret the fundamental astrophysical and nuclear data. This acquired knowledge will be a common base for the areas of astrophysics, nuclear, medical, geology and other inter-disciplinary fields of Physics, Chemistry and Biology. Special skills required for the different fields will be enhanced.

SYLLABUS OF GE 20

THEORY COMPONENT

Unit – I – Atomic Physics (23 Hours)

One-electron atoms: Degeneracy of energy levels and selection rules, modes of relaxation of an excited atomic state,line intensities and the lifetimes of excited states, line shapes and widths

Fine structure of hydrogenic atoms: Shifting of energy levels, splitting of spectral lines, relativistic correction to kinetic energy, spin-orbit term, Darwin term, fine structure spectral lines, Lamb shift (qualitative idea)

Atoms in external magnetic fields: Larmor'stheorem, Stern-Gerlach experiment, normal Zeeman effect,Paschen Back effect, and anomalous Zeeman effect, g-factors

Two and multi-electron systems: Spin multiplicity, singlet and triplet states and selection rules in helium atom, central field approximation, Aufbau and Pauli exclusion principle,

Slater determinant, LS and JJ coupling scheme (equivalent and non-equivalent electrons), term symbols and Hund's rule,Lande' interval rule
Qualitative Discussion of: Lamb shift and Auger effect.

Unit – II - Molecular Physics (22 Hours)

Electronic states of diatomic molecules: Linear combination of atomic orbitals (LCAO), bonding and antibonding orbitals; 'gerade', 'ungerade', molecular orbitals and the ground state electronic configurations for homo and hetero-nuclear diatomic molecules, classification of molecular excited states of diatomic molecule, Vector representation of Orbital and electron spin angular momenta in a diatomic molecule, The Born-Oppenheimer approximation, Concept of Potential energy curve for a diatomic molecule, Morse potential. The Franck-Condon principle

Molecular Spectra of diatomic molecule: Rotational Spectra (rigid and non-rigid rotor), Vibrational Spectra (harmonic and anharmonic), Vibration-Rotation Spectrum of a diatomic molecule, Isotope effect, Intensity of spectral lines

Raman Effect: Classical Theory (with derivation) of Raman effect, pure rotational Raman Lines, Stoke's and Anti-Stoke's Lines, comparison with Rayleigh scattering

Idea of spin resonance spectroscopy (Nuclear Magnetic Resonance, Electron Spin Resonance) with few examples, estimation of magnetic field of the Sun.

References:

Essential Readings:

1) Physics of Atoms and Molecules, B. H. Bransden and C. J. Jochain, 2nd edition, Pearson
2) Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash, 1994, Tata McGraw – Hill
3) Atomic physics, J. B. Rajamand foreword by Louis De Broglie, 2010, S. Chand and Co.
4) Atoms, Molecules and Photons, W. Demtroder, 2nd edition, 2010, Springer
5) Atomic, Nuclear and. Particle Physics. Compiled by. The Physics Coaching Class. University of science and Technology of China,edited By Yung-Kuo Lim. World scientific.
6) Atomic Physics, S.N. Ghoshal, 2019, S. Chand Publication
7) Introduction to Spectroscopy, D. L. Pavia, G. M. Lampman, G. A. Kriz and J. R. Vyvyan, 5th edition, 2014, Brookes/Cole

Additional Readings:

1) Basic Atomic and Molecular Spectroscopy, J. M. Hollas, Royal Society of Chemistry
2) Molecular Spectra and Molecular Structure, G. Herzberg
3) Introduction to elementary particles, D. J Griffiths, 2008, Wiley
4) Atomic and molecular Physics, R. Kumar, 2013, Campus Book Int.
5) The Fundamentals of Atomic and Molecular Physics, Undergraduate Lecture Notes in Physics, 2013, Springer