दिल्ली विश्वविद्यालय
UNIVERSITY OF DELHI

Bachelor of Science (Honours) Physics

(Effective from Academic Year 2019-20)

Revised Syllabus as approved by

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Applicable for students registered with Regular Colleges.

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Preamble

Higher Education in India is in need of reform. On the one hand, while there is a need for increased access to higher education in the country, it is also necessary to improve the quality of higher education. New initiatives and sustained efforts are needed to develop and enhance the spirit of enquiry, analytical ability and comprehension skills of the young generation of students. An emerging knowledge based society requires that they are able to acquire and generate new knowledge and skills, and can creatively apply them to excel in their chosen vocations. Our higher education system needs to inculcate exemplary citizenship qualities and motivate students to contribute to the society at large. Such abilities and qualities of our youth will be crucial for the country to face the challenges of the future.

One of the reforms in undergraduate (UG) education, initiated by the University Grants Commission (UGC) at the national level in 2018, is to introduce the Learning Outcomes-based Curriculum Framework (LOCF) which makes it student-centric, interactive and outcome-oriented with well-defined aims and objectives.

The Department of Physics and Astrophysics, University of Delhi took up the task of drafting the LOCF for UG Physics courses according to guidelines sent in March 2019 by the Undergraduate Curriculum Review Committee (UGCRC)-2019 of the University of Delhi. The Committee of Courses of the Department constituted a Steering Committee, whose composition is given in Annexure 1A, to plan and formulate the LOCF for UG Physics courses of the University. The Steering Committee formed Subject Working Groups (Annexure 1B) to formulate the content of different sets of courses. The Subject Working Groups included teachers from more than twenty colleges of the University, who have experience of teaching the respective courses. About eighty faculty members from the Department of Physics and Astrophysics and Physics Departments of colleges of the University have contributed to this important task. The inputs of the Subject Working Groups were compiled, and the present document prepared by a final drafting team (Annexure 1C).

The University of Delhi offers the undergraduate B.Sc. (Honours) Physics programme, the B.Sc. Physical Sciences programme with Physics and Electronics disciplines, as well as general elective courses in Physics for students of Honours programmes in disciplines other than Physics. The LOCF has been prepared for all of the above.

An earlier draft of the LOCF of the University of Delhi was put in the public domain for stakeholders' comments in May 2019. This was a revised version of the existing Choice Based Credit System (CBCS) undergraduate programme at the University of Delhi. We thank the stakeholders who took time and made effort to give us feedback on the earlier draft. Many of the comments received have helped us improve the LOCF draft.

We acknowledge the use of the document "Learning Outcomes based Curriculum Framework (LOCF) for Undergraduate Programme B.Sc. (Physics) 2019" put up by the UGC on its website in May 2019 (https://www.ugc.ac.in/pdfnews/1884134_LOCF-Final_Physics-report.pdf) and prepared by its Subject Expert Committee for Physics. This document has helped in clarifying the features of the LOCF and is the original source of a significant part of the text of the present document.

Keywords

Core Courses (CC)

Course Learning Outcomes (CLO)

Ability Enhancement Compulsory Course (AECC)

Discipline Specific Electives (DSE)

Generic Electives (GE)

Learning Outcome-based Curriculum Framework (LOCF)

Programme Learning Outcomes

Skill Enhancement Courses (SEC)

Student Centric

Teaching Learning Processes

Learning Outcomes-Based Curriculum Framework for Undergraduate Education in Physics

1. INTRODUCTION

The learning outcomes-based curriculum framework for a degree in B.Sc. (Honours) Physics is intended to provide a comprehensive foundation to the subject, and to help students develop the ability to successfully continue with further studies and research in the subject. The framework is designed to equip students with valuable cognitive abilities and skills so that they are successful in meeting diverse needs of professional careers in a developing and knowledge-based society. The curriculum framework takes into account the need to maintain globally competitive standards of achievement in term of the knowledge and skills in Physics, as well develop scientific orientation, enquiring spirit, problem solving skills and values which foster rational and critical thinking.

Due to the large diversity in India, a central university like the University of Delhi gets students from very different academic backgrounds, regions and language zones. While maintaining high standards, the learning outcome-based curriculum provides enough flexibility to teachers and colleges to respond to diverse needs of students.

The learning outcome-based curriculum framework for undergraduate courses in Physics also allows for flexibility and innovation in the programme design to adopt latest teaching and assessment methods and include introduction to new areas of knowledge in the fast-evolving subject domains. The process of learning is defined by the following steps which form the basis of final assessment of the achievement at the end of the program.

(i)   Development of an understanding and knowledge of basic Physics. This involves exposure to basics facts of nature discovered by Physics through observations and experiments. The other core component of this development is introduction to physics concepts and principles, their theoretical relationships in laws of Physics, and deepening of their understanding via appropriate problems.

(ii) The ability to use this knowledge to analyze new situations and learn skills and tools like laboratory techniques, computational methods, and applied mathematics to find solution, interpret results and make meaningful predictions.

(iii) The ability to synthesize the acquired knowledge and experience for an improved comprehension of the physical problems and to create new skills and tools for their possible solutions.

2.LEARNING OUTCOMES BASED CURRICULUM FRAMEWORK FOR PROGRAMME IN B.SC. (HONS.) PHYSICS

2.1 NATURE AND EXTENT OF THE PROGRAMME IN B.SC. (HONS.) PHYSICS

The B.Sc. (Hons.) Physics programme builds on the basic Physics taught at the +2 level in all the schools in the country. Ideally, the +2 senior secondary school education should aim and achieve a sound grounding in understanding the basic Physics with sufficient content of topics from modern Physics and contemporary areas of exciting developments in physical sciences. The curricula and syllabi should be framed and implemented in such a way that the basic connection between theory and experiment and its importance in understanding Physics is made clear to students. This is very critical in developing a scientific temperament and the urge to learn and innovate in Physics and other sciences. Unfortunately the condition of our school system in most parts of the country lacks the facilities to achieve the above goal, and it is incumbent upon the college/university system to fill gaps in the scientific knowledge and understanding of our country's youth who complete school curricula and enter university education.

Physics is an experimental and theoretical science that studies systematically the laws of nature operating at length scales from the sub-atomic domains to the entire universe. The scope of Physics as a subject is very broad. The core areas of study within the disciplinary/subject area of the B.Sc. (Hons.) Physics programme are: Classical and Quantum Mechanics, Electricity and Magnetism, Thermal and Statistical Physics, Wave theory and Optics, Physics of the Materials, Digital Electronics, and specialized methods of Mathematical Physics and their applications in different branches of the subject. Along with the theoretical course work students also learn physics laboratory methods for different branches of physics, specialized measurement techniques, analysis of observational data, including error estimation, and scientific report writing. The latest addition to Physics pedagogy incorporated in the LOCF framework is computational physics, which involves adaptation of Physics problems for algorithmic solutions, and modelling and simulation of physical phenomenon. The elective modules of the framework offer students choice to gain knowledge and expertise in more specialized domains of Physics like Nuclear and Particle physics, Nanophysics, Astronomy and Astrophysics, etc. and interdisciplinary subject areas like Biophysics, Geophysics, Environmental Physics, Medical Physics, etc.

The physics-based knowledge and skills learnt by students also equip them to be successful in careers other than research and teaching in Physics.

2.2 AIMS OF BACHELOR'S DEGREE PROGRAMME IN B.SC. (HONS.) PHYSICS

The LOCF based UG educational program in Physics aims to
- create the facilities and learning environment in educational institutions to consolidate the knowledge acquired at +2 level, motivate students to develop a deep interest in Physics, and to gain a broad and balanced knowledge and understanding of physical concepts, principles and theories of Physics.

- provide opportunities to students to learn, design and perform experiments in lab, gain an understanding of laboratory methods, analysis of observational data and report writing, and acquire a deeper understanding of concepts, principles and theories learned in the classroom through laboratory demonstration, and computational problems and modelling.
- develop the ability in students to apply the knowledge and skills they have acquired to get to the solutions of specific theoretical and applied problems in Physics.
- to prepare students for pursuing the interdisciplinary and multidisciplinary higher education and/or research in interdisciplinary and multidisciplinary areas, as Physics is among the most important branches of science necessary for interdisciplinary and multidisciplinary research.
- to prepare students for developing new industrial technologies and theoretical tools for applications in diverse branches of the economic life of the country, as Physics is one of the branches of science which contribute directly to technological development; and it has the most advanced theoretical structure to make quantitative assessments and predictions, and
- in light of all of the above to provide students with the knowledge and skill base that would enable them to undertake further studies in Physics and related areas, or in interdisciplinary/multidisciplinary areas, or join and be successful in diverse professional streams including entrepreneurship.

3. GRADUATE ATTRIBUTES FOR B.SC. (HONS.) PHYSICS

Some of the characteristic attributes of a graduate in Physics are
- **Disciplinary knowledge**
 (i) Comprehensive knowledge and understanding of major concepts, theoretical principles and experimental findings in core areas of Physics -like Classical and Quantum mechanics, Thermodynamics and Statistical mechanics, Electricity, Magnetism and Electromagnetic theory, Wave Theory, Optics, Solid State Physics, and Analogue and Digital electronics; and in the chosen disciplinary elective sub field of the subject like Nuclear and Particle Physics, Analytical dynamics, Astronomy and Astrophysics , Advanced Mathematical Physics, Nanophysics and interdisciplinary subfields like Biophysics, Geophysics, Atmospheric Physics, Medical Physics, Embedded Systems, etc..
 (ii) Ability to use physics laboratory methods and modern instrumentation for designing and implementing new experiments in physics, interdisciplinary/multidisciplinary research areas and industrial research.
- **Skilled communicator:** Ability to transmit abstract concepts and complex information relating to all areas in Physics in a clear and concise manner through scientific report writing. Ability to express complex relationships and information through graphical methods and proper tabulation. Ability to explain complex processes through simulation and modelling. Ability to express complex and technical concepts orally in a simple, precise and straightforward language for better understanding.
- **Critical thinking:** Ability 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.

- **Sense of inquiry:** Capability for asking relevant/appropriate questions relating to the issues and problems in the field of Physics. Planning, executing and reporting the results of theoretical or experimental investigation.
- **Team player/worker**: Capable of working effectively in diverse teams in both classroom, laboratory, Physics workshop and in field-based situation.
- **Skilled project manager:** Capable of identifying/mobilizing 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.
- **Digitally Efficient*:* Capable of using computers for computational and simulation studies in Physics. Proficiency in appropriate software for numerical and statistical analysis of data, accessing and using modern e-library search tools, ability to locate, retrieve, and evaluate Physics information from renowned physics archives, proficiency in accessing observational and experimental data made available by renowned research labs for further analysis.
- **Ethical awareness/analytical reasoning*:* The graduates should be capable of demonstrating the ability to think and analyze rationally with modern and scientific outlook and adopt unbiased objectives and truthful actions in all aspects of work. They should be capable of identifying ethical issues related to their work. They should be ready to appropriately acknowledge direct and indirect contributions received from all sources, including from other personnel in the field of their work. They should be willing to contribute to the free development of knowledge in all forms. Further, unethical behavior such as fabrication, falsification or misrepresentation of data, or committing plagiarism, or not adhering to intellectual property rights should be avoided.
- **Social, National and International perspective:** The graduates should be able to develop a perspective about the significance of their knowledge and skills for social well-being. They should have a national as well as an international perspective about their work and career in the chosen field of academic and research activities.
- **Lifelong learners:** Capable of self-paced and self-directed learning aimed at personal development and for improving knowledge/skill development and reskilling in all areas of Physics.

4. QUALIFICATION DESCRIPTORS FOR GRADUATES IN B.Sc. (HONS.) PHYSICS

The qualification descriptor for B.Sc. (Hons.) Physics graduates include the following: They should be able to:
- Demonstrate

(i)   a systematic and coherent understanding of basic Physics including the concepts, theories and relevant experimental techniques in the domains of Mechanics, Electricity and Magnetism, Waves and Optics, Thermal Physics, Quantum Mechanics, Statistical Mechanics, Mathematical Physics and their applications in other areas of Physics;

(ii)   the ability to relate their understanding of physics to other sciences and hence orient their knowledge and work towards multi-disciplinary/inter-disciplinary contexts and problems;

(iii)   procedural knowledge that creates different types of professionals related to different areas of study in Physics and multi/interdisciplinary domains, including research and development, teaching, technology professions, and government and public service;

(iv)   skills in areas of specializations of their elective subfields so that they can continue with higher studies and can relate their knowledge to current developments in those subfields.

- Use knowledge, understanding and skills required for identifying problems and issues relating to Physics, and its interface with other subjects studied in the course; collect relevant quantitative and/or qualitative data from a wide range of sources including various research laboratories of the world, and do analysis and evaluation using appropriate methodologies..

- Use knowledge, understanding and skills required for identifying problems and issues relating to Physics, and its interface with other subjects studied in the course; collect relevant quantitative and/or qualitative data from a wide range of sources from various research laboratories of the world, their application, analysis and evaluation using appropriate methodologies..

- Communicate the results of studies undertaken accurately in a range of different contexts using the main concepts, constructs and techniques of Physics and other subjects studied in the course. Develop communication abilities to present these results in technical as well as popular science meetings.

- Ability to meet their own learning needs, drawing on a range of pedagogic material available on the internet and books, current research and development work and professional materials, and in interaction with other science professionals.

- Apply their knowledge of Physics (theoretical and laboratory skills) to new/unfamiliar contexts to identify and analyze problems and issues, solve complex problems in Physics and its interface with other subjects.

- Demonstrate Physics-related technological skills that are relevant to Physics-related trades and employment opportunities.

5. PROGRAMME LEARNING OUTCOMES IN B.Sc. (HONS.) PHYSICS

Students graduating with the B.Sc. (Honours) Physics degree should be able to

- Acquire
  (i) a fundamental/systematic and coherent understanding of the academic field of basic Physics in areas like Mechanics, Electricity and Magnetism, Waves and Optics, Thermal and Statistical Physics, Quantum Mechanics, Mathematical Physics and their applications to other core subjects in Physics;
  (ii) a wide ranging and comprehensive experience in physics laboratory methods in experiments related to mechanics, optics, thermal physics, electricity, magnetism, digital electronics, solid state physics and modern physics. Students should acquire the ability for systematic observations, use of scientific research instruments, analysis of observational data, making suitable error estimates and scientific report writing.
  (iii) procedural knowledge that creates different types of professionals related to the disciplinary/subject area of Physics, including professionals engaged in research and development, teaching and government/public service;
  (iv) Knowledge and skills in areas related to their specialization area corresponding to elective subjects within the disciplinary/subject area of Physics and current and emerging developments in the field of Physics.

- Demonstrate the ability to use skills in Physics and its related areas of technology for formulating and tackling Physics-related problems and identifying and applying appropriate physical principles and methodologies to solve a wide range of problems associated with Physics.
- Recognize the importance of mathematical modelling simulation and computational physics, and the role of approximation and mathematical approaches to describing the physical world.
- Plan and execute Physics-related experiments or investigations, analyze and interpret data/information collected using appropriate methods, including the use of appropriate software such as programming languages and purpose-written packages, and report accurately the findings of the experiment/investigations while relating the conclusions/findings to relevant theories of Physics.
- Demonstrate relevant generic skills and global competencies such as
  (i) problem-solving skills that are required to solve different types of Physics-related problems with well-defined solutions, and tackle open-ended problems that belong to the disciplinary area boundaries;
  (ii) Investigative skills, including skills of independent investigation of Physics-related issues and problems;
  (iii) Communication skills involving the ability to listen carefully, to read texts and research papers analytically and to present complex information in a concise manner to different groups/audiences of technical or popular nature;
  (iv) analytical skills involving paying attention to detail and ability to construct logical arguments using correct technical language related to Physics and ability to translate them with popular language when needed;
  (v) ICT skills;
  (vi) Personal skills such as the ability to work both independently and in a group.
- Demonstrate professional behavior such as

(i) being objective, unbiased and truthful in all aspects of work and avoiding unethical, irrational behavior such as fabricating, falsifying or misrepresenting data or committing plagiarism;

(ii) the ability to identify the potential ethical issues in work-related situations;

(iii) be committed to the free development of scientific knowledge and appreciate its universal appeal for the entire humanity;

(iii) appreciation of intellectual property, environmental and sustainability issues;

(iv) promoting safe learning and working environment.

6. TEACHING LEARNING PROCESSES

The teaching learning processes play the most important role in achieving the desired aims and objectives of the undergraduate programs in Physics. The LOCF framework emphasizes learning outcomes for every physics course and its parts. This helps in identifying most suitable teaching learning processes for every segment of the curricula. Physics is basically an experimental science with a very elaborate and advanced theoretical structure. Systematic observations of controlled experiments open up windows to hidden properties and laws of nature. Physics concepts and theories are meant to create a systematic understanding of these properties and laws. All principles and laws of physics are accepted only after their verifications and confirmations in laboratory, or observations in the real world, which require scientists trained in appropriate experimental techniques, and engineers to design and make advanced scientific instruments. Physics graduates need a deep understanding of physics concepts, principles and theories, which require familiarity with different branches of mathematical physics. To achieve these goals, the appropriate training of young individuals to become competent scientists, researchers and engineers in future has to be accomplished. For this purpose a very good undergraduate program in Physics is required as a first step. An appropriate teaching-learning procedural protocol for all the colleges is therefore essential. To be specific, it is desirable to have:

Sufficient number of teachers in permanent position to do all the class room teaching and supervise the laboratory experiments to be performed by the students.

- All teachers should be qualified as per the UGC norms and should have good communication skills.
- Sufficient number of technical and other support staff to run the laboratories, libraries, equipment and maintain the infrastructural facilities like buildings, ICT infrastructure, electricity, sanitation, etc.
- Necessary and sufficient infrastructural facilities for the class rooms, laboratories and libraries.
- Modern and updated laboratory equipment needed for the undergraduate laboratories and reference and text books for the libraries.
- Sufficient infrastructure for ICT and other facilities needed for technology-enabled learning like computer facilities, PCs, laptops, Wi-Fi and internet facilities with all the necessary software.

Teachers should make use of all the approaches for an efficient teaching-learning process, i.e.:

(i) Class room teaching with lectures using traditional as well as electronic boards.

(ii) Demonstration of the required experiments in laboratory and seesions on necessary apparatuses, data analysis, error estimation and scientific report writing for effective and efficient learning of laboratory techniques.

(iii) Imparting a problem solving ability which enables a student to apply physical and mathematical concepts to a new and concrete situation is essential to all courses. This can be accomplished through examples discussed in the class or laboratory, assignments and tutorials.

(iv) CBCS curriculum has introduced a significant content of computational courses. Computational physics should be used as a new element in the physics pedagogy, and efforts should be made to introduce computational problems, including simulation and modelling, in all courses.

(v) Teaching should be complimented with students seminar to be organized very frequently.

(vi) Guest lectures and seminars should be arranged by inviting eminent teachers, and scientists.

(vii) Open-ended project work should be given to all students individually, or in group to 2-3 students depending upon the nature of the course.

(viii) Since actual UG program teaching is done in affiliated colleges which have differing levels of infrastructure and student requirements, the University department should organize regular workshops for college faculty on latest laboratory equipment and experiments, and computational physics software for achieving uniform standards.

(ix) Internship of duration varying from one week anytime in the semester, and/or 2-6 weeks during semester break and summer breaks should be arranged by the college for the students to visit other colleges/universities/HEI and industrial organizations in the vicinity. If needed, financial assistance may also be provided for such arrangements.

(x) Special attempts should be made by the institution to develop problem-solving skills and design of laboratory experiments for demonstration at the UG level. For this purpose a mentor system may be evolved where 3-4 students may be assigned to each faculty member.

(xi) Teaching load should be managed such that the teachers have enough time to interact with the students to encourage an interactive/participative learning.

A student completing the Physics Hons course under the CBCS takes 14 core courses, 4 discipline specific elective (DSE) courses, 4 general elective (GE) courses, two skill enhancement courses (SEC) and two ability enhancement compulsory courses (AECC). Since different categories of courses have different objectives and intended learning outcomes, the most efficient and appropriate teaching learning processes would not be same for all categories of courses.

6.1 TEACHING LEARNING PROCESSES FOR CORE COURSES

The objective of Core courses is to build a comprehensive foundation of physics concepts, principles and laboratory skills so that a student is able to proceed to any specialized branch. Rather than a quantitative amalgamation of disparate knowledge, it is much more preferable that students gain the depth of understanding and ability to apply what they have learnt to diverse problems. Problem solving should be integrated into the teaching of core courses and proportionally more time should be spent on it. It is advisable that a list of problems is distributed to students before the discussion of every topic, and they encouraged to solve

these in the self-learning mode, since teachers are unlikely to get time to discuss all of them in the class room. Under the current CBCS system the teaching of core courses suffers from a serious lacuna. A structural reform under CBCS system to allow for tutorial sessions to accompany the core course would greatly facilitate these courses.

In the first year students are fresh from school. Given the diversity of their backgrounds, and the lack of adequate infrastructure and training in the school science learning, special care and teacher attention is essential in the first year. Mentorship with senior students and teachers can help them ease into rigorous of university level undergraduate learning. It is also the time when many students get their first proper exposer to physics laboratory work. Demonstration on the working of required apparatuses should be given in few beginning labs. Sessions on experimental data analysis, error estimation, and scientific report writing are crucial in the first year physics laboratory teaching. Once a good foundation for the experimental physics is created in the first year, then students can work on their own in subsequent labs, and also get motivated to explore experimental physics projects outside their curricula.

Many students get their first exposure to computers as a working tool (rather than a means of communication and entertainment) in computational lab courses. A great degree of hand holding is necessary during first computational physics courses. Since computational work can easily be done outside the designated laboratory hours, mentor ship can be very useful in helping students become comfortable with computers. Colleges should try that students from weaker economic backgrounds especially have adequate access to computers.

6.2 TEACHING LEARNING PROCESSES FOR DISCIPLINE SPECIFIC ELECTIVES

The objective of DSE papers is to expose students to domain specific branches of physics and prepare them for further studies in the chosen field. While students must learn basic theoretical concepts and principles of the chosen domain, a sufficient width of exposure to diverse topics is essential in these papers. Student seminars and projects can be a very fruitful way to introduce students to the latest research level developments. Students should be encouraged to use their computational physics skills to work on publicly available observational data put out by many research labs and observatories worldwide.

6.3 TEACHING LEARNING PROCESSES FOR SKILL ENHANCEMENT COURSES

Skill Enhancement papers are intended to help students develop skills which may or may not be directly applicable to physics learning. These courses introduce an element of diversity of learning environments and expectations. Efforts should be made that students gain adequate 'hands-down' experience in the desired skills. The theory parts of these courses are intended to help students get prepared for such experiences. Since the assessment of these courses is largely college based, teachers should make full use of it to design novel projects.

6.4 TEACHING LEARNING PROCESSES FOR GENERIC ELECTIVES

Physics GE papers are taken by students of other honours courses. Most of these students would have studied physics at the school level, so these courses are not meant to be introductory. However, the teaching of these courses should be oriented to expose the non-physics students to the wonders of physics. Basic level projects that focus on real life applications of physics can be a useful means to generate student interest and motivate them for self-study.

At the end, the main purpose of Physics teaching should be to impart higher level objective knowledge to students in concrete, comprehensive and effective ways. Here, effectiveness implies gaining knowledge and skill which can be applied to solve practical problems as well as attaining the capability of logical thinking and imagination which are necessary for the creation of new knowledge and new discoveries. Once the students understand 'why is it worth learning?' and 'how does it connect to the real world?', they will embrace the curriculum in a way that would spark their imagination and instill a spirit of enquiry in them, so that in future they can opt for further investigations or research. All in all, the teacher should act as a facilitator and guide and not as a guardian of the curriculum.

7. ASSESSMENT METHODS

In the undergraduate education of Physics leading to the B.Sc. (Honours) Physics degree, the assessment and evaluation methods should focus on testing the conceptual understanding of basic concepts and theories, experimental techniques, development of mathematical skills, and the ability to apply the knowledge acquired to solve new problems and communicate the results and findings effectively.

The two perennial shortfalls of the traditional science examination process in our country are the reliance on rote learning for written exams, and a very perfunctory evaluation of laboratory skills. Greater emphasis on problem solving and less importance to textbook derivations discourages rote learning. Theory examinations should be based primarily on unseen problems. Continuous evaluation of students' work in the laboratory, and testing them on extensions of experiments they have already performed can give a more faithful evaluation of their laboratory skills.

Needless to say, there should be a continuous evaluation system for the students. This will enable teachers not only to ascertain the overall progress of learning by the students, but also to identify students who are slow learners and for whom special care should be taken. An appropriate grading system is the 'relative grading system'. It introduces a competitive element among students, but does not excessively penalizes weaker students.

Since the Learning Objectives are defined clearly for each course in the LOCF framework, it is easier to design methods to monitor the progress in achieving the learning objectives during the course and test the level of achievement at the end of the course.

- The courses offered in the undergraduate Physics are the first courses at the college/university level. Formative Assessment for monitoring the progress towards

achieving the learning objectives is an important assessment component, which provides both teachers and students feedback on progress towards learning goals. University of Delhi examination system has 20 percent internal assessment for theory component, and 50 percent for laboratory components. These marks should be distributed in periodic assessments in different modes to serve the intended purpose. Some of the p o s s i b l e methods   for the theory component of Formative Assessment are i) periodic class tests, ii) Regular problem based assignments, iii) unannounced short quizzes iv) individual seminar presentations v) longer assignments for covering theory and derivations not discussed in regular lectures vi) True/False Tests vii) Multiple Choice Tests for large classes viii) Any other innovative tests in the context of the course.

- To help students prepare themselves for formative assessment, and to motivate them for self-learning, it is advisable that a Model Problem Set is made available to them in the beginning of the course, or problem sets are given before discussion of specific topics in class

- In preparing students for Substantive Summative Assessment at the end of the semester it is helpful if a Model/mock question paper is made available to them in the beginning of the course.

Formative assessment for laboratory work may include) Regular evaluation of experiments regarding a) written report of each experiment b) Viva-Voce on each experiment   ii) Test through setting experiments by assembling components   iii) written test on experiments done in the lab and data analysis, iv) Designing innovative kits to test the comprehension and analysis of the experiment done by the students, v) audio visual recording of the experiments being performed by students and its self-appraisal

Formative assessment for computational physics work may include all of the components applicable in laboratory work assessment. It is essential that unseen problems are used in assessment of computational competence.

Since core courses, discipline specific courses, skill enhancement courses and general elective courses have qualitatively different kinds of objectives and learning outcomes, one model of assessment methods will not work for different kinds of courses.

7.1 ASSESSMENT METHODS FOR CORE COURSES

Core courses and associated laboratory curricula lead to the essential set of learning outcomes, which every physics graduate is expected to have. Their assessment methods require rigour, comprehensiveness and uniformity about what is minimally expected from students. Regular interactions mediated through university department among teachers teaching these courses in different colleges may prove to be helpful in this regard. Since depth of understanding of core topics is a highly desirable outcome, assessment for these courses should put greater emphasis on unseen problems, including extensions of textbook derivations done in class.

7.2 ASSESSMENT METHODS FOR DISCIPLINE SPECIFIC ELECTIVES

Discipline specific courses build upon general principles learnt in core courses, and also prepare students for further studies in specific domains of physics. Given the time constraint of only one semester, specific domain exposure is mostly introductory in character. Assessment for these courses should have significant component of open ended methods like seminars and project work. Students have greater chance of proving their individual initiative and ability for self-learning in these methods. These methods also have greater flexibility to reward students for out of curriculum learning.

7.3 ASSESSMENT METHODS FOR SKILL ENHANCEMENT COURSES

Learning in skill enhancement courses is largely experience based. Student performance in these courses is best assessed under continuous evaluation. Students could be assigned a specific task for a class or group of classes, and they could be assessed for their success in meeting the task.

7.4 ASSESSMENT METHODS FOR GENERIC ELECTIVES

General Elective courses are taken by students specializing in disciplines other than physics. The assessment methods for these courses should be oriented towards kindling student interest in the subject. Testing their ability to apply physics concepts in various practical situations through simple problems, and student specific writing and presentation assignments are most suited for assessing students' learning outcomes for these courses. Giving students greater choice of questions to be answered in semester end examinations, and asking a larger fraction of open-ended qualitative questions is recommended for these courses.

8. STRUCTURE OF COURSES IN B.Sc. (HONS.) PHYSICS

8.1 Credit Distribution for B.Sc. (Hons.) Physics

The B.Sc.(Hons.) Physics programme consists of 148 credits based on the Choice Based Credit System (CBCS) approved by the UGC. In a course 1 hour per week of theory or tutorial corresponds to one credit. 2 hours per week of practicals or hands-on work also correspond to one credit. The 148 credits include 84 credits of Core Courses (CC) and 8 credits of Ability Enhancement Compulsory Courses (AECC) which are mandatory. Choice is provided through 24 credits of Discipline Specific Electives (DSE), 8 credits of Skill Enhancement Courses (SEC) and 24 credits of Generic Elective Courses (GEC), the latter to be chosen from disciplines other than Physics.

Table 8.1 Table showing distribution of credits.

Semester	Core Courses (CC) each with 06 credit All 14 courses are compulsory	Generic Elective (GE). To be selected from GE listings of other disciplines	Skill Enhancement Course (SEC) Select any 2 Out of 11 courses	Discipline Specific Elective (DSE) Select four out of 20 courses	Ability Enhancement Compulsory Courses (AECC) Select any 2 out of 3 courses	Total Credit
Sem I	CC-I CC-II	GEC-1		-	AECC-1	22
Sem II	CC-III CC-IV	GEC-2		-	AECC-2	22
Sem III	CC-V CC-VI CC-VII	GEC-3	SEC-1	-	-	28
Sem IV	CC-VIII CC-IX CC-X	GEC-4	SEC-2	-	-	28
Sem V	CC-XI CC-XII	-		DSE-1 DSE-2	-	24
Sem VI	CC-XIII CC-XIV	-		DSE-3 DSE-4	-	24
Total Credit	**84**	**24**	**8**	**24**	**8**	**148**

Table 8.2 DETAILS OF COURSES UNDER B.Sc. (Hons.) PHYSICS

Course   ***Credits**

Theory + Practical/Tutorials

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I. Core Course

(14 Papers) $14 \times (4 + 2)^\# = 84$
Core Course (CC) + Practical*

II. Elective Course

(8 Papers)

A.1. **Discipline Specific Elective*** $4 \times (4 + 2)^\# = 24$ or $4 \times (5 + 1)^{\#\#} = 24$
    (DSE + Practical/Tutorial)
    (4 Papers)

B.1. Generic Elective/
    Interdisciplinary***** $4 \times (4 + 2)^\# = 24$ or $4 \times (5 + 1)^{\#\#} = 24$
    (GEC + Practical/Tutorial)
    (4 Papers)

Optional Dissertation or project work in place of one Discipline Specific Elective paper (6 credits) in 6th Semester

III. Ability Enhancement Courses

1. **Ability Enhancement Compulsory**

(2 Papers of 4 credit each) $2 \times 4 = 8$

    Environmental Science

    English/MIL Communication

2. **Ability Enhancement Elective** (Skill Based) *****

    (2 Papers of 4 credit each) $2 \times (2 + 2)^\# = 8$

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    Total Credits   **148**

College should evolve a system/policy about ECA/Interest/Hobby/ Sports/NCC/ NSS/related courses on its own.

#Theory with practical/ Hands-on Exercise
##Theory with tutorials
* Wherever there is a practical there will be no tutorial and vice-versa. The maximum size of group for practical papers is recommended to be 12 to 15 students and for tutorials 8 to 10 students per group.

8.2 SEMESTER-WISE DISTRIBUTION OF COURSES

CORE COURSES (CC)

Table 8.3 All the courses have 6 credits with 4 credits of theory (4 hours per week) and 2 credits of practicals (4 hours per week).

Core Course type	Unique Paper Code	Semester	Core Papers
CC-I	32221101	I	Mathematical Physics – I (Theory + Lab)
CC-II	32221102	I	Mechanics (Theory + Lab)
CC-III	32221201	II	Electricity and Magnetism (Theory + Lab)
CC-IV	32221202	II	Waves and Optics (Theory + Lab)
CC-V	32221301	III	Mathematical Physics – II (Theory + Lab)
CC-VI	32221302	III	Thermal Physics (Theory + Lab)
CC-VII	32221303	III	Digital Systems and Applications (Theory + Lab)
CC-VIII	32221401	IV	Mathematical Physics – III (Theory + Lab)
CC-IX	32221402	IV	Elements of Modern Physics (Theory + Lab)
CC-X	32221403	IV	Analog Systems and Applications (Theory + Lab)
CC-XI	32221501	V	Quantum Mechanics and Applications (Theory + Lab)
CC-XII	32221502	V	Solid State Physics (Theory + Lab)
CC-XIII	32221601	VI	Electromagnetic Theory (Theory + Lab)
CC-XIV	32221602	VI	Statistical Mechanics (Theory + Lab)

DISCIPLINE SPECIFIC ELECTIVES (DSE)

Table 8.4 All the courses have 6 credits with 4 credits of theory and 2 credits of practical or 5 credits of theory and 1 credit of Tutorials.

Discipline Specific (Physics) Elective papers (Credit: 06 each): Select any 02 papers (DSE-1 and DSE-2)* in V semester and Select any 02 papers (DSE-3 and DSE-4) in VI semester from the following options. **(numbers in brackets indicate number of hours per week dedicated)**

No.	Unique Paper Code	DSE Papers
Odd Semester – V Semester only (DSE-1 and DSE-2)	
1	32227501	Experimental Techniques (4) + Lab (4)
2	32227502	Advanced Mathematical Physics (4) + Lab (4)*
3	32227504	Nuclear and Particle Physics (5) + Tutorials (1)
4	32227505	Physics of Devices and Communication (4) + Lab (4)
5	32227506	Astronomy and Astrophysics (5) + Tutorials (1)
6	32227507	Atmospheric Physics (4) + Lab (4)
7	32227508	Biological Physics (5) + Tutorials (1)
8	32227518	Embedded Systems– Introduction of Microcontroller (4) + Lab(4)
9	xxx3	Linear Algebra and Tensor Analysis (5) + Tutorial (1)*
Even Semester – VI semester only (DSE-3 and DSE-4)	
10	32227612	Nano Materials and Applications (4) + Lab (4)
11	32227613	Communication System (4) + Lab (4)
12	32227615	Medical Physics (4) + Lab (4)
13	32227616	Applied Dynamics (4) + Lab (4)
14	32227621	Digital Signal processing (4) + Lab (4)
15	32227624	Physics of the Earth (5) + Tutorials (1)
16	32227625	Advanced Mathematical Physics II (5) + Tutorial (1)
17	32227626	Classical Dynamics (5) + Tutorial (1)
18	32227627	Dissertation (8)
19	32227628	Verilog and FPGA based system design (4) + Lab (4)
20	xxx4	Advanced Quantum Mechanics (5) + Tutorials (1)

*Papers listed at S. No. 02 (Advanced Mathematical Physics) and 09 (Linear Algebra and Tensor Analysis) are not allowed to be taken together as DSE-1 and DSE-2 in Semester-V.

SKILL ENHANCEMENT COURSES (SEC)

Table 8.5 All courses have 4 credits with 2 credits of theory and 2 credits of Practical /Hands-On/Projects and Field Work to be decided by the College. ***Teachers may give a long duration project based on a SEC paper in the Practical Lab.***

No.	Unique Paper Code	Semester	SEC Papers
1	32223901	III/IV	Physics Workshop Skills
2	32223902	III/IV	Computational Physics Skills
3	32223903	III/IV	Electrical Circuit and Network Skills
4	32223904	III/IV	Basic Instrumentation Skills
5	32223905	III/IV	Renewable Energy and Energy Harvesting
6	32223906	III/IV	Engineering design and prototyping/Technical Drawing
7	32223907	III/IV	Radiation Safety
8	32223908	III/IV	Applied Optics
9	32223909	III/IV	Weather Forecasting
10	XXX1	III/IV	Introduction to Physical Computing
11	XXX2	III/IV	Numerical Analysis

ABILITY ENHANCEMENT COMPULSORY COURSES (AECC)

Table 8.6 All the courses have 4 credits. The detailed content of these courses is NOT mentioned in this document.

AECC	B.Sc. (Hons.) Physics
1	English
2	MIL Communications
3	Environment Science

GENERAL ELECTIVE COURSES (GE)

Table 8.7 All the courses have 6 credits including Theory/Practicals/ Projects. These courses are meant for students studying B.Sc. (Hons.) of other disciplines.

No.	Unique Paper Code	Semester	GE Papers
1	32225101	I	Electricity and Magnetism + Lab
2	32225102	I	Mathematical Physics + Lab
3	32225103	I	Digital, Analog and Instrumentation + Lab
4	32225104	I	Applied Dynamics + Lab
5	32225105	I	Medical Physics + Lab
6	32225201	II	Mechanics + Lab
7	32225202	II	Elements of Modern Physics + Lab
8	32225203	II	Solid State Physics + Lab
9	32225204	II	Embedded Systems – Introduction of Microcontroller + Lab
10	32225205	II	Biological Physics + Tutorial
11	32225310	III	Waves and Optics + Lab
12	32225311	III	Quantum Mechanics + Lab
13	32225312	III	Communication System + Lab
14	32225313	III	Verilog and FPGA based system design + Lab
15	32225314	III	Nano Materials and Applications + Lab
16	32225415	IV	Thermal Physics and Statistical Mechanics + Lab
17	32225416	IV	Digital Signal processing + Lab
18	32225417	IV	Nuclear and Particle Physics + Tutorial
19	32225418	IV	Astronomy and Astrophysics + Tutorial
20	32225419	IV	Atmospheric Physics + Lab
21	32225420	IV	Physics of the Earth + Tutorial

Table 8.8 Semester-wise breakup of types of courses with their credits.
Core Courses are listed in Table 8.3
GE courses are to be chosen from the course listings of other Departments.
SEC courses are to be chosen from Table 8.5
DSE courses are to be chosen from Table 8.4

S.No.	Course opted	Course name	Credits
I	Ability Enhancement Compulsory Course-I	English/ MIL communications/ Environmental Science	4
	Core course I	Mathematical Physics-I	4
	Core Course-I Practical*	Mathematical Physics-I Lab	2
	Core course-II	Mechanics	4
	Core Course-II Practical*	Mechanics Lab	2
	Generic Elective -1	GE-1	4/5
	Generic Elective – 1 Practical/Tutorial*	GE-1 Lab/Tutorial	2/1
II	Ability Enhancement Compulsory Course-II	English/MIL communications/ Environmental Science	4
	Core course-III	Electricity and Magnetism	4
	Core Course-III Practical*	Electricity and Magnetism Lab	2
	Core course-IV	Waves and Optics	4
	Core Course-IV Practical *	Waves and Optics Lab	2
	Generic Elective -2	GE-2	4/5
	Generic Elective -2 Practical/Tutorial*	GE-2 Lab/Tutorial	2/1
III	Core Course-V	Mathematical Physics-II	4
	Core Course-V Practical*	Mathematical Physics-II Lab	2
	Core course-VI	Thermal Physics	4
	Core Course-VI Practical*	Thermal Physics Lab	2
	Core course-VII	Digital Systems and Applications	4
	Core Course-VII Practical*	Digital Systems & Applications Lab	2
	Skill Enhancement Course -1	SEC-1	2
	Skill Enhancement Course -1 Practical*	SEC-1 Lab/Hands-on/field work/project	2
	Generic Elective -3	GE-3	4/5
	Generic Elective -3 Practical/Tutorial*	GE-3 Lab/Tutorial	2/1
IV	Core course-VIII	Mathematical Physics III	4
	Course-VIII Practical/Tutorial*	Mathematical Physics-III Lab	2
	Core course-IX	Elements of Modern Physics	4
	Course-IX Practical/Tutorial*	Elements of Modern Physics Lab	2
	Core Course-X	Analog Systems and Applications	4
	Course- X Practical/Tutorial*	Analog Systems & Applications Lab	2
	Skill Enhancement Course -2	SEC -2	2
	Skill Enhancement Course -2 Practical*	SEC -2 Lab/Hands-on/field work/project	2
	Generic Elective -4	GE – 4	4/5
	Generic Elective-4 Practical/Tutorial*	GE – 4 Lab/Tutorial	2/1
V	Core course-XI	Quantum Mechanics & Applications	4

		Core Course-XI Practical*	Quantum Mechanics Lab	2
		Core course-XII	Solid State Physics	4
		Core Course-XII Practical*	Solid State Physics Lab	2
		Discipline Specific Elective -1	DSE-1	4/5
		Discipline Specific Elective -1 Practical/Tutorial*	DSE-1 Lab/Tutorial	2/1
		Discipline Specific Elective -2	DSE-2	4/5
		Discipline Specific Elective- 2 Practical/Tutorial*	DSE-2 Lab/Tutorial	2/1
VI		Core course-XIII	Electro-magnetic Theory	4
		Core Course-XIII Practical*	Electro-magnetic Theory Lab	2
		Core course-XIV	Statistical Mechanics	4
		Core Course-XIV Practical*	Statistical Mechanics Lab	2
		Discipline Specific Elective -3	DSE-3	4/5
		Discipline Specific Elective -3 Practical/Tutorial*	DSE-3 Lab/Tutorial	2/1
		Discipline Specific Elective-4	DSE-4	4/5
		Discipline Specific Elective -4 Practical/Tutorial*	DSE-4 Lab/Tutorial	2/1
			TOTAL	**148**

* Wherever there is a practical there will be no tutorial and vice-versa.
The maximum size of group for practical papers is recommended to be 12 to 15 students and for tutorials 8 to 10 students per group.

9. DETAILED COURSES FOR PROGRAMME IN B.SC. (HONS.) PHYSICS, INCLUDING COURSE OBJECTIVES, LEARNING OUTCOMES, AND READINGS.

9.1. Core Courses

CC-I: Mathematical Physics-I (32221101)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

- 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.
- 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
- Revise the knowledge of calculus, vectors, vector calculus, probability and probability distributions. These basic mathematical structures are essential in solving problems in various branches of Physics as well as in engineering.
- Draw and interpret graphs of various functions.
- Solve first order differential equations and apply it to physics problems solve linear second order homogeneous and non-homogeneous differential equations with constant coefficients.
- Calculate partial derivatives of function of several variables Understand the concept of gradient of scalar field and 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.
- Apply curvilinear coordinates to problems with spherical and cylindrical symmetries.
- Understand elementary probability theory and the properties of discrete and continuous distribution functions.
- In the laboratory course, learn the fundamentals of the C and C++ programming languages. Also, understanding Monte Carlo techniques, fitting a given data to linear function using method of least squares, approximation of a function by Maclaurin and Taylor's series, finding roots of a given equation and their applications in solving simple physical problems.

Unit 1
Calculus
Functions: Recapitulate the concept of functions. Plot and interpret graphs of functions using the concepts of calculus.

(2 Lectures)

First Order Differential Equations: First order differential Equations: Variable separable, homogeneous, non-homogeneous, exact and inexact differential equations and Integrating Factors. Application to physics problems.

(5 Lectures)

Second Order Differential Equations: Homogeneous Equations with constant coefficients. Wronskian and general solution. Particular Integral with operator method, method of undetermined coefficients and method of variation of parameters. Cauchy-Euler differential equation and simultaneous differential equations of First and Second order.

(13 Lectures)

Unit 2
Vector Analysis
Vector Algebra: Scalars and vectors, laws of vector algebra, scalar and vector product, triple scalar product, interpretation in terms of area and volume, triple cross product, product of four vectors. Scalar and vector fields.

(5 Lectures)

Vector Differentiation: Ordinary derivative of a vector, the vector differential operator ∇. Directional derivatives and normal derivative. Gradient of a scalar field and its geometrical interpretation. Divergence and curl of a vector field. Laplacian operators. Vector identities.

(8 Lectures)

Vector Integration: Ordinary Integrals of Vectors. Double and Triple integrals, change of order of integration, Jacobian. Notion of infinitesimal line, surface and volume elements. Line, surface and volume integrals of Scalar and Vector fields. Flux of a vector field. Gauss' divergence theorem, Green's and Stokes Theorems and their verification (no rigorous proofs).

(14 Lectures)

Orthogonal Curvilinear Coordinates: Orthogonal Curvilinear Coordinates. Derivation of Gradient, Divergence, Curl and Laplacian in Cartesian, Spherical and Cylindrical Coordinate Systems.

(6 Lectures)

Unit 3
Probability and statistics: Independent and dependent event, Conditional Probability. Bayes' Theorem, Independent random variables, Probability distribution functions, special distributions: Binomial, Poisson and Normal. Sample mean and variance and their confidence intervals for Normal distribution.

(7 Lectures)

Practical : 60 Hours

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.

- Highlights the use of computational methods to solve physics problems.
- The course will consist of lectures (both theory and practical) in the Lab. The recommended group size is not more than 15 students.
- Evaluation to be done not on the programming but 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.

Topics	Descriptions with Applications
Introduction and Overview	Computer architecture and organization, memory and Input/output devices,
Basics of scientific computing	Binary and decimal arithmetic, Floating point numbers, single and double precision arithmetic, underflow and overflow - emphasize the importance of making equations in terms of dimensionless variables, Iterative methods
Algorithms and Flow charts	Purpose, symbols and description,
Introduction to C++	Introduction to Programming: Algorithms: Sequence, Selection and Repetition, Structured programming, basic idea of Compilers. Data Types, Enumerated Data, Conversion & 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. 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

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: • 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
Random Number generator	Generating pseudo random numbers To find value of pi using Monte Carlo simulations. To integrate using Monte Carlo Method
Arrays and Functions	Sum and average of a list of numbers, largest of a given list of numbers and its location in the list, sorting of numbers in ascending descending order using Bubble sort and Sequential sort, Binary search, 2-dimensional arrays, matrix operations (sum, product, transpose etc)
Solution of Algebraic and Transcendental equations by Bisection, Newton Raphson and Secant methods	Solution of linear and quadratic equation, solving $\alpha = \tan\alpha$; $I = I_0 [(\sin \alpha)/ \alpha]^2$ in optics, square root of a number.
Data Analysis and Least Square Fitting (Linear case)	Uncertainty, error and precision, mean, standard deviation and error in the mean. Combining uncertainties, Least squares method for fitting data: linear ($y = ax+b$), power law($y = ax^b$) and exponential ($y = ae^{bx}$). To find parameters a, b and errors in them using method of least squares. Ohms law- calculate R, Hooke's law - Calculate spring constant.
Numerical differentiation (Forward and Backward and central difference formulae – Using basic definition)	Given Position with equidistant time data calculate velocity and acceleration

References for Theory:

1. Advanced Engineering Mathematics, D. G. Zill and W. S. Wright, 5 Ed., 2012, Jones and Bartlett Learning.

2. Mathematical Physics, Goswami, 1st edition, Cengage Learning.

3. Engineering Mathematics, S.Pal and S.C. Bhunia, 2015, Oxford University Press.

4. Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India .

5. Mathematical Physics (1995), A.K. Ghatak, IC Goyal and S.J. Chua, Macmillan India, New Delhi.

6. Essential Mathematical Methods, K.F.Riley & M.P.Hobson, 2011, Cambridge Univ. Press.

7. An introduction to ordinary differential equations, E. A. Coddington, 2009, PHI learning.

8. Differential Equations, George F. Simmons, 2007, McGraw Hill.

9. Vector Analysis: Schaum Outline Series, M. Spiegel, McGraw Hill Education (2017).

10. Introduction to Vector Analysis, H.F. Davis and A. D. Snider, Wm. C. Brown Publishers; 6th edition (1991).

11. Statistical data Analysis for The Physical Sciences by Adrian Bevan, Cambridge University Press (2013).

12. Statistics – A Guide to the Use of Statistical Methods n the Physical Sciences, R.J. Barlow, Wiley (1993).

References for Practical:

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. An introduction to Numerical methods in C++, Brian H. Flowers, 2009, Oxford University Press.

5. A first course in Numerical Methods, U.M. Ascher & C. Greif, PHI Learning (2012).

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

7. Applied numerical analysis, Cutis F. Gerald and P.O. Wheatley, Pearson Education, India (2007).

Additional References for Practical

1. 'The C++ Programming Language, Bjarne Stroustrup, Addison-Wesley Professional (2013)

2. Numerical Recipes in C++: The Art of Scientific Computing, W.H. Press et.al., 2^{nd}Edn., Cambridge University Press (2013).

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

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

CC-II: Mechanics (32221102)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

This course begins with the review of Newton's Laws of Motion and ends with the Fictitious Forces and Special Theory of Relativity. Students will also appreciate the Collisions in CM Frame, Gravitation, Rotational Motion and Oscillations. The emphasis of this course is to enhance the understanding of the basics of mechanics. By the end this course, students should be able to solve the seen or unseen problems/numerical in mechanics.

Course Learning Outcomes

Upon completion of this course, students are expected to understand the following concepts which would help them to appreciate the application of the fundamental concepts to the analysis of simple, practical situations related to the real world:

- Understand laws of motion and their application to various dynamical situations.
- Learn the concept of Inertial reference frames and Galilean transformations. Also, the concept of conservation of energy, momentum, angular momentum and apply them to basic problems.
- Understand the analogy between translational and rotational dynamics, and application of both motions simultaneously in analyzing rolling with slipping.
- Understand variable mass system and dynamics of a system of particles.
- Able to write the expression for the moment of inertia about the given axis of symmetry for different uniform mass distributions.
- Understand the phenomena of collisions and idea about center of mass and laboratory frames and their correlation.
- Understand conservative and non-conservative forces and also Potential Energy diagrams
- Understand angular momentum of a system of particle.
- Apply Kepler's law to describe the motion of planets and satellite in circular orbit, through the study of law of Gravitation.
- Understand concept of Geosynchronous orbits
- Explain the phenomenon of simple harmonic motion. Also, quality factor of forced oscillations
- Understand the concept of Centrifugal force and Coriolis forces
- Understand special theory of relativity - special relativistic effects and their effects on the mass and energy of a moving object.
- In the laboratory course, the student shall perform experiments related to mechanics

(compound pendulum), rotational dynamics (Flywheel), elastic properties (Young Modulus and Modulus of Rigidity), fluid dynamics, estimation of random errors in the observations etc.

Unit 1

Fundamentals of Dynamics: Reference frames, Inertial frames, Galilean transformations, Galilean invariance, Review of Newton's Laws of Motion. 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 (1-D, 2-D & 3-D).

(5 Lectures)

Unit 2

Work and Energy: Work and Kinetic Energy Theorem. Conservative and non-conservative forces. Potential Energy. Energy diagram. Stable, unstable and neutral equilibrium. Force as gradient of potential energy. Work & Potential energy. Work done by non-conservative forces. Law of conservation of Energy.

(5 Lectures)

Collisions: Elastic (1-D and 2-D) and inelastic collisions. Centre of Mass and Laboratory frames.

(4 Lectures)

Unit 3

Rotational Dynamics: Angular momentum of a particle and system of particles. Torque. Principle of conservation of angular momentum. Rotation about a fixed axis. Moment of inertia, theorem of parallel and perpendicular axes. Determination of moment of inertia of discrete and continuous objects [1-D, 2-D & 3-D (rectangular, cylindrical and spherical)]. Kinetic energy of rotation. Motion involving both translation and rotation.

(10 Lectures)

Unit 4

Gravitation and Central Force Motion: Law of gravitation. Gravitational potential energy. Inertial and gravitational mass. Potential and field due to spherical shell and solid sphere.

(2 Lectures)

Motion of a particle under a central force field: Two-body problem, its reduction to one-body problem and its solution. Reduction of angular momentum, kinetic energy and total energy. The energy equation and energy diagram. Kepler's Laws. Satellite in circular orbit, Geosynchronous orbits.

(7 Lectures)

Unit 5

Oscillations: Idea of SHM. Differential equation of SHM and its solution. Kinetic energy, potential energy, total energy and their time-average values. Compound pendulum. Damped oscillation. Forced oscillations: Transient and steady states, sharpness of resonance and Quality Factor.

(5 Lectures)

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

(7 Lectures)

Unit 6

Special Theory of Relativity: Outcomes of Michelson-Morley Experiment. Postulates of Special Theory of Relativity. Lorentz Transformations. Simultaneity, Length contraction, Time dilation. Relativistic transformation of velocity, acceleration, frequency and wave number. Mass of relativistic particle. Mass-less Particles. Mass-energy Equivalence. Relativistic Doppler effect (transverse and longitudinal). Relativistic Kinematics (decay problems, inelastic collisions and Compton effect). Transformation of Energy and Momentum.

(15 Lectures)

Practical : 60 Hours

Demonstration cum laboratory sessions on the construction and use of Vernier callipers, screw gauge and travelling microscope, and necessary precautions during their use.

Sessions and exercises on the least count errors, their propagation and recording in final result up to correct significant digits, linearization of data and the use of slope and intercept to determine unknown quantities.

Session on the writing of scientific laboratory reports, which may include theoretical and practical significance of the experiment performed, apparatus description, relevant theory, necessary precautions to be taken during the experiment, proper recording of observations, data analysis, estimation of the error and explanation of its sources, correct recording of the result of the experiment, and proper referencing of the material taken from other sources (books, websites, research papers, etc.)

At least 06 experiments from the following

1. Measurements of length (or diameter) using Vernier Calliper, screw gauge and travelling microscope.
2. To study the random error in observations.
3. To determine the height of a building using a Sextant.
4. To study the motion of the spring and calculate (a) Spring constant and, (b) g.
5. To determine the Moment of Inertia of a Flywheel.
6. To determine g and velocity for a freely falling body using Digital Timing Technique.
7. To determine Coefficient of Viscosity of water by Capillary Flow Method (Poiseuille's method).

8. To determine the Young's Modulus of a Wire by Optical Lever Method.
9. To determine the Modulus of Rigidity of a Wire by Maxwell's needle.
10. To determine the elastic Constants of a wire by Searle's method.
11. To determine the value of g using Bar Pendulum.
12. To determine the value of g using Kater's Pendulum.

References for Theory:

1. An Introduction to Mechanics, Daniel Kleppner & Robert Kolenkow, 2007, Tata McGrawHill
2. Mechanics, DS Mathur, PS Hemne, 2012, S. Chand
3. University Physics, FW Sears, MW Zemansky & HD Young 13/e, 1986, Addison Wesley
4. Mechanics Berkeley Physics course, v.1: Charles Kittel, et.al. 2007,
5. Tata McGraw Hill Physics – Resnick, Halliday & Walker 9/e, 2010, Wiley
6. Engineering Mechanics, Basudeb Bhattacharya, 2nd edn., 2015, Oxford University Press
7. University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole

References for Practical:

1. Advanced Practical Physics for students, B. L. Flint and H.T. Worsnop, 1971, Asia Publishing House
2. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers
3. Engineering Practical Physics, S.Panigrahi & B.Mallick,2015, Cengage Learning India Pvt. Ltd.
4. Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press.
5. A Text Book of Practical Physics, I.Prakash & Ramakrishna, 11th Edn, 2011,Kitab Mahal
6. An Advanced Course in Practical Physics, D. Chattopadhyay & P. C. Rakshit, 2013, New Book Agency (P) Ltd.
7. B.Sc. Practical Physics, H. Singh & P. S. Hemne, 2011, S Chand and Company Ltd
8. B.Sc. Practical Physics, C. L. Arora, 2011, S Chand and Company Ltd.

CC-III: Electricity and Magnetism (32221201)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

Electricity and Magnetism is one of the core courses in Physics curriculum. The course covers static and dynamic electric and magnetic field, and the principles of electromagnetic induction. It also includes analysis of electrical circuits and introduction of network theorems. By the end of the course student should be able to appreciate Maxwell's equations and analyze electrical circuits using network theorems.

Course Learning Outcomes

- Demonstrate the application of Coulomb's law for the electric field, and also apply it to systems of point charges as well as line, surface, and volume distributions of charges.
- Demonstrate an understanding of the relation between electric field and potential, exploit the potential to solve a variety of problems, and relate it to the potential energy of a charge distribution.
- Exploit alternative coordinate systems (cylindrical and spherical coordinates) to solve problems.
- Apply Gauss's law of electrostatics to solve a variety of problems.
- Demonstrate an understanding of electric dipoles and the role of molecular dipoles in the electrostatic response of dielectrics.
- Demonstrate an understanding of the behavior of electric conductors.
- Demonstrate a working understanding of capacitors.
- Calculate the magnetic forces that act on moving charges and the magnetic fields due to currents (Biot- Savart and Ampere laws)
- Understand the concepts of induction and self-induction, to solve problems using Faraday's and Lenz's laws
- Apply Kirchhoff's rules to analyze AC circuits consisting of parallel and/or series combinations of voltage sources and resistors and to describe the graphical relationship of resistance, capacitor and inductor.
- Deal with electromagnetic oscillations, AC currents and oscillation circuits and analyze and solve LCR circuits
- Understand the basics of electrical circuits and analyze circuits using Network Theorems such as Superposition, Thevenin, Norton, Reciprocity, Maximum Power Transfer, etc.
- In the laboratory course the student will get an opportunity to verify network theorems and study different circuits such as RC circuit, LCR circuit.
- Different methods to measure low and high resistance, capacitance, self-inductance, mutual inductance and also strength of a magnetic field and its variation (dB/dX)

Unit 1

Electric Field and Electric Potential: Electric field: Electric field lines. Electric flux. Gauss Law with applications to charge distributions with spherical, cylindrical and planar symmetry.

(6 Lectures)

Conservative nature of Electrostatic Field:. Electrostatic Potential. Laplace's and Poisson equations. The Uniqueness Theorem. Potential and Electric Field of a dipole. Force and Torque on a dipole.

(6 Lectures)

Electrostatic energy of system of charge:. Electrostatic energy of a charged sphere. Conductors in an electrostatic Field. Surface charge and force on a conductor. Capacitance of a system of charged conductors. Parallel-plate capacitor. Capacitance of an isolated conductor. Method of Images and its application to: (1) Plane Infinite Sheet and (2) Sphere.

(10 Lectures)

Dielectric Properties of Matter: Electric Field in matter. Polarization, Polarization Charges. Electrical Susceptibility and Dielectric Constant. Capacitor (parallel plate, spherical, cylindrical) filled with dielectric. Displacement vector **D**. Relations between **E**, **P** and **D**. Gauss' Law in dielectrics.

(8 Lectures)

Unit 2

Magnetic Field: Magnetic force between current elements and definition of Magnetic Field **B**. Biot-Savart's Law and its simple applications: straight wire and circular loop. Current Loop as a Magnetic Dipole and its Dipole Moment (Analogy with Electric Dipole).Ampere's Circuital Law and its application to (1) Solenoid and (2) Toroid. Properties of **B**: curl and divergence. Vector Potential. Magnetic Force on (1) point charge (2) current carrying wire (3) between current elements. Torque on a current loop in a uniform Magnetic Field.

(9 Lectures)

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

(4 Lectures)

Electromagnetic Induction: Faraday's Law. Lenz's Law. Self Inductance and Mutual Inductance. Reciprocity Theorem. Energy stored in a Magnetic Field. Introduction to Maxwell's Equations. Charge Conservation and Displacement current.

(6 Lectures)

Unit 3

Electrical Circuits: AC Circuits: Kirchhoff's laws for AC circuits. Complex Reactance and Impedance. Series LCR Circuit: (1) Resonance, (2) Power Dissipation and (3) Quality Factor, and (4) Band Width. Parallel LCR Circuit.

Network theorems: Ideal constant-voltage and constant-current Sources. Review of Kirchhoff's Current Law& Kirchhoff's Voltage Law. Mesh &Node Analysis. Thevenin theorem, Norton theorem, Superposition theorem, Reciprocity Theorem, Maximum Power Transfer theorem. Applications to dc circuits.

(6 Lectures)

Practical : 60 Hours

Dedicated demonstration cum laboratory sessions on the construction, functioning and uses of different electrical bridge circuits, and electrical devices like the ballistic galvanometer.

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.
Sessions on least square fitting and computer programme to find slope and intercept of straight-line graphs of experimental data. Application to the specific experiments done in the lab.

At least 6 experiments from the following:

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

References for Theory:

1. Fundamentals of Electricity and Magnetism, Arthur F. Kip, 2nd Edn.1981, McGraw-Hill.
2. Electricity, Magnetism & Electromagnetic Theory, S.Mahajanand Choudhury, 2012, Tata McGraw
3. Electricity and Magnetism, Edward M. Purcell, 1986 McGraw-Hill Education
4. Introduction to Electrodynamics, D.J. Griffiths, 3rd Edn., 1998, Benjamin Cummings.

5. Feynman Lectures Vol.2, R.P.Feynman, R.B.Leighton, M.Sands, 2008, Pearson Education
6. Electricity and Magnetism, J.H.Fewkes& J.Yarwood. Vol.I, 1991, Oxford Univ. Press.
7. Problems and Solutions in Electromagnetics (2015), Ajoy Ghatak, K Thyagarajan & Ravi Varshney.
8. Network, Lines and Fields, John D. Ryder, 2nd Edn., 2015, Pearson.
9. Schaum's Outline of Electric Circuits, J. Edminister & M. Nahvi, 3rd Edn., 1995, McGraw Hill.

References for Practical:

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 & 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. An Advanced Course in Practical Physics, D. Chattopadhyay & P. C. Rakshit, 2013, New Book Agency (P) Ltd.
6. Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press
7. B.Sc. Practical Physics, H. Singh & P. S. Hemne, 2011, S Chand and Company Ltd
8. B.Sc. Practical Physics, C. L. Arora, 2011, S Chand and Company Ltd.

CC-IV: Waves and Optics (32221202)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

This is one of the 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.

Course 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 the importance of classical wave equation in transverse and longitudinal waves and solving a range of physical systems on its basis.
- Understand different types of waves and their velocities: Plane, Spherical, Transverse, Longitudinal.
- Understand Concept of normal modes in transverse and longitudinal waves: their frequencies and configurations.
- Understand the concept of temporal and spatial coherence.
- 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's Mirror, Newton's Rings, Michelson Interferometer and Fabry-Perot Interferometer
- Demonstrate basic concepts of Diffraction: Superposition of wavelets diffracted from apertures
- Understand Fraunhoffer Diffraction from apertures: Rectangular, Slit, Double Slit, Grating, Circular apertures.
- Demonstrate fundamental understanding of Fresnel Diffraction: Half period zones, Zone Plate, Fresnel's Integrals, Cornu's Spiral and its applications.
- 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, Fresnel Biprism etc. Resolving power of optical equipment can be learnt first hand.
- The motion of coupled oscillators, study of Lissajous figures and behaviour of transverse, longitudinal waves can be learnt in this laboratory course.

Unit 1

Superposition of Collinear 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 N collinear Harmonic Oscillations with (1) equal phase differences and (2) equal frequency differences.
(6 Lectures)

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

Wave Motion: Plane and Spherical Waves. Longitudinal and Transverse Waves. Plane Progressive (Travelling) Waves. Wave Equation. Particle and Wave Velocities. Pressure of a Longitudinal Wave. Energy Transport. Intensity of Wave.
(4 Lectures)

Superposition of Two Harmonic Waves: Standing (Stationary) Waves in a String: Fixed and Free Ends. Analytical Treatment. Phase and Group Velocities. Changes with respect to

Position and Time. Energy of Vibrating String. Transfer of Energy. Normal Modes of Stretched Strings. Longitudinal Standing Waves and Normal Modes. Open and Closed Pipes. Superposition of N Harmonic Waves.

(8 Lectures)

Unit 2

Wave Optics: Electromagnetic nature of light. Definition and properties of wave front. Huygens Principle. Temporal and Spatial Coherence.

(4 Lectures)

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

(10 Lectures)

Interferometer: Michelson Interferometer-(1) Idea of form of fringes (No theory required), (2) Determination of Wavelength, (3) Wavelength Difference, (4) Refractive Index, and (5) Visibility of Fringes. Fabry-Perot interferometer.

(6 Lectures)

Unit 3

Diffraction:

Fraunhofer diffraction: Single slit. Rectangular and Circular aperture, Resolving Power of a telescope. Double slit. Multiple slits. Diffraction grating. Resolving power of grating.

(10 Lectures)

Fresnel Diffraction: Fresnel's Assumptions. Fresnel's Half-Period Zones for Plane Wave. Explanation of Rectilinear Propagation of Light. Theory of a Zone Plate: Multiple Foci of a Zone Plate. Fresnel's Integral, Cornu`s spiral and its applications. Straight edge, a slit and a wire.

(10 Lectures)

Practical: 60 Hours

Dedicated demonstration cum laboratory session on the construction, and use of spectrometer and lasers, and necessary precautions during their use.

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 06 experiments from the following:

1. To determine the frequency of an electric tuning fork by Melde's experiment and verify λ^2–T law.
2. To investigate the motion of coupled oscillators.

3. To study Lissajous Figures.
4. Familiarization with: Schuster`s focusing; determination of angle of prism.
5. To determine refractive index of the Material of a prism using sodium source.
6. To determine the dispersive power and Cauchy constants of the material of a prism using mercury source.
7. To determine the wavelength of sodium source using Michelson's interferometer.
8. To determine wavelength of sodium light using Fresnel Biprism.
9. To determine wavelength of sodium light using Newton's Rings.
10. To determine the thickness of a thin paper by measuring the width of the interference fringes produced by a wedge-shaped Film.
11. To determine wavelength of (1) Na source and (2) spectral lines of Hg source using plane diffraction grating.
12. To determine dispersive power and resolving power of a plane diffraction grating.

References for Theory:

1. Vibrations and Waves, A.P. French, 1stEdn., 2003, CRC press.
2. Waves: Berkeley Physics Course, vol. 3, Francis Crawford, 2007, Tata McGraw-Hill.
3. Fundamentals of Optics, F.A. Jenkins and H.E. White, 1981, McGraw-Hill
4. Principles of Optics, Max Born and Emil Wolf, 7th Edn., 1999, Pergamon Press.
5. Optics, (2017), 6th Edition, Ajoy Ghatak, McGraw-Hill Education, New Delhi
6. The Physics of Vibrations and Waves, H. J. Pain, 2013, John Wiley and Sons.
7. The Physics of Waves and Oscillations, N.K. Bajaj, 1998, Tata McGraw Hill.
8. Fundamental of Optics, A. Kumar, H.R. Gulati and D.R. Khanna, 2011, R. Chand Publications
9. Optics, Eugene Hecht, 4thEdn., 2014, Pearson Education.

References for Practical:

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 & 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.
5. An Advanced Course in Practical Physics, D. Chattopadhyay & P. C. Rakshit, 2013, New Book Agency (P) Ltd.
6. Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press
7. B.Sc. Practical Physics, H. Singh & P. S. Hemne, 2011, S Chand and Company Ltd
8. B.Sc. Practical Physics, C. L. Arora, 2011, S Chand and Company Ltd.

CC-V: Mathematical Physics-II (32221301)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

- The emphasis of course is to equip students with the mathematical tools required in solving problems interest to physicists.
- To expose students 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.
- This course will aim at introducing the concepts of Fourier series, special functions, solving linear partial differential equations by separation of variable method.

Course Learning Outcomes

On successfully completing this course, the students will be able to

- Represent a periodic function by a sum of harmonics using Fourier series and their applications in physical problems such as vibrating strings etc..
- Expand an odd or even function as half range sine and cosine Fourier series.
- 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 functions and their differential equations and their applications in 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.
- In the laboratory course, learn the basics of the Scilab software, their utility, advantages and disadvantages.
- Apply appropriate numerical method to solve selected physics problems both using computer program in Scilab and using the inbuilt functions from Scilab.
- Analyze the errors obtained in numerical solution to problems and compare different algorithms with respect to accuracy and efficiency.
- Understand the algorithms of Newton and Lagrange interpolation and use them to find intermediate value in a tabulated data
- Perform numerical differentiation and integration (trapezoidal and Simpson methods) of a given function in mathematical or tabulated form

- Solve initial value problems using Euler and Runge Kutta methods.
- Obtain approximate solution to a system of linear equations using Gauss Elimination and Gauss Seidel methods
- Generate and plot Legendre polynomials and Bessel functions and verify their recurrence relation

Unit 1

Fourier Series: Periodic functions. Orthogonality of sine and cosine functions, Dirichlet Conditions (Statement only). Expansion of periodic functions in a series of sine and cosine functions and determination of Fourier coefficients. Even and odd functions and their Fourier expansions (Fourier Cosine Series and Fourier Sine Series). Application. Summing of Infinite Series. Parseval's Identity and its application to summation of infinite series.

(17 Lectures)

Unit 2

Frobenius Method and Special Functions: Singular Points of Second Order Linear Differential Equations and their importance. Frobenius method and its applications to differential equations: Legendre, Bessel, Hermite and Laguerre Differential Equations. Properties of Legendre Polynomials: Rodrigues Formula, Generating Function, Orthogonality. Simple recurrence relations. Expansion of function in a series of Legendre Polynomials. Bessel Functions of the First Kind: Generating Function, simple recurrence relations. Zeros of Bessel Functions ($J_o(x)$ and $J_1(x)$) and Orthogonality.

(24 Lectures)

Unit 3

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

(4 Lectures)

Unit 4

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, rectangular and circular membranes. Solution of 1D heat flow equation. (Wave/Heat equation not to be derived).

(15 Lectures)

Practical : 60 Hours

The aim of this Lab is to use the computational methods to solve physical problems. The course will consist of lectures (both theory and practical) in the Computer Lab. The recommended group size for the lab is not more than 15 students. Evaluation done not on the basis of programming but on the basis of formulating the problem. Minimum 12 programs must be attempted taking at least one from each programming section. The instructor may chose to use Python in place of Scilab covering all features as mentioned.

Topics	Description with Applications
Introduction to Numerical computation software Scilab	Introduction to Scilab, Advantages and disadvantages, Scilab environment, Command window, Figure window, Edit window, Variables and arrays, Initialising 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, 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.
Interpolation by Newton Gregory Forward and Backward difference formula, Error estimation of linear interpolation. Lagrange Interpolation.	Evaluation of trigonometric functions e.g. $sin(x)$, $cos(x)$, $tan(x)$ etc – Given the values at n points in a tabulated form, evaluate the value at an intermediate point.
Numerical Integration: Newton Cotes Integration methods (Trapezoidal and Simpson rules) for definite integrals	Given acceleration with equidistant time data calculate position and velocity and plot them. Application to other mathematical and physical problems
Solution of Linear system of equations: Solve system of linear equations using Gauss elimination method and Gauss Seidal method. Inverse of a matrix (by Gauss elimination)	Application to Solution of mesh equations of electric circuits (3 meshes) Solution of coupled spring mass systems (3 masses)

Generation of Special functions using user defined functions and compare with Scilab built in functions	Generating and plotting Legendre Polynomials Generating and plotting Bessel functions Verification of recurrence relation Use the data obtained above for Legendre polynomials or Bessel's function at N points and find its value at an intermediate point using Lagrange interpolation.
Solution of Ordinary Differential Equations (ODE) First order Differential equation Euler, modified Euler and Runge-Kutta (RK) second and fourth order methods	First order differential equation (Initial value problems) Radioactive decay Current in RC, LC circuits with DC source Newton's law of cooling Classical equations of motion
System of First order Differential Equations	Attempt following problems using RK 4 order method: • Solve the coupled differential equations $dx/dt=y+x-x^3/3$; $dy/dt= -x$ for four initial conditions : $x(0) = 0$, $y(0) = -1$, $-2, -3, -4$. Plot x vs y for each of the four initial conditions on the same screen for $0 \leq t \leq 15$

| Second order differential equation (Euler and RK Methods) | Second Order Differential Equations: Harmonic oscillator (no friction) Damped Harmonic oscillator (Overdamped, Critically damped and Oscillatory behaviour) Forced Harmonic oscillator (Transient and Steady state solution) Apply above to LCR circuits also

The differential equation describing the motion of a pendulum is $\dfrac{d^2\theta}{dt^2} = -sin\theta$. The pendulum is released from rest at an angular displacement a, i.e. $\theta(0) = a$ and $\theta'(0) = 0$. Solve the equation for $a = 0.1$, 0.5 and 1.0 and plot $\theta, \dfrac{d\theta}{dt}$ as a function of time in the range $0 \leqslant t \leqslant 8\pi$. Also plot the analytic solution valid for small $\theta (sin\theta \approx \theta)$

Solve $$x^2\dfrac{d^2y}{dx^2} - 4x(1+x)\dfrac{dy}{dx} + 2(1+x)y = x^3$$ with the initial conditions at $x = 1$ as $y(1) = \dfrac{1}{2}e^2, \dfrac{dy}{dx}(x = 1) = \dfrac{-3}{2}e^2 - 0.5$, in the range $1 < x < 3$. Plot y and $\dfrac{dy}{dx}$ against x in the given range on the same graph. |
| Using Scicos/xcos | Generating sine wave, square wave, sawtooth wave Solution of harmonic oscillator Phase space plots |

References for Theory:

1. Differential Equations, George F. Simmons, 2006, Tata McGraw-Hill.
2. Engineering Mathematics, S.Pal and S.C. Bhunia, 2015, Oxford University Press
3. Mathematical methods for Scientists & Engineers, D.A.Mc Quarrie, 2003, Viva Books
4. Mathematical Methods for Physics and Engineers, K.F Riley, M.P. Hobson and S. J. Bence, 3rd ed., 2006, Cambridge University Press
5. Mathematical Physics, A.K. Ghatak, I.C. Goyal and S.J. Chua, Laxmi Publications Private Limited (2017)
6. Mathematical Methods for Physicists, Arfken, Weber and Harris, Elsevier

References for Practical:

1. Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific and Engineering Applications: A. Vande Wouwer, P. Saucez, C. V. Fernández. 2014 Springer ISBN: 978-3319067896.
2. Documentation at the Scilab homepage: https://www.scilab.org/tutorials
3. Documentation at the Python home page, https://docs.python.org/3/
4. Computational Physics, Darren Walker, Scientific International Pvt. Ltd (2015).
5. Introduction to Numerical Analysis, S.S. Sastry, 5th Edn., PHI Learning Pvt. Ltd. (2012).
6. Applied numerical analysis, Cutis F. Gerald and P.O. Wheatley, Pearson Education, India (2007).
7. An Introduction to Computational Physics, T. Pang, Cambridge University Press (2010).
8. Elementary Numerical Analysis, K.E. Atkinson, 3rd Edn., 2007, Wiley India Edition.

Additional References for Practical:

1. Numerical Recipes : The Art of Scientific Computing, 3rd edition, W.H. Press et.al.,Cambridge University Press.
2. Numerical Analysis, Timothy Sauer, Pearson (2013).

CC-VI: Thermal Physics (32221302)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

This coursework deal with the relationship between the macroscopic properties of the physical system in equilibrium. The primary goal is to understand the fundamental laws of thermodynamics and it's applications to various thermo dynamical systems and processes. In addition, it will also give exposure to students about the Kinetic theory of gases , transport phenomenon involved in ideal gases, phase transitions and behavior of real gases.

Course Learning Outcomes

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

- Comprehend the basic concepts of thermodynamics, the first and the second law of thermodynamics.

- Understand the concept of entropy and the associated theorems, the thermodynamic potentials and their physical interpretations.

- Know about reversible and Irreversible processes.

- Learn about Maxwell's relations and use them for solving many problems in Thermodynamics

- Understand the concept and behavior of ideal and real gases.

- Learn the basic aspects of kinetic theory of gases, Maxwell-Boltzman distribution law, equitation of energies, mean free path of molecular collisions, viscosity, thermal conductivity, diffusion and Brownian motion.

- In the laboratory course, the students are expected to do some basic experiments in thermal Physics, viz., determination of Mechanical Equivalent of Heat (J), coefficient of thermal conductivity of good and bad conductor, temperature coefficient of resistance, variation of thermo-emf of a thermocouple with temperature difference at its two junctions and calibration of a thermocouple.

Unit 1

Zeroth and First Law of Thermodynamics: Extensive and intensive Thermodynamic Variables, Thermodynamic Equilibrium, Zeroth Law of Thermodynamics & Concept of Temperature, Concept of Work & Heat, State Functions, First Law of Thermodynamics and its differential form, Internal Energy, First Law & various processes, Applications of First Law: General Relation between CP and CV, Work Done during Isothermal and Adiabatic Processes, Compressibility and Expansion Co-efficient.

(8 Lectures)

Unit 2

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

(10 lectures)

Unit 3

Entropy: Concept of Entropy, Clausius Theorem. Clausius Inequality, Second Law of Thermodynamics in terms of Entropy. Entropy of a perfect gas. Principle of Increase of

Entropy. Entropy Changes in Reversible and Irreversible processes with examples. Entropy of the Universe. Entropy Changes in Reversible and Irreversible Processes. Principle of Increase of Entropy. Temperature–Entropy diagrams for Carnot's Cycle. Third Law of Thermodynamics. Unattainability of Absolute Zero.

(7 lectures)

Unit 4

Thermodynamic Potentials: Internal Energy, Enthalpy, Helmholtz Free Energy, Gibb"s Free Energy. Their Definitions, Properties and Applications. Magnetic Work, Cooling due to adiabatic demagnetization, First and second order Phase Transitions with examples, Clausius Clapeyron Equation and Ehrenfest equations.
Maxwell's Thermodynamic Relations: Derivation of Maxwell"s thermodynamic Relations and their applications, Maxwell's Relations:(1) Clausius Clapeyron equation, (2) Value of Cp-Cv, (3) Tds Equations, (4) Energy equations.

(14 lectures)

Unit 5

Kinetic Theory of Gases Distribution of Velocities: Maxwell-Boltzmann Law of Distribution of Velocities in an Ideal Gas and its Experimental Verification. Mean, RMS and Most Probable Speeds. Degrees of Freedom. Law of Equipartition of Energy (No proof required). Specific heats of Gases.
Molecular Collisions: Mean Free Path. Collision Probability. Estimation of Mean Free Path. Transport Phenomenon in Ideal Gases: (1) Viscosity, (2) Thermal Conductivity and (3) Diffusion. Brownian Motion and its Significance.

(11 lectures)

Unit 6

Real Gases: Behavior of Real Gases: Deviations from the Ideal Gas Equation. Andrew"s Experiments on CO2 Gas. Virial Equation. Critical Constants. Continuity of Liquid and Gaseous State. Vapour and Gas. Boyle Temperature. van der Waal"s Equation of State for Real Gases. Values of Critical Constants. Law of Corresponding States. Comparison with Experimental Curves.p-V Diagrams. Free Adiabatic Expansion of a Perfect Gas. Joule-Thomson Porous Plug Experiment. Joule-Thomson Effect for Real and vander Waal Gases. Temperature of Inversion. Joule-Thomson Cooling.

(10 lectures)

Practical: 60 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.

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 Cu by Angstrom"s Method.

4. To determine the Coefficient of Thermal Conductivity of a bad conductor by Lee and Charlton‟s disc method.
5. To determine the Temperature Coefficient of Resistance by Platinum Resistance Thermometer (PRT).
6. To study the variation of Thermo-emf of a Thermocouple with Difference of Temperature of its Two Junctions using a null method. And also calibrate the Thermocouple in a specified temperature range.
7. To calibrate a thermocouple to measure temperature in a specified Range using Op-Amp difference amplifier and to determine Neutral Temperature.

References for Theory:

1. Heat and Thermodynamics, M.W. Zemansky, Richard Dittman, 1981, McGraw-Hill.
2. A Treatise on Heat, Meghnad Saha, and B.N.Srivastava, 1958, Indian Press.
3. Thermal Physics, S. Garg, R. Bansal and Ghosh, 2nd Edition, 1993, Tata McGraw-Hill.
4. Thermodynamics, Kinetic Theory & Statistical Thermodynamics, Sears & Salinger. 1988, Narosa.
5. Concepts in thermal Physics: Blundell & Blundell , Oxford Univ. press
6. Thermal Physics, A. Kumar and S.P. Taneja, 2014, R. Chand Publications.

References for Practical:

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 & 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.
5. An Advanced Course in Practical Physics, D. Chattopadhyay & P. C. Rakshit, 2013, New Book Agency (P) Ltd.
6. Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press
7. B.Sc. Practical Physics, H. Singh & P. S. Hemne, 2011, S Chand and Company Ltd
8. B.Sc. Practical Physics, C. L. Arora, 2011, S Chand and Company Ltd.
9. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers.

CC-VII: Digital Systems and Applications (32221303)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

- This is one of the core papers in physics curriculum which introduces the concept of Boolean algebra and the basic digital electronics.
- In this course, students will be able to understand the working principle of CRO, Data processing circuits, Arithmetic Circuits, sequential circuits like registers, counters etc. based on flip flops.
- In addition, students will get an overview of microprocessor architecture and programming.

Course Learning Outcomes

This course lays the foundation for understanding the digital logic circuits and their use in combinational and sequential logic circuit design. It also imparts information about the basic architecture, memory and input/output organization in a microprocessor system. The students also learn the working of CRO.

- Course learning begins with the basic understanding of active and passive components. It then builds
- Concept of Integrated Chips (IC): its classification and uses.
- Differentiating with the Analog and Digital circuits, the concepts of number systems like Binary,
- BCD, Octal and hexadecimal are developed to elaborate and focus on the digital systems.
- Explains the concepts of logic states and logic gates AND, OR, NOT, NAND, NOR, XOR and XNOR as fundamental, universal and derived gates with its utility.
- Covers the realisation of NOT, OR and AND gates using diodes and transistors.
- Students learn how to write logical Boolean statements using the truth table, its simplification using Boolean Algebra, De-Morgan's Theorem and Karnaugh Maps specially the Sum of Products method and realise the corresponding logic circuit.
- Understanding and usage of various important categories of circuits are imparted.
- Data Processing Circuits that are used in communication systems for data selection and transmission.
- Some combinational circuits that perform arithmetic functions like addition and subtraction.
- Sequential Circuits: Beginning with the basic memory elements Flips-Flops, it develops to more elaborate circuits like shift registers and 4-bits counters to provide a basic idea about memory including RAM, ROM and also about memory organization.
- Timer circuits using IC 555 to provide clock pulses to sequential circuits and develop multivibrators.
- Expose students to the Input/output devices, memory organisation, memory interfacing and maps in computer systems.

- Introduces to basic architecture of processing in an Intel 8085 microprocessor and to Assembly Language.
- Also impart understanding of working of CRO and its usage in measurements of voltage, current, frequency and phase measurement.
- In the laboratory he is expected to construct both combinational circuits and sequential circuits by employing NAND as building blocks and demonstrate Adders, Subtractors, Shift Registers, and multivibrators using 555 ICs. He is also expected to use µP 8085 to demonstrate the same simple programme using assembly language and execute the programme using a µP kit.

Unit 1

Introduction to CRO: Block Diagram of CRO. Electron Gun, Deflection System and Time Base. Deflection Sensitivity. Applications of CRO: (1) Study of Waveform, (2) Measurement of Voltage, Current, Frequency, and Phase Difference.

(3 Lectures)

Digital Circuits: Difference between Analog and Digital Circuits, Examples of linear and digital ICs, Binary Numbers, Decimal to Binary and Binary to Decimal Conversion, BCD, Octal and Hexadecimal numbers, AND, OR and NOT Gates (realisation using Diodes and Transistor), NAND and NOR Gates as Universal Gates, XOR and XNOR Gates and application as Parity Checkers.

(6 Lectures)

Unit 2

Boolean algebra: De Morgan's Theorems, Boolean Laws, Simplification of Logic Circuit using Boolean Algebra, Fundamental Products, Idea of Minterms and Maxterms, Conversion of Truth table into Equivalent Logic Circuit by (1) Sum of Products Method and (2) Karnaugh Map. **(7 Lectures)**

Data processing circuits: Multiplexers, De-multiplexers, Decoders, Encoders.

(4 Lectures)

Unit 3

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

(5 Lectures)

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

(6 Lectures)

Unit 4

Timers: IC 555 block diagram and applications: Astable multivibrator and Monostable multivibrator.

(3 Lectures)

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

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

(4 Lectures)

Unit 5

Computer Organization: Input/Output Devices. Data storage (idea of RAM and ROM). Computer memory. Memory organization and addressing. Memory Interfacing. Memory Map.

(6 Lectures)

Unit 6

Intel 8085 Microprocessor Architecture: Main features of 8085. Block diagram. Components. Pin-out diagram. Buses. Registers. ALU. Memory. Stack memory. Timing and Control circuitry. Timing states. Instruction cycle, Timing diagram of MOV and MVI.

(10 Lectures)

Introduction to Assembly Language: 1 byte, 2 byte and 3 byte instructions.

(4 Lectures)

Practical: 60 Hours

Session on the construction and use of CRO, and other 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 06 experiments each from section A and Section B

Section-A: Digital Circuits Hardware design/Verilog Design

1. To design a combinational logic system for a specified Truth Table.
(a) To convert Boolean expression into logic circuit &design it using logic gate ICs
(b) To minimize a given logic circuit.
2. Half Adder, Full Adder and 4-bit binary Adder.
3. Half Subtractor, Full Subtractor, Adder-Subtractor using Full Adder I.C.
4. To build Flip-Flop (RS, Clocked RS, D-type and JK) circuits using NAND gates.
5. To build JK Master-slave flip-flop using Flip-Flop ICs
6. To build a 4-bit Counter using D-type/JK Flip-Flop ICs and study timing diagram.
7. To make a 4-bit Shift Register (serial and parallel) using D-type/JK Flip-Flop ICs.
8. To measure (a) Voltage, and (b) Time period of a periodic waveform using CRO and to design an astable multivibrator of given specifications using 555 Timer.
9. To design a monostable multivibrator of given specifications using 555 Timer.

Section-B: Programs using 8085 Microprocessor:

1. Addition and subtraction of numbers using direct addressing mode
2. Addition and subtraction of numbers using indirect addressing mode

3. Multiplication by repeated addition.
4. Division by repeated subtraction.
5. Handling of 16-bit Numbers.
6. Use of CALL and RETURN Instruction.
7. Block data handling.
8. Parity Check
9. Other programs (e.g. using interrupts, etc.).

References

1. Digital Principles and Applications, A.P.Malvino, D.P.Leach and G. Saha, 8th Ed., 2018, Tata McGraw Hill Education
2. Fundamentals of Digital Circuits, Anand Kumar, 4th Edn, 2018, PHI Learning Pvt. Ltd. Digital Circuits and systems, Venugopal, 2011, Tata McGraw Hill
3. Digital Electronics G K Kharate ,2010, Oxford University Press
4. Logic circuit design, Shimon P. Vingron, 2012, Springer
5. Digital Electronics, Subrata Ghoshal, 2012, Cengage Learning. Digital Electronics, S.K. Mandal, 2010, 1st edition, McGraw Hill
6. Microprocessor Architecture Programming & applications with 8085, 2002, R.S. Goankar, Prentice Hall.
7. Digital Computer Electronics, A.P. Malvino, J.A. Brown, 3rd Edition, 2018, Tata McGraw Hill Education.
8. Modern Digital Electronics, R.P. Jain, 4th Edition, 2010, Tata McGraw Hill
9. Basic Electronics: A text lab manual, P.B.Zbar, A.P.Malvino, M.A.Miller, 1994, McGraw Hill.
10. Microprocessor 8085: Architecture, Programming and interfacing, A.Wadhwa,2010, PHI Learning

CC-VIII: Mathematical Physics III (32221401)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

The emphasis of the course is on applications in solving problems of interest to physicists. Students are t be examined on the basis of problems, seen and unseen. Demonstrate understanding of the basic concepts underlying complex analysis and complex integration. Develop an understanding of Fourier and Laplace Transform to solve real world problems

Course Learning Outcomes

After completing this course, student will be able to

- Determine continuity, differentiability and analyticity of a complex function and find the derivative of a function.
- Understand properties of elementary complex functions (polynomials, reciprocals, exponential, trigonometric, hyperbolic, etc) of single complex variable.
- Work with multi-valued functions (logarithmic, complex power, inverse trigonometric function) and determine branches of these functions
- Evaluate a contour integral using parametrization, 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 and find the residues use the residue theory to evaluate a contour integral and real integral.
- Find the Fourier transform and the inverse Fourier transform of a function and understand their properties
- Understand the properties of Laplace transform and inverse Laplace transform and use it to solve boundary value problems.
- In the laboratory course, the students should apply their C++/Scilab/Python programming language to solve the following problems:

    i. Solve boundary value problems represented by ordinary differential equations.
    ii. Perform numerical integration using Gauss quadrature methods.
    iii. Approximate a periodic function by a few terms in the Fourier series and understand the behavior at the point of discontinuity.
    iv. Understand the limit in which a Gaussian function behaves like a Dirac Delta Function
    v. Solve partial differential equations numerically.
    vi. Find fast Fourier transform and Laplace transform of a given function numerically.
    vii. Plot Legendre polynomials and the Bessel functions of different orders and interpretations of the results.
    viii. Weighted of a given data to a graph.

Unit 1

Complex Analysis

Complex Analysis: Brief Revision of Complex Numbers and their Graphical Representation. Euler's formula, De-Moivre's theorem, Roots of Complex Numbers. Functions of Complex Variables. Analyticity and Cauchy-Riemann Equations. Examples of analytic functions. Singularities: poles, removable singularity, essential singularity, branch points, branch cut. Integration of a function of a complex variable. Cauchy-Goursat Theorem, Cauchy's Inequality. Cauchy's Integral formula. Simply and multiply connected region. Laurent and Taylor's expansion. Residues and Residue Theorem. Application of Contour Integration in solving Definite Integrals.

(30 Lectures)

Unit 2

Integrals Transforms

Fourier Transforms: Fourier Integral theorem (Statement only). Fourier Transform (FT). Examples: FT of single pulse, trigonometric, exponential and Gaussian functions. FT of derivatives, Inverse FT, Convolution theorem. Properties of FT s (translation, change of scale, complex conjugation, etc.). Solution of one dimensional Wave Equation using FT. Fourier Sine Transform (FST) and Fourier Cosine Transform (FCT).

(12 Lectures)

Unit 3

Laplace Transforms: Laplace Transform (LT) of Elementary functions. Properties of LTs: Change of Scale Theorem, Shifting Theorem. LTs of 1st and 2nd order Derivatives and Integrals of Functions, Derivatives and Integrals of LTs. LT of Unit Step function, Periodic Functions. Convolution Theorem. Inverse LT. Application of Laplace Transforms to 2nd order Differential Equations, Coupled differential equations of 1st order. Solution of 1-D heat equation (semi-infinite bar) using LT.

(15 Lectures)

Unit 4

Dirac delta function: Definition and properties. Representation of Dirac delta function as a Fourier Integral. Laplace and Fourier Transform of Dirac delta function.

(3 Lectures)

Practical: 60 Hours

The aim of this Lab is to use the computational methods to solve physical problems. The course will consist of lectures (both theory and practical) in the Computer Lab. Evaluation done not only on the basis of programming but also on the basis of formulating the problem. At least ten programs must be attempted taking at least one from each programming section. The program list is only suggestive and students should be encouraged to do more problems.

C^{++}/C/Scilab/Python based simulations experiments on Mathematical Physics problems like

1. Boundary Value Problems :
- Solution to Ordinary Differential equation (Boundary Value Problems using finite Difference and shooting methods) :
  $y''(x) + y(x) = 0$ with $y(0) = 1, y(\pi/2) = 1$ solve for $0 < x < \pi$.
- Solve for the steady state concentration profile y(x) in the reaction-diffusion problem given by $y''(x) - y(x) = 0$ with $y(0) = 1, y(1) = 0$.
- Solution to Partial Differential equation :
- Finite Difference and Crank-Nicholson methods to solve Laplace equation, wave equation, and Heat Equation.

2. Gauss Quadrature Integration Method : Gauss Legendre, Gauss Lagaurre and Gauss Hermite. :
- Verification of Orthogonality of Legendre Polynomials.

$$\int_{-1}^{+1} P_n(\mu) P_m(\mu) d\mu = \frac{2}{(2n + 1)} \delta_{n,m}$$

- Complex analysis: Integrate $\int_{-\infty}^{\infty} \frac{1}{(x^2 + 2)} dx$ numerically and check with contour integration.

3. Dirac Delta Function: representations of Dirac delta function as a limiting sequence of functions. Verify the properties of Dirac Delta function. e.g. Evaluate

$\frac{1}{\sqrt{2\pi\sigma^2}} \int exp\left(\frac{-(x - 2)^2}{2\sigma^2}\right)(x + 3)dx$, for $\square$ = 1, 0.1, 0.01 and show that it tends to 5. Use Hermite Gauss quadrature method and also Simpson method with appropriate limits.

4. Fourier Series:

- Program to sum $\sum_{n=1}^{\infty} (0.2)^n$
- Evaluate the Fourier coefficients of a given periodic function (e.g. square wave, triangle wave, half wave and full wave rectifier)

5. Least square fitting of linear line with weightage to error in data points for a given data set using user defined function.

6. Integral transform:
- Fast Fourier Transform of e^{-x^2}
- Perform circuit analysis of a general LCR circuit using Laplace's transform.

References for Practical:

1. Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific and Engineering Applications: A. Vande Wouwer, P. Saucez, C. V. Fernández. 2014 Springer.
2. Documentation at the Scilab homepage: https://www.scilab.org/tutorials

3. Documentation at the Python home page, https://docs.python.org/3/
4. Computational Physics, Darren Walker, Scientific International Pvt. Ltd (2015).
5. Introduction to Numerical Analysis, S.S. Sastry, 5th Edn., PHI Learning Pvt. Ltd. (2012).
6. An Introduction to Computational Physics, T. Pang, Cambridge University Press (2010).
7. Elementary Numerical Analysis, K.E. Atkinson, 3rd Edn., 2007, Wiley India Edition.
8. Partial Differential Equations for Scientists and Engineers, Stanley J. Farlow Dover Publications.

Additional References for Practical:

1. Numerical Recipes : The Art of Scientific Computing, 3rd edition, W.H. Press et.al.,Cambridge University Press.
2. Numerical Analysis, Timothy Sauer, Pearson (2013).
3. Fourier Transform and Its Applications, 2nd Edition (McGraw-Hill electrical and electronic engineering series)
4. Ronald Newbold Bracewell , McGraw-Hill; 2nd edition (1978).

CC-IX: Elements of Modern Physics (32221402)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

This course introduces modern development in Physics that ushered in relativity and quantum physics which not only revolutionized mankind's understanding of time, space, atomic and sub-atomic structures that make up the matter around us, but also led to fascinating developments in technology that are being witnessed all around us. Beginning with technological marvels like electronics, spectroscopy, semiconductor based devices, IC chips, lasers, harnessing of nuclear energy, satellite communication, atomic clocks, GPS, space travel, scanning tunneling microscope, nano-materials, nano-technology, CCDs, etc. modern physics brought forth useful tools in our daily lives like laptop computers, mobile phones, laser pointers, LEDs, LCD screens, so on and so forth. Therefore, the objective of this course is to teach the physical and mathematical foundations necessary for learning various topics in modern physics. Starting from Planck's law, this course introduces experimental observation of photo-ejection of electrons, idea of wave-particle duality as well as Bohr model of atoms and, then it develops the formulation of Schrodinger equation and the idea of probability interpretation associated with wave-

functions. It also introduces basic underlying concepts involved in laser physics as well as that in nuclear physics, so crucial for high energy physics, nuclear technology and astrophysics.

Course 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 and ability to discuss and interpret experiments that reveal the dual nature of matter.

- Quantum measurements and the theory of wave packets and uncertainty principle.
- The central concepts of quantum mechanics: wave functions, momentum and energy operator, the Schrodinger equation, time dependent and time independent cases, probability density and the normalization techniques, skill development on problem solving e.g. one dimensional rigid box, tunneling through potential barrier, step potential, rectangular barrier.
- The properties of nuclei like density, size, binding energy, nuclear forces and structure of atomic nucleus, liquid drop model and nuclear shell model and mass formula.
- Decay rates and lifetime of radioactive decays like alpha, beta, gamma decay. Neutrino, its properties and its role in theory of beta decay.
- Fission and fusion well as nuclear processes to produce nuclear energy in nuclear reactor and stellar energy in stars.
- Various interactions of electromagnetic radiation with matter. Electron positron pair creation.
- The spontaneous and stimulated emission of radiation, optical pumping and population inversion. Three level and four level lasers. Ruby laser and He-Ne laser in details. Basic lasing.
- In the laboratory course, the students will get opportunity to measure Planck's constant by more than one method, verify photoelectric effect and determination of the work Function of a metal, determine e/m of electron.
- Ionization potential of atoms, wavelength of the emission lines in the spectrum of Hydrogen atom, absorption lines in the rotational spectrum of molecules.
- The wavelength of Laser sources by single and Double slit experiment and the wavelength and angular spread of He-Ne Laser using plane diffraction grating.

Unit 1

Planck's quantum, Planck's constant and light as a collection of photons; Blackbody Radiation: 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. Double-slit experiment with electrons. Probability. Wave amplitude and wave functions.

(12 Lectures)

Unit 2

Position measurement : gamma ray microscope thought experiment; Wave-particle duality leading to Heisenberg uncertainty principle; Uncertainty relations involving canonical pair of variables: Derivation from Wave Packets; Impossibility of a particle following a

trajectory; Estimating minimum energy of a confined particle using uncertainty principle; Energy-time uncertainty principle: origin of natural width of emission lines as well as estimation of the mass of the virtual particle that mediates a force from the observed range of the force

(7 Lectures)

Unit 3

Two-slit interference experiment with photons, atoms and particles; linear superposition principle as a consequence; Schrodinger equation for non-relativistic particles; Momentum and Energy operators; stationary states; physical interpretation of a wave function, probabilities and normalization; Probability and probability current densities in one dimension.

(10 Lectures)

Unit 4

One dimensional infinitely rigid box : energy eigenvalues, eigenfunctions and their normalization; Quantum dot as an example; Quantum mechanical scattering and tunneling in one dimension : across a step potential & across a rectangular potential barrier.
Lasers: Metastable states. Spontaneous and Stimulated emissions. Optical Pumping and Population Inversion.

(14 Lectures)

Unit 5

Size and structure of atomic nucleus and its relation with atomic weight; Impossibility of an electron being in the nucleus as a consequence of the uncertainty principle. Nature of nuclear force, N-Z graph, Liquid Drop model: semi-empirical mass formula and binding energy.

(6 Lectures)

Unit 6

Radioactivity: stability of the nucleus; Law of radioactive decay; Mean life and half-life; Alpha decay; Beta decay: energy released, spectrum and Pauli's prediction of neutrino; Gamma ray emission, energy-momentum conservation: electron-positron pair creation by gamma photons in the vicinity of a nucleus. Fission and fusion: mass deficit, relativity and generation of energy; Fission : nature of fragments and emission of neutrons. Fusion and thermonuclear reactions driving stellar evolution (brief qualitative discussions).

(11 Lectures)

Practical: 60 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.

At least 05 experiments from the following:

1. To determine value of Boltzmann constant using V-I characteristic of PN diode.
2. To determine work function of material of filament of directly heated vacuum diode.
3. To determine the ionization potential of mercury.
4. To determine value of Planck's constant using LEDs of at least 4 different colours.
5. To determine the wavelength of H-alpha emission line of Hydrogen atom.
6. To determine the absorption lines in the rotational spectrum of Iodine vapour.
7. To study the diffraction patterns of single and double slits using laser and measure its intensity variation using Photosensor & compare with incoherent source– Na.
8. Photo-electric effect: photo current versus intensity and wavelength of light; maximum energy of photo-electrons versus frequency of light
9. To determine the value of e/m by (a) Magnetic focusing or (b) Bar magnet.

References

1. Concepts of Modern Physics, Arthur Beiser, 2002, McGraw-Hill.
2. Introduction to Modern Physics, Rich Meyer, Kennard, Cooper, 2002, Tata McGraw Hill
3. Physics for scientists and Engineers with Modern Physics, Jewett and Serway, Cengage Learning 2010
4. Quantum Mechanics: Theory and Applications, (2019), (Extensively revised 6th Edition), Ajoy Ghatak and S. Lokanathan, Laxmi Publications, New Delhi
5. Quantum Physics, Berkeley Physics, Vol.4. E.H.Wichman, 1971, Tata McGraw-Hill Co.30
6. Theory and Problems of Modern Physics, Schaum`s outline, R. Gautreau and W. Savin, 2nd Edn, Tata McGraw-Hill Publishing Co. Ltd.
7. Modern Physics, G.Kaur and G.R. Pickrell, 2014, McGraw Hill
8. Introduction to Modern Physics by M Mani & G K Mehta, Affiliated East-West Press, 1990.
9. Modern Physics by R A Serway, C J Moses and C A Moyer, 3rd edition, Thomson Brooks Cole, 2012.
10. Modern Physics for Scientists and Engineers by S T Thornton and A Rex, 4th edition, Cengage Learning, 2013.
11. Modern Physics by G Aruldhas and P Rajagopal. PHI Learning Pvt. Ltd., 2016.

Books for Numericals:

1. Schaum's Outline of Modern Physics, McGraw-Hill, 1999.
2. Schaum's Outline of College Physics, by E. Hecht, 11th edition, McGraw Hill, 2009.
3. Modern Physics by K Sivaprasath and R Murugeshan, S Chand Publication, 2010.
4. Quantum Mechanics: 500 problems and solutions by G. Aruldhas. PHI Learning Pvt. Ltd., 2016.

Additional Resources:

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. Quantum Theory, David Bohm, Dover Publications, 1979

4. Lectures on Quantum Mechanics: Fundamentals and Applications, eds. A. Pathak and Ajoy Ghatak, Viva Books Pvt. Ltd., 2019
5. Introduction to Quantum Mechanics, David J. Griffith, 2005, Pearson Education.

Suggested/Classic 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.

CC-X: Analog Systems and Applications (32221403)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

- This is one of the core papers i n physics curriculum where students will get to learn about the physics of semiconductor p-n junction and devices such as rectifier diodes, Zener diode, photodiode etc. and bipolar junction transistors.
- Transistor biasing and stabilization circuits are explained. The concept of feedback is discussed in amplifiers a the oscillator circuits are also studied.
- By the end of the syllabus, students will also have an understanding of operational amplifiers and their applications.

Course Learning Outcomes

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

- To have knowledge about characteristics of semiconductor materials in terms of band structure, movement of charge carriers and to explain properties of n and p type semiconductors.
- To know the basic concepts of PN junction diode, its fabrication, conduction mechanism and determine its barrier potential and width.
- To learn structure and operation of simple PN junction devices such as LED, photo diodes, Solar cells, Zener diodes etc.

- To apply the basics of diodes to describe working of rectifier circuits and quantitatively explain effect of capacitance filter, line and load regulation
- NPN and PNP transistors and basic configurations namely common base, common emitter and common collector, and also about current and voltage gain.
- To understand the structure and operation of Bipolar Junction transistors. Also be able to explain various current components and characteristics of different configurations.
- To describe the application of transistors for current and voltage applications, need for biasing and stabilization in transistor amplifiers.
- To analyze single stage CE and two stage RC coupled transistor amplifier using h-parameter model of the transistor.
- To ingest the effect of feedback in amplifiers and apply them to design different type of oscillators.
- To distinguish ideal and practical op-amps, comprehend need for op-amps and their electrical parameters.
- To understand various operating modes of Op-amps and its linear and non-linear application particularly application as D to A and A to D converter and acquire skill to design circuits for different Op-amp applications.
- In the laboratory course, the students will design combinational logic system for a given equation minimizing the logic circuit, Adder, Subtractor, Flip-Flops, 4-bit counter, Shift Register, Multivibrator using 555 Timer.
- Also programming using 8085 Microprocessor

Unit 1
Semiconductor Diodes: P and N type semiconductors. Energy Level Diagram. Conductivity and Mobility, Concept of Drift velocity.PN Junction Fabrication (Simple Idea). Barrier Formation in PN Junction Diode. Derivation for Barrier Potential, Barrier Width and Current for abrupt Junction. Equation of continuity, Current Flow Mechanism in Forward and Reverse Biased Diode.

(9 Lectures)

Unit 2

Two-terminal Devices and their Applications: (1) Rectifier Diode: Half-wave Rectifiers. Centre-tapped and Bridge Full-wave Rectifiers, Calculation of Ripple Factor and Rectification Efficiency, C-filter, (2) Zener Diode and Voltage Regulation. Principle, structure and characteristics of (1) LED, (2) Photodiode and (3) Solar Cell, Qualitative idea of Schottky diode and Tunnel diode.

(7 Lectures)

Unit 3

Bipolar Junction transistors: n-p-n and p-n-p Transistors. I-V characteristics of CB and CE Configurations. Active, Cutoff and Saturation Regions. Current gains α and β. Relations between α and β. Load Line analysis of Transistors. DC Load line and Q-point. Physical Mechanism of Current Flow.

(6 Lectures)

Unit 4

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

(10 Lectures)

Coupled Amplifier: Two stage RC-coupled amplifier and its frequency response.

(4 Lectures)

Unit 5

Feedback in Amplifiers: Positive and Negative Feedback. Effect of negative feedback on Input Impedance, Output Impedance, Gain, Stability, Distortion and Noise.

(4 Lectures)

Sinusoidal Oscillators: Barkhausen's Criterion for self-sustained oscillations. RC Phase shift oscillator, determination of Frequency. Hartley & Colpitts oscillators.

(4 Lectures)

Unit 6

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

(4 Lectures)

Applications of Op-Amps: (1) Inverting and non-inverting amplifiers, (2) Adder, (3) Subtractor, (4) Differentiator, (5) Integrator, (6) Log amplifier, (7) Comparator and Zero crossing detector (8) Wein bridge oscillator.

(9 Lectures)

Conversion: D/A Resistive networks (Weighted and R-2R Ladder). Accuracy and Resolution.

(3 Lectures)

Practical : 60 Hours

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 08 experiments from the following:

1. To study the V-I characteristics of a Zener diode and its use as voltage regulator.
2. Study of V-I & power curves of solar cells, and find maximum power point & efficiency.
3. To study the characteristics of a Bipolar Junction Transistor in CE configuration.
4. To study the various biasing configurations of BJT for normal class A operation.
5. To design a CE transistor amplifier of a given gain (mid-gain) using voltage divider bias.
6. To study the frequency response of voltage gain of a two stage RC-coupled transistor amplifier.
7. To design a Wien bridge oscillator for given frequency using an op-amp.

8. To design a phase shift oscillator of given specifications using BJT.
9. To design a digital to analog converter (DAC) of given specifications.
10. To design an inverting amplifier using Op-amp (741,351) for dc voltage of given gain
11. (a) To design inverting amplifier using Op-amp(741,351) & study its frequency response
    (b) To design non-inverting amplifier using Op-amp (741,351) & study frequency response
12. (a) To add two dc voltages using Op-amp in inverting and non-inverting mode
    (b) To study the zero-crossing detector and comparator.
13. To design a precision Differential amplifier of given I/O specification using Op-amp.
14. To investigate the use of an op-amp as an Integrator.
15. To investigate the use of an op-amp as a Differentiator.
16. To design a circuit to simulate the solution of simultaneous equation and 1st/2ndorder differential equation.

References

1. Integrated Electronics, J. Millman and C.C. Halkias, 1991, Tata Mc-Graw Hill. Electronics: Fundamentals and Applications, J.D. Ryder, 2004, Prentice Hall.
2. Solid State Electronic Devices, B.G.Streetman & S.K.Banerjee, 6th Edn.,2009, PHI
3. Learning Electronic Devices & circuits, S.Salivahanan & N.S.Kumar, 3rd Ed., 2012, Tata Mc-Graw Hill OP-Amps
4. Linear Integrated Circuit, R. A. Gayakwad, 4th edition, 2000, Prentice Hall
5. Microelectronic circuits, A.S. Sedra, K.C. Smith, A.N. Chandorkar, 2014, 6th Edn., Oxford University Press. Semiconductor Devices: Physics and Technology, S.M. Sze, 2nd Ed., 2002, Wiley India
6. Microelectronic Circuits, M.H. Rashid, 2nd Edition, Cengage Learning
7. Microelectronic Devices & Circuits, David A.Bell, 5th Edn.,2015, Oxford University Press
8. Basic Electronics: Principles and Applications, C.Saha, A.Halder, D.Ganguli, 1st Edition, 2018, Cambridge University Press
9. Electronic Principles, A. Malvino, D.J. Bates, 7th Edition, 2018, Tata Mc-Graw Hill Education.
10. Basic Electronics: A text lab manual, P.B.Zbar, A.P.Malvino, M.A.Miller, 1994, Mc-Graw Hill. OP-Amps
11. Electronic Devices & circuit Theory, R.L. Boylestad & L.D. Nashelsky, 2009, Pearson

CC-XI: Quantum Mechanics &Applications (32221501)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

After learning the elements of modern physics, students would be poised to learn more advanced topics like how to solve the Schrodinger equation for spherically symmetric potentials. Then, in this course, eigenvalues and eigen functions of the Hamiltonian as well as the orbital angular momentum would be studied. Furthermore, application of Schrodinger equation to various quantum mechanical problems would be taken up. The spin angular momentum of electrons would also be introduced in the course.

Course Learning Outcomes

The Students will be able to learn the following from this course:

- Familiarization with quantum mechanics formulation.
- After an exposition of inadequacies of classical mechanics in explaining microscopic phenomena, quantum theory formulation is introduced through Schrodinger equation.
- The interpretation of wave function of quantum particle and probabilistic nature of its location and subtler points of quantum phenomena are exposed to the student.
- Methods to solve time-dependent and time-independent Schrodinger equation
- Through understanding the behavior of quantum particle encountering a barrier potential, the student gets exposed to solving non-relativistic hydrogen atom, for its spectrum and eigenfunctions.
- Study of influence of electric and magnetic fields on atoms will help in understanding Stark effect and Zeeman Effect respectively.
- Angular momentum: Orbital angular momentum and spin angular momentum.
- Bosons and fermions - symmetric and anti-symmetric wave functions.
- Application to atomic systems
- In the laboratory course, with the exposure in computational programming in the computer lab, the student will be in a position to solve Schrodinger equation for ground state energy and wave functions of various simple quantum mechanical one-dimensional and three dimensional potentials.

Unit 1

Time dependent Schrodinger equation: Time dependent Schrodinger equation and dynamical evolution of a quantum state; Properties of Wave Function. Interpretation of

Wave Function: Probability and probability current densities in three dimensions; Conditions for Physical Acceptability of Wave Functions. Normalization. Linearity and Superposition Principles. Eigenvalues and Eigenfunctions. Position, momentum and Energy operators; commutator of position and momentum operators; Expectation values of position and momentum. Wave Function of a Free Particle.

(12 Lectures)

Unit 2

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

(12 Lectures)

Unit 3

General discussion of bound states in an arbitrary potential: continuity of wave function, boundary condition and emergence of discrete energy levels; application to one-dimensional problem-square well potential; Quantum mechanics of simple harmonic oscillator: energy levels and energy eigenfunctions using Frobenius method; Hermite polynomials; ground state, zero point energy & uncertainty principle.

(10 Lectures)

Unit 4

Quantum theory of hydrogen-like atoms: time independent Schrodinger equation in spherical polar coordinates; separation of variables for second order partial differential equation; angular momentum operator & quantum numbers; Radial wavefunctions from Frobenius method; shapes of the probability densities for ground and first excited states; Orbital angular momentum quantum numbers l and m; s, p, d shells.

(10 Lectures)

Unit 5

Atoms in Electric and Magnetic Fields: Electron angular momentum. Angular momentum quantization. Electron Spin and Spin Angular Momentum. Larmor's Theorem. Spin Magnetic Moment. Stern-Gerlach Experiment. Normal Zeeman Effect: Electron Magnetic Moment and Magnetic Energy.

(8 Lectures)

Unit 6

Many electron atoms: Pauli's Exclusion Principle. Symmetric and Anti-symmetric Wave Functions. Spin orbit coupling. Spectral Notations for Atomic States. Total angular momentum. Spin-orbit coupling in atoms-L-S and J-J couplings.

(8 Lectures)

Practical : 60 Hours

Use C/C++/Scilab/Python for solving the following problems based on Quantum Mechanics like:

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

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

where m is the reduced mass of the electron. Obtain the energy eigenvalues and plot the corresponding wavefunctions. Remember that the ground state energy of the hydrogen atom is ≈ -13.6 eV. Take e = 3.795 (eVÅ)$^{1/2}$, ħc = 1973 (eVÅ) and m = 0.511x10^6 eV/c^2.

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

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

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

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

Find the energy (in eV) of the ground state of the atom to an accuracy of three significant digits. Also, plot the corresponding wavefunction. Take e = 3.795 (eVÅ)$^{1/2}$, m = 0.511x10^6 eV/c^2, and a = 3 Å, 5 Å, 7 Å. In these units ħc = 1973 (eVÅ). The ground state energy is expected to be above -12 eV in all three cases.

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

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

For an harmonic oscillator potential

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

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

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

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

Where μ is the reduced mass of the two-atom system for the Morse potential

$$V(r) = D(e^{-2ar'} - e^{-ar'}), r' = \frac{r - r_0}{r}$$

Find the lowest vibrational energy (in MeV) of the molecule to an accuracy of three significant digits. Also plot the corresponding wave function.

Take: m = 940x10^6 eV/c^2, D = 0.755501 eV, α = 1.44, r_0 = 0.131349 Å

Where μ is the reduced mass of the two-atom system for the Morse potential

Find the lowest vibrational energy (in MeV) of the molecule to an accuracy of three significant digits. Also plot the corresponding wave function.

Take: m = 940x10^6 eV/c^2, D = 0.755501 eV, α = 1.44, r_o = 0.131349 Å

Laboratory based experiments (Optional):

5. Study of Electron spin resonance- determine magnetic field as a function of the resonance frequency
6. Study of Zeeman effect: with external magnetic field; Hyperfine splitting
7. Quantum efficiency of CCD

References for Theory:

1. Quantum Mechanics, Robert Eisberg and Robert Resnick, 2nd Ed., 2002, Wiley.
2. Introduction to Quantum Mechanics, D.J. Griffith, 2nd Ed. 2005, Pearson Education
3. Basic Quantum Mechanics, A. Ghatak, Macmillan, 2009
4. Quantum Mechanics for Scientists & Engineers, D.A.B. Miller, 2008, Cambridge University Press
5. Quantum Mechanics: Theory and Applications, (2019), (Extensively revised 6th Edition), Ajoy Ghatak and S. Lokanathan, Laxmi Publications, New Delhi.

References for Practical:

1. Schaum's outline of Programming with C++. J.Hubbard, 2000,McGraw-Hill Publication
2. An introduction to computational Physics, T.Pang, 2nd Edn.,2006, Cambridge Univ. Press
3. Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific & Engineering Applications: A. Vande Wouwer, P. Saucez, C. V. Fernández.2014 Springer.
4. Scilab (A Free Software to Matlab): H. Ramchandran, A.S. Nair. 2011 S. Chand & Co.
5. A Guide to MATLAB, B.R. Hunt, R.L. Lipsman, J.M. Rosenberg, 2014, 3rd Edn., Cambridge University Press

Additional Resources:

1. Lectures on Quantum Mechanics: Fundamentals and Applications, eds. A. Pathak and Ajoy Ghatak, Viva Books Pvt. Ltd., 2019.
2. A Text book of Quantum Mechanics, P.M.Mathews and K.Venkatesan, 2nd Ed., 2010, McGraw Hill
3. Introduction to Quantum Mechanics, R. H. Dicke and J. P. Wittke, Addison-Wesley Publications, 1966
4. Quantum Mechanics, Leonard I. Schiff, 3rd Edn. 2010, Tata McGraw Hill.

5. Quantum Mechanics, Eugen Merzbacher, 2004, John Wiley and Sons, Inc.
6. The Principles of Quantum Mechanics, P. A. M. Dirac, Clarendon Press, 2004

CC-XII: Solid State Physics (32221502)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

This syllabus begins with introduction to the basic concepts and principles to understand the various properties exhibited by condensed matter, especially solids. These properties depend on the chemical constituents making the particular solid and their arrangement in the crystal. A semi-classical approach is used to introduce various models, from toy model to a higher level, suitable to explain the particular property exhibited by the solid. The syllabus is specifically designed to guide the students to learn how to create a theoretical model for a particular property and appreciate the beauty that lies in these solids through their properties.

Course Learning Outcomes

On successful completion of the module students should be able to

*   Elucidate the concept of lattice, crystals and symmetry operations.
*   Explain the concepts such as the reciprocal lattice and the Brillouin zone and the dynamics of atoms and electrons in solids.
*   Explain diffraction of X-rays by solids to determine the crystal structure.
*   Understand the elementary lattice dynamics and its influence on the properties of materials.
*   Understand lattice vibrations, phonons and in depth Einstein and Debye theory of specific heat of solids.
*   Describe the main features of the physics of electrons in solids.
*   Understand the origin of energy bands, and how they influence electronic behavior.
*   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 phase transitions and the preliminary concept and experiments related to superconductivity in solid.
*   Apply the gained knowledge to solve problems in solid state physics using relevant mathematical tools.
*   To appreciate how matter exhibits such interesting and wonderful properties and communicate the importance of solid state physics in the modern society.
*   To 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.

Unit 1

Crystal Structure: Solids: Amorphous and Crystalline Materials. Lattice Translation Vectors. Lattice with a Basis. Types of Lattices. Unit Cell, Symmetry and Symmetry Elements. Miller Indices. Reciprocal Lattice. Brillouin Zones. Diffraction of X-rays: single crystal and powder method. Bragg's Law, Laue Condition. Ewalds' construction. Atomic and Geometrical Factor. Simple numerical problem on SC, BCC, FCC.

(14 Lectures)

Unit 2

Elementary Lattice Dynamics: Lattice Vibrations and Phonons: Linear Monoatomic and Diatomic Chains. Acoustical and Optical Phonons. Qualitative Description of the Phonon Spectrum in Solids. Dulong and Petit's Law, Einstein and Debye theories of specific heat of solids. T^3 law.

(10 Lectures)

Unit 3

Electrons in Solids: Electrons in metals- Introduction to Drude Model, Density of states (1-D, 2-D, 3-D) (basic idea), Elementary band theory: Kronig Penney model. Band Gap, direct and indirect bandgap. Effective mass, mobility, Hall Effect (Metal and Semiconductor).

(10 Lectures)

Unit 4

Magnetic Properties of Matter: Dia-, Para-, Ferri- and Ferromagnetic Materials. Classical Langevin Theory of dia– and Para- magnetism. Hunds's rule. Weiss's Theory of Ferromagnetism and Ferromagnetic Domains. Curie's law. B-H Curve. soft and hard material and Energy Loss Hysteresis.

(9 Lectures)

Unit 5

Dielectric Properties of Materials: Polarization. Local Electric Field in solids. Depolarization Field. Electric Susceptibility. Polarizability. Clausius Mossotti Equation. Classical Theory of Electric Polarizability. AC polarizability, Normal and Anomalous Dispersion. Complex Dielectric Constant. Langevin-Debye equation.

(9 Lectures)

Unit 6

Introduction to basics of phase transitions: Landau theory for ferromagnetic materials (No derivation).

(3 Lectures)

Superconductivity: Experimental Results. Critical Temperature. Critical magnetic field. Meissner effect. Type I and type II Superconductors, London's Equation and Penetration Depth. Isotope effect. Idea of BCS theory (No derivation).

(5 Lectures)

Practical : 60 Hours

Sessions on the construction and use of specific measurement instruments and experimental apparatuses used in the solid state 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.

At least 06 experiments from the following:

1. Measurement of susceptibility of paramagnetic solution (Quinck's Tube Method).
2. To measure the Magnetic susceptibility of solids.
3. To determine the Coupling Coefficient of a piezoelectric crystal.
4. To study the dielectric response of materials with frequency.
5. To determine the complex dielectric constant and plasma frequency of a metal using Surface Plasmon Resonance (SPR) technique.
6. To determine the refractive index of a dielectric material using SPR technique.
7. To study the PE Hysteresis loop of a Ferroelectric Crystal.
8. To draw the BH curve of Iron (Fe) using solenoid & determine the energy loss from Hysteresis loop.
9. To measure the resistivity of a semiconductor (Ge) with temperature (up to 150^0C) by four-probe method and determine its band gap.
10. To determine the Hall coefficient of a semiconductor sample.
11. Analysis of X-Ray diffraction data in terms of unit cell parameters and estimation of particle size.
12. Measurement of change in resistance of a semiconductor with magnetic field.

References for Theory:

1. Introduction to Solid State Physics, Charles Kittel, 8thEd.,2004, Wiley India Pvt. Ltd.
2. Elements of Solid State Physics, J.P. Srivastava, 2ndEd.,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.
6. Elementary Solid State Physics, M.Ali Omar, 2006, Pearson
7. Solid State Physics, Rita John, 2014, McGraw Hill
8. Solid State Physics, M.A. Wahab, 2011, Narosa Publications.

References for Practical:

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 & Ramakrishna, 11th Ed., 2011, Kitab Mahal
3. Elements of Solid State Physics, J.P. Srivastava, 2nd Ed., 2006, Prentice-Hall of India
4. An Advanced Course in Practical Physics, D. Chattopadhyay & P. C. Rakshit, 2013, New Book Agency (P) Ltd.
5. Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press
6. B.Sc. Practical Physics, H. Singh & P. S. Hemne, 2011, S Chand and Company Ltd
7. B.Sc. Practical Physics, C. L. Arora, 2011, S Chand and Company Ltd.
8. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers.

CC-XIII: Electromagnetic Theory (32221601)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

Electromagnetic theory is a core course in B. Sc. (Honours) Physics curriculum. The course covers Maxwell's equations, propagation of electromagnetic (em) waves in different homogeneous-isotropic as well as anisotropic unbounded and bounded media, production and detection of different types of polarized em waves, general information as waveguides and fibre optics.

Course Learning Outcomes

- Concept of Maxwell Equations, role of displacement current, gauge transformations, scalar and vector potentials, Coulomb and Lorentz gauge, boundary conditions at the interface between different media.
- Apply Maxwell's equations to deduce wave equation, electromagnetic field energy, momentum and angular momentum density.
- Understanding of Poynting Theorem and poynting vector.
- Electromagnetic wave propagation in unbounded media: Vacuum, dielectric medium, conducting medium, plasma.
- Electromagnetic wave propagation in bounded media.
- Understand the laws of reflection and refraction and to calculate the reflection and transmission coefficients at plane interface in bounded media.
- Polarization of Electromagnetic Waves: Linear, Circular and Elliptical Polarization. Production as well as detection of waves in laboratory.
- Knowledge of phase retardation plates Quarter-Wave and Half-Wave Plates.
- Babinet Compensator and its uses.
- Experimental verification of Fresnel's theory.
- Understand the features of planar optical wave guide and obtain the Electric field components, Eigen value equations, phase and group velocities in a dielectric wave guide.
- Understand the fundamentals of propagation of electromagnetic waves through optical fibres and calculate numerical apertures for step and graded indices and transmission losses.
- In the laboratory course, the student get an opportunity to perform experiments with Polarimeter, Babinet Compensator, Ultrasonic grating, simple dipole antenna

- To demonstrate principles of Interference, Refraction and diffraction of light using monochromatic sources of light, microwaves.

- Verify the laws of Polarisation for plane polarised light.

- To determine the refractive index of glass and liquid using total internal reflection of light.

Unit 1

Maxwell Equations: Review of Maxwell's equations. Displacement Current. Vector and Scalar Potentials. Gauge Transformations: Lorentz and Coulomb Gauge. Poynting's Theorem and Poynting's Vector. Electromagnetic (em) Energy Density. Physical Concept of Electromagnetic Field Energy Density. Momentum Density and Angular Momentum Density.

(12 Lectures)

Unit 2

EM Wave Propagation in Unbounded Media: Plane em waves through vacuum and isotropic dielectric medium: transverse nature, refractive index, dielectric constant, wave impedance. Plane em waves through conducting medium: relaxation time, skin depth, attenuation constant. Wave propagation through dilute plasma: electrical conductivity of ionized gases, plasma frequency, refractive index, skin depth.

(10 Lectures)

Unit 3

EM Waves in Bounded Media: Boundary conditions at a plane interface between two media. Reflection & Refraction of plane em waves at plane interface between two dielectric media-Laws of Reflection & Refraction. Fresnel's Formulae for perpendicular & parallel polarization, Brewster's law. Reflection & Transmission coefficients. Total internal reflection, evanescent waves. Metallic reflection (normal Incidence)

(10 Lectures)

Unit 4

Polarization of EM Waves: Propagation of em waves in an Anisotropic Media. Symmetric Nature of Dielectric Tensor. Fresnel's Formula. Uniaxial and Biaxial Crystals. Light Propagation in Uniaxial Crystal. Double Refraction. Polarization by Double Refraction. Description of Linear, Circular and Elliptical Polarization. Nicol Prism. Ordinary & extraordinary refractive indices. Production & detection of Plane, Circularly and Elliptically Polarized Light. Phase Retardation Plates: Quarter-Wave and Half-Wave Plates. Babinet Compensator and its Uses. Analysis of Polarized Light

(12 Lectures)

Rotatory Polarization: Optical Rotation. Biot's Laws for Rotatory Polarization. Fresnel's Theory of optical rotation. Calculation of angle of rotation. Experimental verification of Fresnel's theory. Specific rotation. Laurent's half-shade polarimeter.

(5 Lectures)

Unit 5

Wave Guides: Planar optical wave guides. Planar dielectric wave guide ($-d/2 < x < d/2$). Condition of continuity at interface. Phase shift on total reflection. Eigenvalue equations. Phase and group velocity of guided waves. Field energy and Power transmission.

(8 Lectures)

Optical Fibres: Acceptance Angle, Numerical Aperture. Step and Graded Index fibres (Definitions Only). Single and Multiple Mode Fibres.

(3 Lectures)

Practical: 60 Hours

Sessions on the construction and use of specific measurement instruments 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 06 experiments from the following

1. To verify the law of Malus for plane polarized light.
2. To determine the specific rotation of sugar solution using Polarimeter.
3. To analyze elliptically polarized Light by using a Babinet's compensator.
4. To study dependence of radiation on angle for a simple Dipole antenna.
5. To determine the wavelength and velocity of ultrasonic waves in a liquid (Kerosene Oil, Xylene, etc.) by studying the diffraction through ultrasonic grating.
6. To study the reflection, refraction of microwaves
7. To study Polarization and double slit interference in microwaves.
8. To determine the refractive index of liquid by total internal reflection using Wollaston's air-film.
9. To determine the refractive Index of (1) glass and (2) a liquid by total internal reflection using a Gaussian eyepiece.
10. To study the polarization of light by reflection and determine the polarizing angle for air-glass interface.
11. To verify the Stefan`s law of radiation and to determine Stefan's constant.
12. To determine Boltzmann constant using V-I characteristics of PN junction diode.
13. To find Numerical Aperture of an Optical Fibre.
14. To verify Brewster's Law and to find the Brewster's angle.

References for Theory:

1. Introduction to Electrodynamics, D.J. Griffiths, 3rd Ed., 1998, Benjamin Cummings.
2. Electromagnetic Field and Waves, P. Lorrain and D. Corson, 2nd Ed., 2003, CBS Publisher.
3. Elements of Electromagnetics, M.N.O. Sadiku, 2001, Oxford University Press.
4. Fundamentals of Electromagnetics, M.A.W. Miah, 1982, Tata McGraw Hill
5. Problems and solution in Electromagnetics (2015), Ajoy Ghatak, K Thyagarajan & Ravi Varshney.
6. Electromagnetic field Theory, R.S. Kshetrimayun, 2012, Cengage Learning

7. Engineering Electromagnetic, Willian H. Hayt, 8th Edition, 2012, McGraw Hill.
8. Electromagnetics, J.A. Edminster, Schaum Series, 2006, Tata McGraw Hill.
9. Electromagnetic field theory fundamentals, B.Guru and H.Hiziroglu, 2015, Cambridge University Press
10. Classical Electrodynamics, J.D. Jackson, 3rd Edn., 2010, Wiley
11. Principle of Optics, M. Born and E. Wolf, 6th Edn., 1980, Pergamon Press
12. Optics, (2017), 6th Edition, Ajoy Ghatak, McGraw-Hill Education, New Delhi

References for Practical:

1. Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.
2. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers
3. Electromagnetic Field Theory for Engineers & Physicists, G. Lehner, 2010, Springer
4. An Advanced Course in Practical Physics, D. Chattopadhyay & P. C. Rakshit, 2013, New Book Agency (P) Ltd.
5. Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press
6. B.Sc. Practical Physics, H. Singh & P. S. Hemne, 2011, S Chand and Company Ltd
7. B.Sc. Practical Physics, C. L. Arora, 2011, S Chand and Company Ltd.
8. Engineering Practical Physics, S.Panigrahi & B.Mallick,2015, Cengage Learning India Pvt. Ltd.

CC-XIV: Statistical Mechanics
(32221602)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

The Statistical Mechanics deals with the derivation of the macroscopic parameters (internal energy, pressure, specific heat etc.) of a physical system consisting of large number of particles (solid, liquid or gas) from knowledge of the underlying microscopic behavior of atoms and molecules that comprises it. The main objective of this course work is to introduce the techniques of Statistical Mechanics which has applications in various fields including Astrophysics, Semiconductors, Plasma Physics, Bio-Physics etc. and in many other directions.

Course Learning Outcomes

By the end of the course, students will be able to:

- Understand the concepts of microstate, macrostate, ensemble, phase space, thermodynamic probability and partition function.
- Understand the use of Thermodynamic probability and Partition function for calculation of thermodynamic variables. Difference between the classical and quantum statistics
- Understand the combinatoric studies of particles with their distinguishably or indistinguishably nature and conditions which lead to the three different distribution laws e.g. Maxwell-Boltzmann distribution, Bose-Einstein distribution and Fermi-Dirac distribution laws of particles and their derivation.
- Comprehend and articulate the connection as well as dichotomy between classical statistical mechanics and quantum statistical mechanics.
- Learn to apply the classical statistical mechanics to derive the law of equipartition of energy and specific heat.
- Understand the Gibbs paradox, equipartition of energy and concept of negative temperature in two level system.
- Learn to derive classical radiation laws of black body radiation. Wiens law, Rayleigh, Jeans law, ultraviolet catastrophe. Saha ionization formula.
- Learn to calculate the macroscopic properties of degenerate photon gas using BE distribution law, understand Bose-Einstein condensation law and liquid Helium. Bose derivation of Plank's law
- Understand the concept of Fermi energy and Fermi level, calculate the macroscopic properties of completely and strongly degenerate Fermi gas, electronic contribution to specific heat of metals.

- Understand the application of F-D statistical distribution law to derive thermodynamic functions of a degenerate Fermi gas, electron gas in metals and their properties.
- Calculate electron degeneracy pressure and ability to understand the Chandrasekhar mass limit, stability of white dwarfs against gravitational collapse.
- In the laboratory course, the students gets an opportunity to verify Stefan's Law of radiation and determine Stefan's constant.
- Design and perform some experiments to determine Boltzmann' Constant.
- Use Computer simulations to study:
- Planck's Black Body radiation Law and compare with the Wien's Law and Raleigh - Jean's Law in appropriate temperature region.
- Specific Heat of Solids by comparing, Dulong-Petit, Einstein's and Debye's Laws and study their temperature dependence
- Compare the following distributions as a function of temperature for various energies and the parameters of the distribution functions: (i) Maxwell Boltzmann distribution (ii) Bose Einstein distribution (iii) Fermi Dirac distribution

Unit 1

Classical Statistics: Macrostates and Microstates, Phase Space, Entropy and Thermodynamic Probability, Maxwell-Boltzmann Distribution Law, Partition Function, Thermodynamic Functions of an Ideal Gas, Classical Entropy Expression, Gibbs Paradox, Sackur-Tetrode equation. Saha's Ionization Formula. Law of Equipartition of Energy (with proof)– Applications to Specific Heat of gas and solids and its Limitations, Thermodynamic Functions of a Finite Level System, Negative Temperature.

(24 Lectures)

Unit 2

Bose-Einstein Statistics: B-E Distribution law, Thermodynamic functions of a strongly degenerate Bose Gas, Bose Einstein condensation, properties of liquid He (qualitative description), Radiation as a photon gas and Thermodynamic functions of photon gas. Bose derivation of Planck's law.

(12 Lectures)

Unit 3

Fermi-Dirac Statistics: Fermi-Dirac Distribution Law, Thermodynamic functions of a Completely and strongly degenerate Fermi Gas, Fermi Energy Electron gas in a Metal, Specific Heat of Metals, Relativistic Fermi gas, White Dwarf Stars, Chandrasekhar Mass Limit.

(12 Lectures)

Unit 4

Theory of Radiation: Properties of Thermal Radiation and Radiation Pressure. Blackbody Radiation and its spectral distribution. Kirchhoff law. Stefan-Boltzmann law and its Thermodynamic proof. Wien's Displacement law. Wien's Distribution Law. Rayleigh-Jean's Law. Ultraviolet Catastrophe. Planck's Quantum Postulates. Planck's Law of Blackbody Radiation Deduction of Wien's Distribution Law, Rayleigh-Jeans Law, Stefan-Boltzmann Law and Wien's Displacement law from Planck's law.

(12 Lectures)

Practical: 60 Hours

Use C/C++/Scilab/Python other numerical simulations for solving the problems based on Statistical Mechanics like:

1. Computational analysis of the behavior of a collection of particles in a box that satisfy Newtonian mechanics and interact via the Lennard-Jones potential, varying the total number of particles N and the initial conditions:

a) Study of local number density in the equilibrium state (i) average; (ii) fluctuations
b) Study of transient behavior of the system (approach to equilibrium)
c) Relationship of large N and the arrow of time
d) Computation of the velocity distribution of particles for the system and comparison with the Maxwell velocity distribution.

2. Plot the probability of various macrostates in coin-tossing experiment (two level system) versus number of heads with 4, 8, 16 coins etc.

3. Computation of the partition function Z(b) for the systems with a finite number of single particle levels (e.g., 2 level, 3 level etc.) and finite number of non-interacting particles N under Maxwell-Boltzmann/ Fermi-Dirac/Bose Einstein statistics:

a) Study the behavior of Z(b), average energy, C_v, and entropy and its dependence upon the temperature, total number of particles N and the spectrum of single particle energy states.
b) Plot the probability of occupancy of all the states w.r.t. temperature.

4. Plot the Maxwell speed distribution function at different temperatures in a 3-dimension system. Calculate the average speed, root mean square and most probable speed

5. Plot Specific Heat of Solids w.r.t temperature

a) Dulong-Petit law,
b) Einstein distribution function
c) Debye distribution function

6. Plot the following functions with energy at different temperatures
a) Maxwell-Boltzmann distribution
b) Fermi-Dirac distribution
c) Bose-Einstein distribution

7. Plot the distribution of particles w.r.t. energy (dN/de versus e) in 3 Dimensions for
a) Relativistic and non-relativistic bosons both at high and low temperature.
b) Relativistic and non-relativistic fermions both at high and low temperature.

8. Plot Planck's law of Black body radiation w.r.t. wavelength/frequency at different temperatures. Compare it with Rayleigh-Jeans Law and Wien's distribution law for a given temperature.

References for Theory:

1. Statistical Mechanics, R.K. Pathria, Butterworth Heinemann: 2nd Ed., 1996.
2. Statistical Physics, Berkeley Physics Course, F. Reif, Tata McGraw-Hill, 2008,.
3. Fundamentals of statistical and thermal physics, F. Reif, Waveland Press, 2009.
4. Statistical Mechanics, K. Huang, John Wiley & Sons, 2nd Ed., 1987.
5. Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Francis W. Sears and Gerhard L. Salinger, Narosa, 1986.
6. A treatise on Heat, M.N. Saha and B.N. Srivastava.
7. Statistical Physics, F. Mandl, 2nd Edn., Wiley, 2003.
8. Statistical Mechanics: An Introduction, E. Guha, Alpha Science Intl Ltd, 2007
9. Problems and Solutions on Thermodynamics and Statistical Mechanics, Yung-Kuo Lim (NUS, Singapore), Major American Univ. Ph.D. Qualifying Questions and Solutions – Physics, 1990.
10. Problems in Thermodynamics and Statistical Physics, Peter T. Landsberg, Courier Corporation, 2014.
11. An Introduction to thermal physics: D. Schroeder, Pearson.
12. Introductory Statistical Mechanics, R. Bowley and M. Sanchez, 2nd Edn., Oxford Univ. Press, 2007.

References for Practical:

1. Elementary Numerical Analysis, K.E. Atkinson, 3rdEdn. 2007, Wiley India Edition
2. Statistical Mechanics, R.K. Pathria, Butterworth Heinemann: 2nd Ed., 1996
3. Introduction to Modern Statistical Mechanics, D. Chandler, Oxford University Press, 1987
4. Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Francis W. Sears and Gerhard L. Salinger, 1986, Narosa.
5. Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, 2009, Springer
6. Statistical and Thermal Physics with computer applications, Harvey Gould and Jan Tobochnik, Princeton University Press, 2010.

Additional References:

1. Thermal Physics: Kinetic Theory, Thermodynamics and Statistical Mechanics, C.K. Ghosh, R.K. Bansal and S.C. Garg, 2nd Ed, McGraw Hill Education, 2013
2. A Textbook of Statistical Mechanics, S. Chandra and M. K. Sharma, CBS Publishers & Distributors, 2016.
3. Fundamentals of Quantum Mechanics Statistical Mechanics & Solid State Physics, S.P. Kuila, New Central Book Agency (P) Ltd., 2012.

9.2. Discipline Specific Elective-(DSE)

DSE: Experimental Techniques (32227501)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

This paper aims to describe the errors in measurement and statistical analysis of data required while performing an experiment. Also, students will learn the working principle, efficiency and applications of transducers & industrial instrument like digital multimeter, RTD, Thermistor, Thermocouples and Semiconductor type temperature sensors.

Course Learning Outcomes

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

- Learn the measurement systems, errors in measurements and statistical treatment of data.
- About Noise and signal, signal to noise ratio, different types of noises and their identification.
- Concept of electromagnetic interference and necessity of grounding.
- Understand principle of working and industrial applications of various transducers like Electrical, Thermal and Mechanical systems commonly used to measure Temperature and Position in industry.
- Develop an understanding of construction and working of different measuring instruments.
- Develop an understanding of construction, working and use of different AC and DC bridges and its applications.

Unit 1

Measurements: Accuracy and precision. Significant figures. Error and uncertainty analysis. Types of errors: Gross error, systematic error, random error. Statistical analysis of data (Arithmetic mean, deviation from mean, average deviation, standard deviation, chi-square) and curve fitting. Gaussian distribution.

(7 Lectures)

Signals and Systems: Fluctuations and Noise in measurement system. S/N ratio and Noise figure. Noise in frequency domain. Sources of Noise: Inherent fluctuations, Thermal noise, Shot noise, 1/f noise

(3 Lectures)

Shielding and Grounding: Methods of safety grounding. Energy coupling. Grounding. Shielding: Electrostatic shielding. Electromagnetic Interference.

(4 Lectures)

Unit 2

Transducers & industrial instrumentation (working principle, efficiency, applications): Static and dynamic characteristics of measurement Systems. Generalized perform ance of systems, Zero order first order, second order and higher order systems. Electrical, Thermal and Mechanical systems. Calibration. Qualitative difference between Transducers and sensors. Types of sensors (Physical, Chemical and Biological), Characteristics of Transducers. Transducers as electrical element and their signal conditioning. Temperature transducers: RTD, Thermistor, Thermocouples, Semiconductor type temperature sensors (AD590, LM35, LM75) and signal conditioning. Linear Position transducer: Strain gauge, Piezoelectric. Inductance change transducer: Linear variable differential transformer (LVDT), Capacitance change transducers. Radiation Sensors: Principle of Gas filled detector, ionization chamber, scintillation detector.

(21 Lectures)

Unit 3

Digital Multimeter: Comparison of analog and digital instruments. Block diagram of digital multimeter, principle of measurement of I, V, C. Accuracy and resolution of measurement.

(5 Lectures)

Impedance Bridges and Q-meter: Block diagram and working principles of RLC bridge. Q-meter and its working operation. Digital LCR bridge.

(4 Lectures)

Unit 4

Vacuum Systems: Characteristics of vacuum: Gas law, Mean free path. Application of vacuum. Vacuum system- Chamber with roughing and backing, Mechanical pumps (Rotary and root pumps), Diffusion pump & Turbo Molecular pump, Ion pumps, Pumping speed, throughput, Pressure gauges (Pirani, Penning, ionization, cold cathode).

(16 Lectures)

Practical: 60 Hours

PRACTICAL- DSE LAB: Experimental Techniques Lab

Sessions on the construction and use of specific measurement instruments and experimental apparatuses used in the 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.

At least 06 experiments each from the following

1. Determine output characteristics of a LVDT & measure displacement using LVDT

2. Measurement of Strain using Strain Gauge, level using capacitive transducer, distance using ultrasonic transducer
3. To study the characteristics of a Thermostat and determine its parameters.
4. Calibrate Semiconductor type temperature sensor (AD590, LM35, LM75) and Resistance Temperature Device (RTD).
5. Create vacuum in a small chamber using a mechanical (rotary) pump and measure the chamber pressure using a pressure gauge.
6. Comparison of pickup of noise in cables of different types (co-axial, single shielded, double shielded, without shielding) of 2mlength, understanding of importance of grounding using function generator of mV level & an oscilloscope.
7. To design and study the Sample and Hold Circuit.
8. Design and analyze the Clippers and Clampers circuits using junction diode
9. To plot the frequency response of a microphone.
10. To measure Q of a coil and influence of frequency, using a Q-meter.

References

1. Experimental Methods for Engineers, J.P. Holman, McGraw Hill
2. Introduction to Measurements and Instrumentation, A.K. Ghosh, 4th Edition, 2017, PHI Learning Pvt. Ltd.
3. Transducers and Instrumentation, D.V.S. Murty, 2nd Edition, PHI Learning Pvt. Ltd.
4. Instrumentation Devices and Systems, C.S.Rangan, G.R. Sarma, V.S.V. Mani, Tata McGraw Hill
5. Electronic circuits: Handbook of design & applications, U.Tietze, Ch.Schenk, Springer
6. Basic Electronics: A text lab manual, P.B.Zbar, A.P.Malvino, M.A.Miller, 1990, Mc-Graw Hill
7. Measurement, Instrumentation and Experiment Design in Physics & Engineering, M.Sayer and A. Mansingh, 2005, PHI Learning.

DSE: Advanced Mathematical Physics - I (32227502)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

The course is intended to impart the concept of generalized mathematical constructs in terms of Algebraic Structures (mainly Vector Spaces) and Tensors to have in-depth analysis of our physical system.

Course Learning Outcomes

- Demonstration of Algebraic Structures in n-dimension. Application of Vector Spaces & Matrices in the quantum world.
- Learn the basic properties of the linear vector space such as linear dependence and independence of vectors, change of basis, isomorphism and homomorphism, linear transformations and their representation by matrices.
- Learn the basic properties of matrices, different types of matrices viz., Hermitian, skew Hermitian, orthogonal and unitary matrices and their correspondence to physical quantities, e.g., operators in quantum mechanics. They should also learn how to find the eigenvalues and eigenvectors of matrices.
- Learn some basic properties tensors, their symmetric and antisymmetric nature, the Cartesian tensors, the general tensors, contravariant, covariant and mixed tensors and their transformation properties under coordinate transformations, physical examples of tensors such as moment of inertia tensor, energy momentum tensor, stress tensor, strain tensor etc.
- Learn how to express the mathematical equations for the Laws of Physics in their co-variant forms.
- Learn how to express a mathematical equation concerned with an event compatible with the physical system.
- In the laboratory course, the students are expected to solve the problems using the Scilab/C++ computer language like Multiplication of matrices, Diagonalization of a matrix, Inverse of a matrix, Solutions of differential equations satisfied by different orthogonal polynomials and special function, Determination of wave functions for stationary states as eigenfunctions of Hermitian differential operators and also the energy eigenvalues etc.

Unit 1

Linear Vector Spaces Abstract Systems: Binary Operations and Relations. Introduction to Groups and Fields.
Vector Spaces and Subspaces. Linear Independence and Dependence of Vectors. Basis and Dimensions of a Vector Space. Change of basis. Homomorphism and Isomorphism of Vector Spaces. Linear Transformations. Algebra of Linear Transformations. Non-singular Transformations. Representation of Linear Transformations by Matrices.

(12 Lectures)

Unit 2

Matrices, Addition and Multiplication of Matrices: Null Matrices. Diagonal, Scalar and Unit Matrices. Upper- Triangular and Lower-Triangular Matrices. Transpose of a Matrix. Symmetric and Skew-Symmetric Matrices. Conjugate of a Matrix. Hermitian and Skew-Hermitian Matrices. Singular and Non-Singular matrices. Orthogonal and Unitary Matrices. Similar Matrices. Trace of a Matrix. Inner Product.

(8 Lectures)

Unit 3

Eigen-values and Eigenvectors: Finding Eigen – values and Eigen vectors of a Matrix. Diagonalization of Matrices. Properties of Eigen-values and Eigen Vectors of Orthogonal, Hermitian and Unitary Matrices. Cayley-Hamiliton Theorem (Statement only). Finding inverse of a matrix using Cayley-Hamiltion Theorem. Use of Matrices in Solving ordinary

second order differential equations and Coupled Linear Ordinary Differential Equations of first order. Functions of a Matrix.

(10 Lectures)

Unit 4

Cartesian Tensors: Transformation of Co-ordinates and fundamentals of Tensors. Einstein's Summation Convention. Relation between Direction Cosines. Algebra of Tensors: Sum, Difference and Product of Two Tensors. Contraction. Quotient Law of Tensors. Symmetric and Anti-symmetric Tensors. Invariant Tensors: Kronecker and Alternating Tensors. Association of Anti-symmetric Tensor of Order Two and Vectors.

(8 lectures)

Unit 5

Applications of Cartesian Tensors: Vector Calculus using Cartesian Tensors: Scalar and Vector Products of 2, 3, 4 vectors. Gradient, Divergence and Curl of Tensor Fields. Tensor notation of Laplacian operator. Proof of Vector Identities involving scalar and vector products and vector identities involving Del operator using Tensor notation. Isotropic Tensors (Definition only). Tensorial Character of Physical Quantities. Moment of Inertia Tensor. Stress and Strain Tensors: Symmetric Nature. Elasticity Tensor. Generalized Hooke's Law.

(12 lectures)

Unit 6

General Tensors: Transformation of Co-ordinates. Contravariant & Covariant Vectors. Contravariant, Covariant and Mixed Tensors. Kronecker Delta and Permutation Tensors. Algebra of Tensors. Sum, Difference & Product of Two Tensors. Contraction. Quotient Law of Tensors. Symmetric and Anti- symmetric Tensors. Metric Tensor in cartesian, cylindrical, spherical coordinates.

(10 Lectures)

Practical: 60 Hours

PRACTICAL- DSE LAB: Advanced Mathematical Physics-I

Scilab/C^{++}/Python based simulations experiments based on Mathematical Physics problems like (at least 06 experiments)

1. Linear algebra:
- Multiplication of two 3 x 3 matrices.
- Power and Inverse Power methods for finding largest and smallest Eigenvalue and eigenvectors of matrices. QR method e.g.

$$\begin{pmatrix} 2 & 1 & 1 \\ 1 & 3 & 2 \\ 3 & 1 & 4 \end{pmatrix}; \begin{pmatrix} 1 & -i & 3+4i \\ +i & 2 & 4 \\ 3-4i & 4 & 3 \end{pmatrix}; \begin{pmatrix} 2 & -i & 2i \\ +i & 4 & 3 \\ -2i & 3 & 5 \end{pmatrix}$$

2. Orthogonal polynomials as eigenfunctions of Hermitian differential operators.
3. Determination of the principal axes of moment of inertia through diagonalization (Matrix can be generated for a given distribution of discrete masses).

4. Study of geodesics in Euclidean and other spaces (surface of a sphere, etc): Using variational principal find the shortest curve between two points. Suggested Physics problem: problem of refraction.
5. Application to solve differential equations for a bound system – Eigen value problem.
6. Application to computer graphics:
   Write operators for shear, strain, two dimensional rotational problems, Reflection, Translation etc. Plot old and new coordinates.
7. Lagrangian formulation in classical mechanics with constraints.
8. Vector space of wave functions in Quantum Mechanics: Position and Momentum differential operators and their commutator, wave functions for stationary states as eigenfunction

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Note: Students opting for Linear algebra and Tensor analysis as one option in DSE cannot opt Advanced mathematical physics-I course as second option.

References for Theory:

1. Mathematical Tools for Physics, James Nearing, 2010, Dover Publications
2. Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber and F.E.Harris,1970, Elsevier.
3. Theory and Problems of Linear Algebra, Seymour Lipschutz, 1987, McGraco-Hill Inc.
4. Theory and Problems of Vector Analysis and an introduction to Tensor Analysis, Murray R. Spiegel, 1974, McGraw Hill, Inc.
5. Elementary Linear Algebra, Applications Version, Howard Anton and Chris Rorres, Wiley Student edition.
6. Modern Mathematical Methods for Physicists and Engineers, C.D. Cantrell, 2011, Cambridge University Press.
7. Introduction to Matrices & Linear Transformations, D.T.Finkbeiner,1978, Dover Pub.
8. Mathematics for Physicists, Susan M. Lea, 2004, Thomson Brooks/Cole

References for Practical:

1. An Introduction to Computational Physics, T. Pang, Cambridge University Press (2010).
2. Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific and Engineering Applications: A. Vande Wouwer, P. Saucez, C. V. Fernández. 2014 Springer, ISBN: 978-3319067896
3. Scilab by example: M. Affouf, 2012, ISBN: 978-1479203444
4. Documentation at the Python home page, https://docs.python.org/3/
5. Learning Scientific Programming with Python, Christian Hill, Cambridge University Press (2016)

Additional Resources:

1. Introduction to Vectors and Tensors, Ray M Bowen, C -C Wang, Dover Publications (2009)
2. An Introduction to Linear Algebra and Tensors, M A Akivis, V V Goldberg, Richard and Silverman, Dover Publications (2012)
3. Computational Problems for Physics: With Guided Solutions Using Python, Rubin H. Landau, Manuel José Páez, CRC Press (2018).
4. https://arxiv.org/pdf/1703.09738.pdf
5. 'The C++ Programming Language, Bjarne Stroustrup, Addison-Wesley Professional (2013)
6. Numerical Recipes in C^{++}: The Art of Scientific Computing, W.H. Press et.al., 2^{nd}Edn., Cambridge University Press (2013).
7. Elementary Numerical Analysis, K.E. Atkinson, 3rd Edn., 2007, Wiley India Edition

<div align="center">

DSE: Nuclear and Particle Physics (32227504)
Credit : 06 (Theory-05, Tutorial-01)
Theory : 75 Hours
Tutorial : 15 Hours

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Course Objective

The objective of the course is to impart the understanding of subatomic particles and their properties. It will emphasize to gain knowledge about the different nuclear techniques and their applications in different branches of Physics and application to society. The phenomenology and experimental foundations of nuclear and particle physics are explored in this course. Emphasis is on the fundamental forces and particles, as well as composites. The students will learn how cutting-edge research is trying to answer the big questions about our universe. In addition they will learn how new ideas find their way from fundamental research to specific applications that have practical value. They will understand the relevance of everything from development and construction of a nuclear physics experimental equipment including accelerators and detectors, and eventually their use in order to study the structure of nucleus. By the end of the course, the students would be able to explain the basic properties of nuclei, classify elementary particles into hadrons and leptons, and understand how hadrons are constructed from quarks. They will also learn about flavor quantum numbers such as isospin, strangeness, etc. The course will focus on the developments of problem based skills.

Course Learning Outcomes

- To be able to understand the basic properties of nuclei as well as knowledge of experimental determination of the same, the concept of binding energy, its various dependent parameters, N-Z curves and their significance
- To appreciate the formulations and contrasts between different nuclear models such as Liquid drop model, Fermi gas model and Shell Model and evidences in support.
- Knowledge of radioactivity and decay laws. A detailed analysis, comparison and energy kinematics of alpha, beta and gamma decays.
- Familiarization with different types of nuclear reactions, Q- values, compound and direct reactions.
- To know about energy losses due to ionizing radiations, energy losses of electrons, gamma ray interactions through matter and neutron interaction with matter. Through the section on accelerators students will acquire knowledge about Accelerator facilities in India along with a comparative study of a range of detectors and accelerators which are building blocks of modern day science.
- It will acquaint students with the nature and magnitude of different forces, particle interactions, families of sub- atomic particles with the different conservation laws, concept of quark model.
- The acquired knowledge can be applied in the areas of nuclear medicine, medical physics, archaeology, geology and other interdisciplinary fields of Physics and Chemistry. It will enhance the special skills required for these fields.

Unit 1

General Properties of Nuclei: Constituents of nucleus and their Intrinsic properties, quantitative facts about mass, radii, charge density, matter density (experimental determination of each), binding energy, average binding energy and its variation with mass number, main features of binding energy versus mass number curve, N/Z plot, angular momentum, parity, magnetic moment, electric moments.

(10 Lectures)

Unit 2

Nuclear Models: Liquid drop model approach, semi empirical mass formula and significance of its various terms, condition of nuclear stability, nucleon separation energies (up to two nucleons), Fermi gas model (degenerate fermion gas, nuclear symmetry potential in Fermi gas), evidence for nuclear shell structure and the basic assumptions of shell model.

(11 Lectures)

Unit 3

Radioactivity decay: Decay rate and equilibrium (Secular and Transient) (a) Alpha decay: basics of α-decay processes, theory of α-emission, 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 rays emission from the excited state of the nucleus & kinematics, internal conversion.

(10 Lectures)

Unit 4

Nuclear Reactions: Types of Reactions, units of related physical quantities, Conservation Laws, kinematics of reactions, Q-value, reaction rate, reaction cross section, Concept of

compound and direct reaction, resonance reaction, Coulomb scattering (Rutherford scattering).

(8 Lectures)

Unit 5

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 (photoelectric effect, Compton scattering, pair production), neutron interaction with matter.

(9 Lectures)

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

(9 Lectures)

Particle Accelerators: Accelerator facility available in India: Van-de Graaff generator (Tandem accelerator), Linear accelerator, Cyclotron, Synchrotrons (Principal, construction, working, advantages and disadvantages).

(7 Lectures)

Unit 6

Particle physics: Particle interactions (concept of different types of forces), basic features, Cosmic Rays, types of particles and its families, Conservation Laws (energy and momentum, angular momentum, parity, baryon number, Lepton number, Isospin, Strangeness) concept of quark model, color quantum number and gluons.

(11 Lectures)

References

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. Concepts of Nuclear Physics by B L Cohen, Tata McGraw Hill Publication, 1974.
4. Introductory Nuclear Physics by K S Krane, Wiley-India Publication, 2008.
5. Nuclear Physics: principles and applications by J Lilley, Wiley Publication, 2006.
6. Physics and Engineering of Radiation Detection by S N Ahmed, Academic Press Elsevier, 2007.
7. Radiation detection and measurement, G F Knoll, John Wiley & Sons, 2010.
8. Techniques for Nuclear and Particle Physics experiments by WR Leo, Springer, 1994.
9. Introduction to Modern Physics by Mani & G K Mehta, Affiliated East-West Press, 1990.
10. Introduction to elementary particles by D J Griffiths, Wiley, 2008.
11. Modern Physics by R A Serway, C J Moses and C A Moyer, 3rd edition, Thomson Brooks Cole, 2012.
12. Modern Physics for Scientists and Engineers by S T Thornton and A Rex, 4th edition,

Cengage Learning, 2013.
13. Concepts of Modern Physics by Arthur Beiser, McGraw Hill Education, 2009.
14. Modern Physics by G Aruldhas and P Rajagopal. PHI Learning Pvt. Ltd., 2016.

Books for Numericals:

1. Schaum's Outline of Modern Physics, McGraw-Hill, 1999.
2. Schaum's Outline of College Physics, by E. Hecht, 11th edition, McGraw Hill, 2009.
3. Modern Physics by K Sivaprasath and R Murugeshan, S Chand Publication, 2010.

Additional Resources:

1. Nuclear Physics "Problem-based Approach" Including MATLAB by Hari M. Aggarwal, PHI Learning Pvt. Ltd. (2016).

DSE: Physics of Devices and Communication (32227505)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

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. Digital Data serial and parallel Communication Standards are described along with the understanding of communication systems.

Course Learning Outcomes

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

- Students will develop the basic knowledge of semiconductor device physics and electronic circuits along with the practical technological considerations and applications.
- They will be able to understand the operation of devices such as UJT, JFET, MOS, various bias circuits of MOSFET, Charge coupled Devices and Tunnel Diode.
- Students will learn to analyze MOSFET circuits and develop an understanding of MOSFET I-V characteristics and the allowed frequency limits.
- Another objective of this paper is to introduce students with the IC fabrication technology involving the process of diffusion, implantation, oxidation and etching with an emphasis on photolithography and electron-lithography.

- Students will learn to 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.
- Students will learn basic principles of phase locked loop (PLL) and understand its operation.
- They will gain an understanding of Digital Data serial and parallel Communication Standards. Knowledge of USB standards and GPIB.
- Also, students will understand different blocks in communication system, need of modulation, modulation processes and different modulation schemes.

Unit 1

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

(17 Lectures)

Unit 2

Processing of Devices: Basic process flow for IC fabrication. Crystal plane and orientation. Diffusion and implantation of dopants. Passivation. Oxidation Technique for Si. Contacts and metallization technique. Wet etching. Dry etching (RIE). Positive and Negative Masks. Photolithography. Electron-lithography, Basic idea of SSI, MSI, LSI, VLSI and USI.

(14 Lectures)

Unit 3

RC Filters: Passive-Low pass and High pass filters, Active (1st order butterworth) -Low Pass, High Pass, Band Pass and band Reject Filters.

(3 Lectures)

Phase Locked Loop (PLL): Basic Principles, Phase detector (XOR and edge triggered), Voltage Controlled Oscillator (Basics, varactor). Lock and capture. Basic idea of PLL IC (565 or 4046).

(6 Lectures)

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

(5 Lectures)

Unit 4

Introduction to communication systems: Block diagram of electronic communication system, Need for modulation. Amplitude modulation. Modulation Index. Analysis of Amplitude Modulated wave. Sideband frequencies in AM wave. CE Amplitude Modulator. Demodulation of AM wave using Diode Detector. Frequency modulation and demodulation, basic idea of Frequency, Phase, Pulse and Digital Modulation including ASK, PSK, FSK.

Practical: 60 Hours

PRACTICAL- DSE LAB: Physics of Devices and Communication

Session on the construction and use of CRO, and other 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 06 experiments each from section-A and section-B:

Section-A:

1. To design a power supply using bridge rectifier and study effect of C-filter.
2. To design the active Low pass and High pass filters of given specification.
3. To design the active filter (wide band pass and band reject) of given specification.
4. To study the output and transfer characteristics of a JFET.
5. To design a common source JFET Amplifier and study its frequency response.
6. To study the output characteristics of a MOSFET.
7. To study the characteristics of a UJT and design a simple Relaxation Oscillator.
8. To design an Amplitude Modulator using Transistor.
9. To design PWM, PPM, PAM and Pulse code modulation using ICs.
10. To design an Astable multivibrator of given specifications using transistor.
11. To study a PLL IC (Lock and capture range).
12. To study envelope detector for demodulation of AM signal.
13. Study of ASK and FSK modulator.
14. Glow an LED via USB port of PC.
15. Sense the input voltage at a pin of USB port and subsequently glow the LED connected with another pin of USB port.

Section-B: SPICE/MULTISIM simulations for electronic circuits and devices

1. To verify the Thevenin and Norton Theorems.
2. Design and analyze the series and parallel LCR circuits
3. Design the inverting and non-inverting amplifier using an Op-Amp of given gain
4. Design and Verification of op-amp as integrator and differentiator
5. Design the 1st orderactive low pass and high pass filters of given cutoff frequency
   (i) Design a Wein`s Bridge oscillator of given frequency.
   (ii)Design clocked SR and JK Flip-Flop`s using NAND Gates
   (iii)Design 4-bit asynchronous counter using Flip-Flop ICs
   (iv) Design the CE amplifier of a given gain and its frequency response.
   (v)10.Design an Astable multivibrator using IC555 of given duty cycle.

References

1. Physics of Semiconductor Devices, S.M.Sze and K.K.Ng, 3rd Edition 2008, John Wiley & Sons
2. Op-Amps & Linear Integrated Circuits, R.A.Gayakwad,4 Ed. 2000, PHI Learning Pvt. Ltd
3. Electronic Devices and Circuits, A. Mottershead, 1998, PHI Learning Pvt. Ltd.
4. Electronic Communication systems, G. Kennedy, 1999, Tata McGraw Hill.
5. Introduction to Measurements & Instrumentation, A.K.Ghosh, 4th Edition, 2017, PHI Learning
6. Semiconductor Physics and Devices, D.A. Neamen, 2011, 4th Edition, McGraw Hill
7. PC based instrumentation; Concepts and Practice, N. Mathivanan, 2007, Prentice-Hall of India
8. Basic Electronics: A text lab manual, P.B.Zbar, A.P.Malvino, M.A.Miller,1994, Mc-Graw Hill
9. Integrated Electronics, J. Millman and C.C. Halkias, 1991, Tata Mc-Graw Hill.
10. Electronics: Fundamentals and Applications, J.D. Ryder, 2004, Prentice Hall.
11. Introduction to PSPICE using ORCAD for circuits& Electronics, M.H.Rashid,2003, PHI Learning.

DSE: Astronomy and Astrophysics (32227506)
Credit : 06 (Theory-05, Tutorial-01)
Theory : 75 Hours
Tutorial : 15 Hours

Course Objective

This DSE paper for Physics Hons students is designed to provide students with the basic knowledge about the theory and techniques of observational astronomy and physics of the astrophysical phenomenon. This course follows the tradition of theoretical rigour and comprehensiveness of Physics Hons course of the University of Delhi. It applies theoretical concepts and mathematical techniques Physics Hons students have learnt in their earlier courses to astronomical and astrophysical phenomenon.

Course Learning Outcomes

After this course students will be familiar with essential features and techniques of astronomy, and will understand how laws of physics are applied to astrophysical phenomenon. Students will also gain an understanding of the latest developments in the field of astronomy and astrophysics. After this course students will be well equipped to take advanced level post graduate courses in astronomy and astrophysics. They will also be prepared to do student research level internships at research institutes.

During this course students will specifically learn:

- Significance of astronomical scales, basic concepts of positional astronomy like astronomical coordinate systems, transformations between different astronomical coordinate systems, and astronomical methods to determine distances, and time, and temperature and radius of a star.
- Basic parameters of stars like brightness, radiant flux, luminosity, magnitude, spectral classification. H-R diagram
- About various types of telescopes and telescope mountings.
- Understand the physics of the Sun, including solar MHD, Alfven's theorem, chromosphere, corona, and solar activity
- Understand the physics of stars, hydrostatic equilibrium, temperature gradient, stellar energy sources
- Acquire basic knowledge of the Milky Way, its structure, rotation, nucleus and Oort's constants
- Learn about the large scale structure of the universe, cosmic distance ladder, Hubble Law, Newtonian cosmology and Friedman models.

Unit 1

Introduction to Astronomy and Astronomical Scales: Overview of the Night Sky, Diurnal and Yearly motions of the Sun, Stars and Constellations. Size, Mass, Density and Temperature of Astronomical Objects. Basic concepts of Positional Astronomy: Celestial Sphere, Geometry of a Sphere, Spherical Triangle, Astronomical Coordinate Systems, Horizon System, Equatorial System, Conversion of Coordinates. Rising and Setting Times, Measurement of Time, Side real Time, Apparent Solar Time, Mean Solar Time, Equation of Time, Astronomical Time Systems (LMT, UT, UTC).

(16 Lectures)

Unit 2

Basic Parameters of Stars: Determination of Distance by Parallax Method; Proper Motion, Brightness, Radiant Flux and Luminosity, Apparent andAbsolute Magnitude Scales, Distance Modulus, Extinction, Determination of Temperature and Radius of a star; Stellar Spectra,Atomic Spectra Revisited, Introduction to Boltzman and Saha Equations, Balmer Lines of H, H and K lines of Ca, Spectral Types and Their Temperature Dependence, Black Body Approximation, Luminosity Classification, H R Diagram and Relations Between Stellar Parameters.

(16 Lectures)

Unit 3

Observational Tools and Physical Principles: 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 and Radio Telescopes, Current Indian Observatories. Virial theorem for N particle systems, applications in astrophysics. Systems in Thermodynamic Equilibrium, Equations for Hydrostatic equilibrium, Mean Molecular Weight of stellar gas, Stellar Energy Sources.

(16 Lectures)

Unit 4

Sun and the Milky Way: Solar Parameters, Sun's Internal Structure, Solar Photosphere, Solar Atmosphere, Chromosphere. Corona, Solar Activity, Solar Magneto-Hydrodynamics, Alfven's Theorem. Basic Structure and Properties of the Milky Way, Nature of rotation of the Milky Way (Differential rotation of the Galaxy and Oort Constants, Rotation Curve of the Galaxy and the Dark Matter, Nature of the Spiral Arms), Properties of and Around the Galactic Nucleus.

(15 Lectures)

Unit 5

Cosmology: Standard Candles (Cepheids and SNe Type1a), Cosmic Distance Ladder, Olbers Paradox, Hubble Expansion, Cosmological Principle, Newtonian Cosmology and Friedmann Models

(12 Lectures)

References

1. Fundamental of Astronomy (Fourth Edition), H. Karttunen et al. Springer
2. Astrophysics Stars and Galaxies K D Abhyankar, Universities Press
3. Modern Astrophysics, B.W. Carroll & D.A. Ostlie, Addison-Wesley Publishing Co.
4. Textbook of Astronomy and Astrophysics with elements of cosmology, V.B. Bhatia, Narosa Publication.
5. The Physical Universe: An Introduction to Astronomy, F H Shu, University Science Books
6. Baidyanath Basu, An introduction to Astrophysics, Second printing, Prentice - Hall of India Private limited, New Delhi,2001.
7. Introductory Astronomy and Astrophysics, M. Zeilik and S.A. Gregory, 4th Edition, Saunders College Publishing.
8. Explorations: Introduction to Astronomy, Thomos Arny and Stephen Schneider, 2014, 7th edition, McGraw Hill
9. Principles of Stellar Dynamics, S Chandrasekhar, Dover Books

DSE: Atmospheric Physics (32227507)
Credit:06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical: 60 Hours

Course Objective

This paper aims to describe the characteristics of earth's atmosphere and also its dynamics.

Course Learning Outcomes

- Good knowledge of Earth's atmosphere, its composition, effective temperature, Greenhouse effect. Hydrostatic equation and atmospheric thermodynamics. Local winds, clouds, fog, monsoon, cyclones, sea breeze and land breeze and thunderstorms etc.

- Essential knowledge of the instruments of meteorological observation, meteorological processes and systems.

- Understanding atmospheric dynamics, fundamental forces, conservation laws, rotating coordinate system and equations of motion. Circulation, vorticity, various types of circulations, atmospheric oscillations: biannual, annual and semi-annual oscillations.

- Understanding atmospheric waves. Surface water waves, accoustic waves, buoyancy waves, atmospheric gravity waves (AGW) and its propagation in non-homogeneous medium, Lamb and Rossy waves and their propagation in 3-dimension. Wave absorption and non linear effects.

- Skills to use atmospheric Radar and Lidar to study atmospheric phenomenon, basic knowledge of Radars and Lidars including Radar equation and signal processing. Develop numerical skills to do data analysis from Radar and Lidar.

- Knowledge of the classification and properties of aerosols, their concentrations and size distribution. Production and removal of aerosols. Radiative and health effects and observation techniques for aerosols.

- Understanding the absorption and scattering of solar radiation, Rayleigh scattering and Mie scattering, Boyer-Lambert law, optical phenomenon in atmosphere. Basics of radiometry.

- In the laboratory course through computer simulations students will learn Atmospheric wave using Dispersion relations, Kelvin waves, Rossby waves and Mountain waves.

(i) Offline and if possible online processing of RADAR data: VHF RADAR, X-band RADAR, UHF RADAR.
(ii) Offline and Online processing of LIDAR data
(iii) Study of Radiosonde data and its interpretation in terms of the atmospheric parameters
(iv) Interpretation of the satellite data using radio Occultation technique
(v) Time Series Analysis of Temperature using long term data and implications for climate change.

Unit 1

General features of Earth's atmosphere: Thermal structure of the Earth's Atmosphere, Composition of atmosphere, Hydrostatic equation, Potential temperature, Atmospheric Thermodynamics, Greenhouse effect, Local winds, monsoons, fogs, clouds, precipitation, Atmospheric boundary layer, Sea breeze and land breeze. Instruments for meteorological observations including RS/RW, meteorological processes and convective systems, fronts, Cyclones and anticyclones, thunderstorms.

(12 Lectures)

Unit 2

Atmospheric Dynamics: Scale analysis, Fundamental forces, Basic conservation laws, The Vectorial form of the momentum equation in rotating coordinate system, scale analysis of equation of motion, Applications of the basic equations, Circulations and vorticity, Atmospheric oscillations, Quasi biennial oscillation, annual and semi-annual oscillations, Mesoscale circulations, The general circulations, Tropical dynamics.

(12 Lectures)

Unit 3

Atmospheric Waves: Surface water waves, wave dispersion, acoustic waves, buoyancy waves, propagation of atmospheric gravity waves (AGWs) in a nonhomogeneous medium, Lamb wave, Rossby waves and its propagation in three dimensions and in sheared flow, wave absorption, non-linear consideration.

(12 Lectures)

Unit 4

Atmospheric Radar and Lidar: Radar equation and return signal, Signal processing and detection, Various type of atmospheric radars, Applications of radars to study atmospheric phenomena, Lidar and its applications, Application of Lidar to study atmospheric phenomenon. Data analysis tools and techniques.

(12 Lectures)

Unit 5

Atmospheric Aerosols: Spectral distribution of the solar radiation, Classification and properties of aerosols, Production and removal mechanisms, Concentrations and size distribution, Radiative and health effects, Observational techniques for aerosols, Absorption and scattering of solar radiation, Rayleigh scattering and Mie scattering, Bouguert-Lambert law, Principles of radiometry, Optical phenomena in atmosphere, Aerosol studies using Lidars.

(12 Lectures)

Practical : 60 Hours
PRACTICAL- DSE LAB: Atmospheric Physics

Scilab/C ++ based simulations experiments based on Atmospheric Physics problems like
At least 05 Experiments from the following

1. Numerical Simulation for atmospheric waves using dispersion relations
    a. Atmospheric gravity waves (AGW)
    b. Kelvin waves
    c. Rossby waves, and mountain waves
2. Offline and online processing of radar data
    a. VHF radar,
    b. X-band radar, and
    c. UHF radar
3. Offline and online processing of LIDAR data
4. Radiosonde data and its interpretation in terms of atmospheric parameters using vertical profiles in different regions of the globe.
5. Handling of satellite data and plotting of atmospheric parameters using radio occultation technique
6. Time series analysis of temperature using long term data over metropolitan cities in India – an approach to understand the climate change
7. PM 2.5 measurement using compact instruments
8. Field visits to National center for medium range weather forecasting, India meteorological departments, and ARIES Nainital to see onsite radiosonde balloon launch, simulation on computers and radar operations on real time basis.

References

1. Fundamental of Atmospheric Physics, M.L Salby; Academic Press, Vol 61, 1996
2. The Physics of Atmosphere – John T. Houghton; Cambridge University press; 3 rd edn. 2002.
3. An Introduction to dynamic meteorology – James R Holton; Academic Press, 2004
4. Radar for meteorological and atmospheric observations – S Fukao and K Hamazu, Springer Japan, 2014

DSE: Biological Physics (32227508)
Credit : 06 (Theory-05, Tutorial-01)
Theory : 75 Hours
Tutorial : 15 Hours

Course Objective

- To familiarize the students with the basic facts and ideas of biology from a quantitative perspective.
- To show them how ideas and methods of physics enrich our understanding of biological systems at diverse length and time scales.
- To give them a flavour of the interface between biology, chemistry, physics and mathematics.

Course 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.
- Gain a systems level perspective on organisms and appreciate how networks of interactions of many components give rise to complex behavior.
- Perform mathematical and computational modelling of certain aspects of living systems.

Unit 1

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. Allometric scaling laws.

(6 Lectures)

Unit 2

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.

(18 Lectures)

Unit 3

Molecular motion in cells: Random walks and applications to biology: Diffusion; models of macromolecules. Entropic forces: Osmotic pressure; polymer elasticity.
Chemical forces: Self assembly of amphiphiles. Molecular motors: Transport along microtubules. Flagellar motion: bacterial chemotaxis.

(22 Lectures)

Unit 4

The complexity of life: At the level of a cell: The numbers of distinct metabolites, genes and proteins in 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. Brain as an information processing system. At the level of an ecosystem and the biosphere: Foodwebs. Feedback cycles and self- sustaining ecosystems.

(20 Lectures)

Unit 5

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. Examples.

(9 Lectures)

References

1. Biological Physics: Energy, Information, Life; Philip Nelson (W H Freeman &Co, NY, 2004)
2. Physical Biology of the Cell (2nd Edition); Rob Phillips et al (Garland Science, Taylor & Francis Group, London & NY, 2013)
3. An Introduction to Systems Biology; Uri Alon (Chapman and Hall/CRC, Special Indian Edition, 2013)
4. Evolution; M. Ridley (Blackwell Publishers, 2009, 3rd edition).

DSE: Embedded systems - Introduction to Microcontroller (32227518)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

- This paper gives a review of microprocessor and introduces microcontroller 8051.
- Here, students will learn about the 8051 I/O port programming, various addressing modes, Timer and counter programming, Serial port programming with and without interrupt and interfacing 8051 microcontroller to peripherals.

Course Learning Outcomes

This is a course to familiarize/ introduce students to designing and developing embedded systems. It provides the students with an introductory coverage of embedded systems. The learning outcomes of the course are:

- Knowledge of the major components that constitute an embedded system.
- Understand what is a microcontroller, microcomputer embedded system.
- Description of the architecture of a 8051 microcontroller.
- Write simple programs for 8051 microcontroller in C language.
- Understand key concepts of 8051 microcontroller systems like I/O operations, interrupts, programming of timers and counters.
- Interfacing of 8051 microcontroller with peripherals
- Understand and explain concepts and architecture of embedded systems
- Implement small programs to solve well-defined problems on an embedded platform.
- Develop familiarity with tools used to develop an embedded environment
- Learning to use the Arduino Uno (an open source microcontroller board) in simple applications.

Unit 1

Embedded system introduction: Introduction to embedded systems and general purpose computer systems, architecture of embedded system, classifications, applications and purpose of embedded systems.

(4 Lectures)

8051 microcontroller: Introduction and block diagram of 8051 microcontroller, architecture of 8051, 8051 assembly language programming, Program Counter and ROM memory map, Data types and directives, Flag bits and Program Status Word (PSW) register, Jump, loop and call instructions.

(12 Lectures)

Unit 2

8051 I/O port programming: Introduction of I/O port programming, pin out diagram of 8051 microcontroller, I/O port pins description & their functions, I/O port programming in 8051 (using assembly language), I/O programming: Bit manipulation.

(4 Lectures)

Programming: 8051 addressing modes and accessing memory using various addressing modes, assembly language instructions using each addressing mode, arithmetic and logic instructions, 8051 programming in C: for time delay & I/O operations and manipulation, for arithmetic and logic operations, for ASCII and BCD conversions.

(12 Lectures)

Unit 3

Timer and counter programming: Programming 8051 timers, counter programming.

(3 Lectures)

Serial port programming with and without interrupt: Introduction to 8051 interrupts, programming timer interrupts, programming external hardware interrupts and serial communication interrupt, interrupt priority in the 8051.

(6 Lectures)

Interfacing 8051 microcontroller to peripherals: Parallel and serial ADC, DAC interfacing, LCD interfacing.

(2 Lectures)

Unit 4

Programming Embedded Systems: Structure of embedded program, infinite loop, compiling, linking and locating, downloading and debugging.

(3 Lectures)

Embedded system design and development: Embedded system development environment, file types generated after cross compilation, disassembler/ decompiler, simulator, emulator and debugging, embedded product development life-cycle, trends in embedded industry.

(8 Lectures)

Unit 5

Introduction to Arduino: Pin diagram and description of Arduino UNO. Basic programming and applications.

(6 Lectures)

Practical : 60 Hours
PRACTICALS- DSE LAB: Embedded systems - Introduction to Microcontroller

Sessions on the construction and use of specific measurement instruments and experimental apparatuses used in the 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.

8051 microcontroller-based Programs and experiments (at least 06 experiments):

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 segment 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, some information on LCD display, interfacing a keyboard.
12. Arduino based programs and experiments:
13. Make a LED flash at different time intervals.
14. To vary the intensity of LED connected to Arduino
15. To control speed of a stepper motor using a potential meter connected to Arduino
16. To display "PHYSICS" on LCD/CRO.

References

1. Embedded Systems: Architecture, Programming & Design, Raj Kamal, 2008,Tata McGraw Hill
2. The 8051 Microcontroller and Embedded Systems Using Assembly and C, M.A. Mazidi, J.G. Mazidi, and R.D. McKinlay, 2nd Ed., 2007, Pearson Education India.
3. Microcontrollers in practice, I.Susnea and M.Mitescu, 2005, Springer.
4. Embedded Systems & Robots, Subrata Ghoshal, 2009, Cengage Learning
5. Introduction to embedded system, K.V. Shibu, 1st edition, 2009, McGraw Hill
6. Embedded Microcomputer systems: Real time interfacing, J.W.Valvano 2011, Cengage Learning
7. Microprocessors and Microcontrollers, Krishna Kant, 2nd Edition, 2016. PHI learning Pvt. Ltd.
8. Embedded System, B.K. Rao, 2011, PHI Learning Pvt. Ltd.

DSE: Linear Algebra and Tensor Analysis (xxx3)
Credit : 06 (Theory-05, Tutorial-01)
Theory : 75 Hours
Tutorial : 15 Hours

Course Objective

The course is intended to impart the concept of generalized mathematical constructs in terms of Algebraic Structures (mainly Vector Spaces) and Tensors to have in-depth analysis of our Physical System.

Course Learning Outcomes

- Demonstration of Algebraic Structures in n-dimension. Application of Vector Spaces & Matrices in the quantum world.
- Learn the basic properties of the linear vector space such as linear dependence and independence of vectors, change of basis, isomorphism and homomorphism, linear transformations and their representation by matrices.
- Learn the basic properties of matrices, different types of matrices viz., Hermitian, skew Hermitian, orthogonal and unitary matrices and their correspondence to physical quantities, e.g, operators in quantum mechanics. They should also learn how to find the eigenvalues and eigenvectors of matrices.
- Learn some basic properties tensors, their symmetric and antisymmetric nature, the Cartesian tensors, the general tensors, contravariant, covariant and mixed tensors and their transformation properties under coordinate transformations, physical examples of tensors such as moment of inertia tensor, energy momentum tensor, stress tensor, strain tensor etc.
- Learn how to express the mathematical equations for the Laws of Physics in their co-variant forms.
- Learn how to express a mathematical equation concerned with an event compatible with the physical system.

Unit 1

Vector Space and Subspace: Binary Operations, Groups, Rings & Fields, Vector Space & Subspace, Examples of Vector Spaces, Euclidean Vector Spaces: Length and Distance in Rn, Matrix notation for vectors in Rn,Four Subspaces associated with a Matrix

(8 Lectures)

Basic and Dimension: Linear Dependence and Independence of vectors, Spanning a Space, Basis and Dimensions, Rank and Nullity of a Matrix, Examples from Real Function Space and Polynomial Space, Orthogonal Vectors and Subspaces, Orthogonal Basis, Gram-Schmidt process of generating an Orthonormal Basis

(4 Lectures)

Unit 2

Linear Transformation: Function and Mapping, General Linear Transformations and Examples, Kernel and Range of a Matrix Transformation, Homomorphism and Isomorphism of vector space, Singular and Non-singular Mapping/Transformations, Algebra of Linear operator.

(8 Lectures)

Invertible operators: Identity Transformation, Matrices and Linear Operators, Matrix Representation of a Linear transformation and change of basis, Similarity.

(5 Lectures)

Unit 3

Matrices and Matrix Operations: Addition and Multiplication of Matrices, Null Matrices, Diagonal, Scalar and Unit Matrices, Upper Triangular and Lower-Triangular Matrices, Transpose of a Matrix, Symmetric and Skew-Symmetric Matrices, Matrices for Networks, Matrix Multiplication and System of Linear Equations, Augmented Matrix, Echelon Matrices, Gauss Elimination and Gauss-Jordan Elimination, Inverse of a Matrix, Elementary Matrix, Conjugate of a Matrix. Hermitian and Skew-Hermitian Matrices, Determinants, Evaluating Determinants by Row Reduction, Properties of Determinants, Adjoint of a Matrix, Singular and Non-Singular matrices, Orthogonal Matrix, Unitary Matrices, Trace of a Matrix, Inner Product.

(12 Lectures)

Unit 4

Eigen-values and Eigenvectors: Finding Eigen-values and Eigen vectors of a Matrice. Diagonalization of Matrices. Properties of Eigen-values and Eigen Vectors of Orthogonal, Hermetian and Unitary Matrices. Cayley- Hamiliton Theorem (Statement only).Finding inverse of a matrix using Cayley-Hamiltion Theorem. Use of Matrices in Solving Coupled Linear Ordinary Differential Equations of first order. Functions of a Matrix.

(8 Lectures)

Unit 5

Cartesian Tensor: Transformation of co-ordinates, Einstein's summation convention, Relation between Direction Cosines, Tensors, Algebra of Tensors: Sum, Difference and Product of Two Tensors. Contraction, Quotient Law of Tensors, Symmetric and Anti-symmetric Tensors, Invariant Tensors: Kronecker and Alternating Tensors, Association of Antisymmetric Tensor of Order Two and Vectors. Vector Algebra and calculus using Cartesian Tensors: Scalar and Vector Products of 2, 3, 4 vectors. Gradient, Divergence and Curl of Tensor Fields. Vector Identities. Tensorial Character of Physical Quantities. Moment of Inertia Tensor. Stress and Strain Tensors: Symmetric Nature. Elasticity Tensor.Generalized Hooke's Law.

(16 Lectures)

Unit 6

Geometrical Applications: Equation of a line, Angle between lines. Projection of a line on another line. Condition for two lines to be coplanar. Foot of the Perpendicular from a Point on a Line, Rotation Tensor, Isotropic tensors (definition only), Moment of Inertia tensors .

(4 Lectures)

General Tensors: Transformation of Co-ordinates, Contravariant & Covariant Vectors, Contravariant, Covariant and Mixed Tensors, Kronecker Delta and Permutation Tensors, Algebra of Tensors, Sum, Difference & Product of Two Tensors, Contraction, Quotient Law of Tensors, Symmetric and Anti- symmetric Tensors, Metric Tensor.

(10 Lectures)

References

9. Mathematical Tools for Physics, James Nearing, 2010, Dover Publications
10. Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber and F.E.Harris,1970, Elsevier.
11. Theory and Problems of Linear Algebra, Seymour Lipschutz, 1987, McGraco-Hill Inc.
12. Theory and Problems of Vector Analysis and an introduction to Tensor Analysis, Murray R. Spiegel, 1974, McGraw Hill, Inc.
13. Elementary Linear Algebra, Applications Version, Howard Anton and Chris Rorres, Wiley Student edition.
14. Modern Mathematical Methods for Physicists and Engineers, C.D. Cantrell, 2011, Cambridge University Press.
15. Introduction to Matrices & Linear Transformations, D.T. Finkbeiner,1978, Dover Pub.
16. Mathematics for Physicists, Susan M. Lea, 2004, Thomson Brooks/Cole

DSE: Nano Materials and Applications (32227612)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

The syllabus introduces the basic concepts and principles to categories and understand nanomaterial. 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 propertie are 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.

Course Learning Outcomes
On successful completion of the module students should be able to

- Explain the difference between nanomaterials and bulk materials and their properties.
- Explain various methods for the synthesis/growth of nanomaterials including top down and bottom up approaches.
- 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 various characterization tools required to study the structural, optical and electrical properties of nanomaterials.
- Analyze the data obtained from the various characterization techniques: X-ray diffraction, electron microscopy, Atomic Force Microscopy and Scanning Tunneling Microscopy.
- 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.
- Explain the Interger Quantum Hall Effect and the concept of Landau Levels, and edge states in 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.
- Explain why nanomaterials exhibit properties which are sometimes very opposite, like magnetic, to their bulk counterparts.
- In the Lab course the student will synthesize nanoparticles by different chemical routs and characterize them in the laboratory using the different techniques he has learnt in the theory. He will also carry out thin film preparation and prepare capacitors and evaluate its performance. He also expected to fabricate a PN diode and study its I-V characteristics.

Unit 1

NANOSCALE SYSTEMS: Density of states (3D, 2D, 1D,0D),Length scales in physics, Nanostructures: 1D, 2D and 3D confined nanostructures (thin films, nanowires, nanorods, nanodots), Schrodinger equation- Infinite potential well, potential step, potential box,Band structure and density of states of materials at nanoscale (Quantitative for 3D, 2D, 1D, 0D), Size Effects in nano systems, Applications of quantum confinement of carriers in 3D, 2D, 1D nanostructures and its consequences on electronic and optical properties. Numerical problems based on above topics.

(14 Lectures)

Unit 2

SYNTHESIS OF NANOSTRUCTURE MATERIALS (Qualitative): Top down and Bottom up approach, Photolithography. Ball milling. Spin coating, Vacuum deposition: Physical vapor deposition (PVD): Thermal evaporation, Sputtering, Pulsed Laser Deposition (PLD), electric arc deposition for CNT, C_{60}, grapheme, Chemical vapor

deposition (CVD). Preparation through colloidal methods (Metals, Metal Oxide nanoparticles), Molecular Beam Epitaxy (MBE) growth of quantum dots.

(5 Lectures)

Unit 3

CHARACTERIZATION: Structure and Surface morphology: X-Ray Diffraction (XRD). Scanning Electron Microscopy (SEM). Transmission Electron Microscopy (TEM).Atomic Force Microscopy (AFM).Scanning Tunneling Microscopy (STM).
Spectroscopy: Working principle of UV-Vis spectroscopy, IR Spectroscopy, Raman and Photoluminescence Spectroscopy and study the size dependent properties using these techniques.

(11 Lectures)

Unit 4

OPTICAL PROPERTIES: Quasi-particles and collective excitations (Qualitative idea).Quantitative treatment of excitons, Radiative processes: General formalization-absorption, emission and luminescence. Optical properties of nanoparticles as a function of size, defects and impurities: deep level and surface defects. Numerical problems based on above topics.

(10 Lectures)

Unit 5

ELECTRON TRANSPORT: time and length scales of electrons in solids, Carrier transport in nanostructures: diffusive and ballistic transport, Charging effect, Coulomb blockade effect. Single electron transfer devices (no derivation).Conductance quantization: 2DEG in GaAs and integer quantum hall effect (Quantitative), conductance quantization in 1D structures using split gate in 2DEG (no derivation).Numerical problems based on above topics.

(14 Lectures)

Unit 6

APPLICATIONS (Qualitative): Applications of nanoparticles, quantum dots, nanowires and thinfilms for photonic devices (LED, solar cells). CNT based transistors. Nanomaterial Devices: Quantum dots heterostructurelasers, optical switching and optical data storage. Magnetic quantum well; magnetic dots-magnetic data storage.Micro Electromechanical Systems (MEMS), NanoElectromechanical Systems (NEMS).

(6 Lectures)

Practical : 60 Hours
PRACTICALS- DSE LAB: Nano Material and Applications Lab

Sessions on the construction and use of specific measurement instruments and experimental apparatuses used in the nano physics lab, including necessary precautions.

Sessions on the review of experimental data analysis and its application to the specific experiments done in the lab.

At least 06 experiments from the following:

1. Synthesis of metal (Au/Ag)nanoparticles by chemical route and study its optical absorption properties.
2. Synthesis of semiconductor (CdS/ZnO/TiO2/Fe2O3etc) nanoparticles and study its XRD and optical absorption properties as a function of time.
3. Surface Plasmon study of metal nanoparticles by UV-Visible spectrophotometer.
4. Analysis of XRD pattern of nanomaterials and estimation of particle size.
5. To study the effect of size on the color of nanomaterials.
   (i) To prepare composite of CNTs with other materials.
   (ii) Growth of quantum dots by thermal evaporation.
   (iii)Prepare a disc of ceramic of a compound and study its XRD.
   (iv)Fabricate a thin film of nanoparticles by spin coating (or chemical route) andstudy its XRD and transmittance spectra in UV-Visible region.
   (v) Prepare a thin film capacitor and measure capacitance as a function oftemperature or frequency.
   (vi) Fabricate a PN junction diode by diffusing Al over the surface of N-type Si/Geand study itsV-I characteristic.
   (vii) Fabricate thin films (polymer, metal oxide) using electro-deposition
   (viii) To study variation of resistivity or sheet resistance with temperature of the fabricated thin films using four probe method.

References for Theory:

1. C.P. Poole, Jr. Frank J. Owens, Introduction to Nanotechnology 1st edition (2003) Wiley India Pvt.Lt..
2. S.K. Kulkarni, Nanotechnology: Principles & Practices 2nd edition(2011) (Capital Publishing Company)
3. K.K. Chattopadhyay and A. N. Banerjee, Introduction to Nanoscience and Technology (2009) (PHI Learning Private Limited).
4. Introduction to Nanoelectronics, V.V. Mitin, V.A. Kochelap and M.A. Stroscio, 2011, Cambridge University Press.
5. Richard Booker, Earl Boysen, Nanotechnology for Dummies (2005) (Wiley Publishing Inc.).
6. Introductory Nanoscience by Masaru Kuno, (2012) Garland science Taylor and Francis Group
7. Solid State Physics by J. R. Hall and H. E. Hall, 2nd edition (2014) Wiley·
8. Electronic transport in mesoscopic systems by Supriyo Datta (1997) Cambridge University Press.
9. Fundamentals of molecular spectroscopy by C. N. Banwell and E. M. McCASH, 4th edition, McGrawHill. Reference Books for Practicals:
10. C.P. Poole, Jr. Frank J. Owens, Introduction to Nanotechnology 1st edition (2003) Wiley India Pvt.Ltd..
11. S.K. Kulkarni, Nanotechnology: Principles & Practices 2nd edition (2011) (Capital Publishing Company)
12. K.K. Chattopadhyay and A. N. Banerjee, Introduction to Nanoscience and Technology (2009) (PHI Learning Private Limited).

Additional Resources:

1. Quantum Transport in semiconductor nanostructures by Carla Beenakker and HenK Van Houten (1991) (available at arXiv: cond-mat/0412664) open source
2. Sara cronewett Ph.D. thesis (2001).

DSE: Communication System (32227613)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

- 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 and mobile telephony system are introduced.

Course 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 analyze 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.
- They will study the concept of Mobile radio propagation, cellular system design and understand mobile technologies like GSM and CDMA.
- Students will understand evolution of mobile communication generations 2G, 3G, and 4G with their characteristics and limitations.
- This paper will essentially connect the text book knowledge with the most popular communication technology in real world.

- Students will apply the theory that they have learned in the theory class to gain hands on experience in building modulation and demodulation circuits; Transmitters and Receivers for AM and FM. Also to construct TDM, PAM, PWM, PPM and ASK, PSK and FSK modulator and verify their results.

Unit 1

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.

(4 Lectures)

Analog Modulation: Amplitude Modulation, modulation index and frequency spectrum. Generation of AM (Emitter Modulation), Amplitude Demodulation (diode detector), Single Sideband (SSB) systems, advantages of SSB transmission, Concept of Single side band generation and detection. Frequency Modulation (FM) and Phase Modulation (PM), modulation index and frequency spectrum, equivalence between FM and PM, Generation of FM using VCO, FM detector (slope detector),Qualitative idea of Super heterodyne receiver.

(12 Lectures)

Unit 2

Analog Pulse Modulation: Channel capacity, Sampling theorem, Basic Principles-PAM, PWM, PPM, modulation and detection technique for PAM only, Multiplexing (time division multiplexing and frequency division multiplexing).

(9Lectures)

Unit 3

Digital Pulse Modulation: Need for digital transmission, Pulse Code Modulation, Digital Carrier Modulation Techniques, Sampling, Quantization and Encoding. Concept of Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), Phase Shift Keying(PSK), and Binary Phase Shift Keying (BPSK).

(10 Lectures)

Unit 4

Satellite Communication: Introduction, need, 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 earth station.

(10 Lectures)

Unit 5

Mobile Telephony System: Basic concept of mobile communication, frequency bands used in mobile communication, concept of cell sectoring and cell splitting, SIM number, IMEI number, need for data encryption, architecture (block diagram) of mobile communication network, idea of GSM, CDMA, TDMA and FDMA technologies, simplified block diagram

of mobile phone handset, 2G, 3G and 4G concepts (qualitative only), GPS navigation system (qualitative idea only).

(15 Lectures)

Practical: 60 Hours
PHYSICS LAB-DSE LAB: Communication System Lab

Session on the construction and use of CRO, and other experimental apparatuses used in the lab, including necessary precautions.

Sessions on the review of experimental data analysis and its application to specific experiments done in the lab.

At Least 05 Experiments from the following

1. To design an Amplitude Modulator using Transistor
2. To study envelope detector for demodulation of AM signal
3. To study FM - Generator and Detector circuit
4. To study AM Transmitter and Receiver
5. To study FM Transmitter and Receiver
6. To study Time Division Multiplexing (TDM)
7. To study Pulse Amplitude Modulation (PAM)
8. To study Pulse Width Modulation (PWM)
9. To study Pulse Position Modulation (PPM)
10. To study ASK, PSK and FSK modulators

References

1. Electronic Communications, D. Roddy and J. Coolen, Pearson Education India.
2. Advanced Electronics Communication Systems- Tomasi, 6th Edn. Prentice Hall.
3. Modern Digital and Analog Communication Systems, B.P. Lathi, 4th Edition, 2011, Oxford University Press.
4. Electronic Communication systems, G. Kennedy, 3rd Edn., 1999, Tata McGraw Hill.
5. Principles of Electronic communication systems – Frenzel, 3rd edition, McGraw Hill
6. Communication Systems, S. Haykin, 2006, Wiley India
7. Electronic Communication system, Blake, Cengage, 5th edition.
8. Wireless communications, Andrea Goldsmith, 2015, Cambridge University Press
9. Introduction to Communication systems, U. Madhow, 1st Edition, 2018, Cambridge University Press

DSE: Medical Physics (32227615)
Credit : 06 (Theory-04, Practical-02)
Theory: 60 Hours
Practical : 60 Hours

Course Objective

This course introduces a student to the basics of Medical Physics.

Course Learning Outcomes
This course will enable the student to

* Focus on the application of Physics to clinical medicine.
* Gain a broad and fundamental understanding of Physics while developing particular expertise in medical applications.
* Learn about the human body, its anatomy, physiology and BioPhysics, exploring its performance as a physical machine.
* Learn diagnostic and therapeutic applications like the ECG, Radiation Physics, X-ray technology, ultrasound and magnetic resonance imaging.
* Gain knowledge with reference to working of various diagnostic tools, medical imaging techniques
* Understand interaction of ionizing radiation with matter - its effects on living organisms and its uses as a therapeutic technique and also radiation safety practices.
* Imparts functional knowledge regarding need for radiological protection and the sources of an approximate level of radiation exposure for treatment purposes.
* In the laboratory course, the student will be exposed to the workings of various medical devices and getting familiarized with various detectors used in medical imaging, medical diagnostics. The hands-on experience will be very useful for the students from job perspective.

Unit 1

PHYSICS OF THE BODY-I: Basic Anatomical Terminology: Standard Anatomical Position, Planes. Familiarity with terms like- Superior, Inferior, Anterior, Posterior, Medial, Lateral, Proximal and Distal. Mechanics of the body: Skeleton, forces, and body stability. Muscles and dynamics of body movement. Physics of Locomotors Systems: joints and movements, Stability and Equilibrium. Energy household of the body: Energy balance in the body, Energy consumption of the body, Heat losses of the body, Thermal Regulation. Other Systems in the body: Pressure system of body. Physics of breathing, Physics of cardiovascular system.

Unit 2

PHYSICS OF THE BODY-II: Acoustics of the body: Nature and characteristics of sound, Production of speech, Physics of the ear, Diagnostics with sound and ultrasound. Optical system of the body: Physics of the eye. Electrical system of the body: Physics of the nervous system, Electrical signals and information transfer.

(10 Lectures)

Unit 3

PHYSICS OF DIAGNOSTIC AND THERAPEUTIC SYSTEMS-I: X-Rays: Electromagnetic spectrum, production of x-rays, x-ray spectra, Brehmsstrahlung, Characteristic x-ray. X-ray tubes & types: Coolidge tube, x-ray tube design, tube cooling stationary mode, Rotating anode x-ray tube, Tube rating, quality and intensity of x-ray. X-ray generator circuits, half wave and full wave rectification, filament circuit, kilo voltage circuit. Single and three phase electric supply. Power ratings. Types of X-Ray Generator, high frequency generator, exposure timers and switches, HT cables.

(7 Lectures)

Radiation Physics: Radiation units exposure, absorbed dose, units: rad, gray, relative biological effectiveness, effective dose- Rem & Sievert, inverse square law. Interaction of radiation with matter Compton & photoelectric effect, linear attenuation coefficient. Radiation Detectors: ionization (Thimble chamber, condenser chamber), chamber. Geiger Muller counter, Scintillation counters and Solid-State detectors, TFT.

(7 Lectures)

Unit 4

MEDICAL IMAGING PHYSICS: Evolution of Medical Imaging, X-ray diagnostics and imaging, Physics of nuclear magnetic resonance (NMR), NMR imaging, MRI Radiological imaging, Ultrasound imaging, Physics of Doppler with applications and modes, Vascular Doppler. Radiography: Filters, grids, cassette, X-ray film, film processing, fluoroscopy. Computed tomography scanner- principle and function, display, generations, mammography. Thyroid uptake system and Gamma camera (Only Principle, function and display).

(9 Lectures)

RADIATION ONCOLOGY PHYSICS: External Beam Therapy (Basic Idea): Telecobalt,Conformal Radiation Therapy (CRT), 3DCRT, IMRT, Image Guided Radiotherapy, EPID, Rapid Arc, Proton Therapy, Gamma Knife, Cyber Knife. Contact Beam Therapy (Basic Idea): Brachytherapy- LDR and HDR, Intra Operative Brachytherapy. Radiotherapy, kilo voltage machines, deep therapy machines, Telecobalt machines, Medical linear accelerator. Basics of Teletherapy units, deep X-ray, Telecobalt units, Radiation protection, external beam characteristics, dose maximum and build up – bolus, percentage depth dose, tissue maximum ratio and tissue phantom ratio, Planned target Volume and Gross Tumour Volume.

(9 Lectures)

Unit 5

RADIATION AND RADIATION PROTECTION: Principles of radiation protection, protective materials-radiation effects, somatic, genetic stochastic and deterministic effect.

Personal monitoring devices: TLD film badge, pocket dosimeter, OSL dosimeter. Radiation dosimeter. Natural radioactivity, Biological effects of radiation, Radiation monitors. Steps to reduce radiation to Patient, Staff and Public. Dose Limits for Occupational workers and Public. AERB: Existence and Purpose.

(5 Lectures)

Unit 6

PHYSICS OF DIAGNOSTIC AND THERAPEUTIC SYSTEMS-II: Diagnostic nuclear medicine: Radiopharmaceuticals for radioisotope imaging, Radioisotope imaging equipment, Single photon and positron emission tomography. Therapeutic nuclear medicine: Interaction between radiation and matter Dose and isodose in radiation treatment. Medical Instrumentation: Basic Ideas of Endoscope and Cautery, Sleep Apnea and Cpap Machines, Ventilator and its modes.

(5 Lectures)

Practical: 60 Hours
PHYSICS LAB-DSE LAB: Medical Physics Lab

Sessions on the construction and use of specific measurement instruments and experimental apparatuses used in the 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.

1. Understanding the working of a manual Hg Blood Pressure monitor, Stethoscope and to measure the Blood Pressure.
2. Understanding the working of a manual optical eye-testing machine and to learn eye-testing procedure.
3. Correction of Myopia (short sightedness) using a combination of lenses on an optical bench/breadboard.
4. Correction of Hypermetropia/Hyperopia (long sightedness) using a combination of lenses on an optical bench/breadboard.
5. To learn working of Thermoluminescent dosimeter (TLD) badges and measure the background radiation.
    (i) Familiarization with Geiger-Muller (GM) Counter & to measure background radiation
    (ii) Familiarization with Radiation meter and to measure background radiation.
    (iii) Familiarization with the Use of a Vascular Doppler.

References

1. Medical Physics, J.R. Cameron and J.G.Skofronick, Wiley (1978)
2. Basic Radiological Physics Dr. K.Thayalan- Jayapee Brothers Medical Publishing Pvt. Ltd. New Delhi (2003)
3. Christensen's Physics of Diagnostic Radiology: Curry, Dowdey and Murry - Lippincot Williams and Wilkins (1990)
4. Physics of the human body, Irving P. Herman, Springer (2007).
5. Physics of Radiation Therapy: F M Khan - Williams and Wilkins, 3 rd edition (2003)

6. The essential physics of Medical Imaging: Bushberg, Seibert, Leidholdt and Boone Lippincot Williams and Wilkins, Second Edition (2002)
7. Handbook of Physics in Diagnostic Imaging: R.S.Livingstone: B.I. Publication Pvt Ltd.
8. The Physics of Radiology-H E Johns and Cunningham.
9. Physics of Radiation Therapy : F M Khan - Williams and Wilkins, 3rd edition (2003)
10. Handbook of Physics in Diagnostic Imaging: R.S. Livingstone: B.I. Publications Pvt Ltd.

DSE: Applied Dynamics (32227616)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

Most processes encountered in nature are inherently nonlinear. 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. Specific topics include maps and flows in one and two dimensions, phase portraits, bifurcations, chaos, fractals and elementary fluid dynamics. Students will obtain familiarity with concepts and methods in the field of dynamical systems, apply those concepts and methods to analyze dynamic models analytically and computationally, and will learn how to interpret and critically evaluate the results of those analyses. 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. Students will also appreciate the introduction to chaos and fractals. The emphasis of this course is to enhance the understanding of the basics of applied dynamics. By the end of this course, students should be able solve the seen or unseen problems/numerical in applied dynamics.

Course Learning Outcomes

Upon successful course completion, a student will be able to:
- Demonstrate understanding of the concepts that underlay the study of dynamical systems. Use the analytical and computational methods covered in this course to analyze dynamical systems models.
- Understand fractals as self-similar structures by giving examples from nature and develop mathematical models for simple fractal structures.
- Understand various forms of dynamics and different routes to chaos.
- Analyze the behavior of dynamical systems (e.g. find periodic orbits and assess their stability, draw phase portraits, etc.).
- Understand basic Physics of fluids and its dynamics theoretically and experimentally and by computational simulations: Basic properties of fluids including viscosity, thermal conductivity, mass diffusivity, equation of state. Also, Physics of different types of fluid flow phenomena as well as fluid flow visualizations like streamlines, pathlines and streakline flows.

- Apply the techniques of nonlinear dynamics to physical processes drawn from a variety of scientific and engineering disciplines.
- Analyze uniform and non uniform oscillators (flows on circle)
- Draw phase portraits and interpret them in several applications from biology, physics, chemistry and engineering.
- In the Lab course, students will be able to perform Simulations/Lab experiments on: Determination of the coupling Coefficients of Coupled pendulums and other coupled Oscillators, Simulation of Simple Population Models, Experimental growth and Decay, Logistic growth, Species Competition, Predator-Prey Dynamics, Simple genetic circuits, Solve rate equations numerically for some simple chemical reactions, Simulation of Fractal Formation in Deterministic Fractals, Self Similar Fractals and Fractals in nature like Trees, Coastlines and Earthquakes, Simulation of some Fluid Flow Models like Streamlines, Pathlines, and Streakline flows

Unit 1

Introduction to Dynamical systems: Definition of a continuous first order dynamical system. The idea of phase space, flows and trajectories. Simple mechanical systems as first order dynamical systems: simple and damped harmonic oscillator. Sketching flows and trajectories in phase space. 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. Rate equations for chemical reactions e.g. auto catalysis, bistability.

(22 Lectures)

Unit 2

Introduction to Chaos and Fractals: Chaos in nonlinear equations - Logistic map and Lorenz equations: Dynamics from time series. Parameter dependence- steady, periodic and chaotic states. Cobweb iteration. Fixed points. Defining chaos- a periodic, bounded, deterministic and sensitive dependence on initial conditions. Period- Doubling route to chaos.

Self-similarity and fractal geometry: Fractals in nature - trees, coastlines, earthquakes, etc. Need for fractal dimension to describe self-similar structure. Deterministic fractal vs. self-similar fractal structure.

(18 Lectures)

Unit 3

Elementary Fluid Dynamics: Importance of fluids: Fluids in the pure sciences, fluids in technology. Study of fluids: Theoretical approach, experimental fluid dynamics, computational 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, other fluid properties and equation of state; Flow phenomena- flow dimensionality, steady and unsteady flows, uniform and non-uniform flows, viscous and inviscid flows, incompressible and compressible flows, laminar and turbulent flows, rotational and irrotational flows, separated and unseparated flows. Flow visualization - streamlines, pathlines, Streaklines.

(20 Lectures)

Practical: 60 Hours

PHYSICS LAB-DSE LAB: Applied Dynamics Lab

Sessions on the review of experimental data analysis and its application to the specific experiments done in the lab.
Computing and visualizing trajectories using software such as Scilab, Maple, Octave, XPPAUT based on Applied Dynamics problems like (at least 06 experiments)

1. To determine the coupling coefficient of coupled pendulums.
2. To determine the coupling coefficient of coupled oscillators.
3. To determine the coupling and damping coefficient of damped coupled oscillator.
4. To study population models e.g. exponential growth and decay, logistic growth, predator-prey dynamics.
5. To study rate equations for chemical reactions e.g. auto catalysis, bistability.
    (i)   To study examples from game theory.
    (ii) To study period doubling route to chaos in logistic map.
    (iii) To study various attractors of Lorenz equations.
    (iv) Computational visualization of fractal formations of Deterministic fractal.
    (v)   Computational visualization of fractal formations of self-similar fractal.
    (vi) Computational visualization of fractal formations of Fractals in nature – trees, coastlines, earthquakes.
    (vii) Computational Flow visualization - streamlines, pathlines, Streaklines.

References for Theory:

1. Nonlinear Dynamics and Chaos, S.H. Strogatz, Levant Books, Kolkata, 2007
2. Understanding Nonlinear Dynamics, Daniel Kaplan and Leon Glass, Springer.
3. Nonlinear Dynamics: Integrability, Chaos and Patterns, M. Lakshmanan and S. Rajasekar, Springer, 2003.
4. An Introduction to Fluid Dynamics, G.K.Batchelor, Cambridge Univ. Press, 2002
5. Fluid Mechanics, 2nd Edition, L. D. Landau and E. M. Lifshitz, Pergamon Press, Oxford, 1987.

References for Practical:

1. Nonlinear Dynamics and Chaos, Steven H. Strogatz, Levant Books, Kolkata, 2007
2. Understanding Nonlinear Dynamics, Daniel Kaplan and Leon Glass, Springer.
3. An Introduction to Fluid Dynamics, G.K.Batchelor, Cambridge Univ. Press, 2002
4. Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific and Engineering Applications: A. Vande Wouwer, P. Saucez, C. V. Fernández. 2014 Springer

DSE: Digital Signal Processing (32227621)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

- This paper describes the discrete-time signals and systems, Fourier Transform Representation of Aperiodic Discrete-Time Signals.
- This paper also highlights the concept of filters and realization of Digital Filters.
- At the end of the syllabus, students will develop an understanding of Discrete and fast Fourier Transform.

Course Learning Outcomes

In this course, students will be able to develop a thorough understanding of the central elements of discrete time signal processing theory and correlate this theory with the real-world signal processing applications. At the end of this course, students will be able to develop following learning outcomes:

- Students will learn basic discrete-time signal and system types, convolution sum, impulse and frequency response concepts for linear time-invariant (LTI) systems.
- The student will be in position to understand use of different transforms and analyze the discrete time signals and systems. They will learn to analyze a digital system using z-transforms and discrete time Fourier transforms, region of convergence concepts, their properties and perform simple transform calculations,.
- The student will realize the use of LTI filters for filtering different real world signals. The concept of transfer
- Function and difference-Equation System will be introduced. Also, they will learn to solve Difference Equations.
- Students will develop an ability to analyze DSP systems like linear-phase, FIR, IIR, All-pass, averaging and notch Filter etc.
- Students will be able to understand the discrete Fourier transform (DFT) and realize its implementation using FFT techniques.
- Students will be able to learn the realization of digital filters, their structures, along with their advantages and disadvantages. They will be able to design and understand different types of digital filters such as finite & infinite impulse response filters for various applications.

- In the Lab course, the students will realize various concepts using Scilab simulations like Digital Filters and their classifications based on the response, design and algorithm, Fluency in using Fast Fourier Transform, Signal generation, realization of systems and finding their transfer function, characterization using pole-zero plots and designing digital filters.

Unit 1

Discrete-Time Signals and Systems: Classification of Signals, Transformations of the Independent Variable, Periodic and Aperiodic Signals, Energy and Power Signals, Even and Odd Signals, Discrete-Time Systems, System Properties. Impulse Response, Convolution Sum; Graphical Method; Analytical Method, Properties of Convolution; Commutative; Associative; Distributive; Shift; Sum Property System Response to Periodic Inputs, Relationship Between LTI System Properties and the Impulse Response; Causality; Stability; Invertibility, Unit Step Response.

(10 Lectures)

Unit 2

Discrete-Time Fourier Transform: Fourier Transform Representation of Aperiodic Discrete-Time Signals, Periodicity of DTFT, Properties; Linearity; Time Shifting; **Frequency Shifting;** Differencing in Time Domain; Differentiation in Frequency Domain; Convolution Property. The z-Transform: Bilateral (Two-Sided) z-Transform, Inverse z-Transform, Relationship Between z-Transform and Discrete-Time Fourier Transform, z-plane, Region-of- Convergence; Properties of ROC, Properties; Time Reversal; Differentiation in the z-Domain; Power Series Expansion Method (or Long Division Method); Analysis and Characterization of LTI Systems; Transfer Function and Difference-Equation System. Solving Difference Equations.

(15 Lectures)

Unit 3

Filter Concepts: Phase Delay and Group delay, Zero-Phase Filter, Linear-Phase Filter, Simple FIR Digital Filters, Simple IIR Digital Filters, All pass Filters, Averaging Filters, Notch Filters.

(5 Lectures)

Discrete Fourier Transform: Frequency Domain Sampling (Sampling of DTFT), The Discrete Fourier Transform (DFT) and its Inverse, DFT as a Linear transformation, Properties; Periodicity; Linearity; Circular Time Shifting; Circular Frequency Shifting; Circular Time Reversal; Multiplication Property; Parseval's Relation, Linear Convolution Using the DFT (Linear Convolution Using Circular Convolution), Circular Convolution as Linear Convolution with aliasing.

(10 Lectures)

Unit 4

Fast Fourier Transform: Direct Computation of the DFT, Symmetry and Periodicity Properties of the Twiddle factor (WN), Radix-2 FFT Algorithms; Decimation-In-Time (DIT) FFT Algorithm; Decimation-In-Frequency (DIF) FFT Algorithm, Inverse DFT Using FFT Algorithms.

(5 Lectures)

Unit 5

Realization of Digital Filters: Non Recursive and Recursive Structures, Canonic and Non Canonic Structures, Equivalent Structures (Transposed Structure), FIR Filter structures; Direct-Form; Cascade-Form; Basic structures for IIR systems; Direct-Form I. Finite Impulse Response Digital Filter: Advantages and Disadvantages of Digital Filters, Types of Digital Filters: FIR and IIR Filters; Difference Between FIR and IIR Filters, Desirability of Linear-Phase Filters, Frequency Response of Linear-Phase FIR Filters, Impulse Responses of Ideal Filters, Windowing Method; Rectangular; Triangular; Kaiser Window, FIR Digital Differentiators. Infinite Impulse Response Digital Filter: Design of IIR Filters from Analog Filters, IIR Filter Design by Approximation of Derivatives, Backward Difference Algorithm, Impulse Invariance Method.

(15 Lectures)

Practical: 60 Hours
PRACTICAL-DSE LAB: Digital Signal Processing Lab

At least 06 experiments from the following using Scilab/Matlab. Introduction to Numerical computation software Scilab/Matlab be introduced in the lab.

1. Write a program to generate and plot the following sequences: (a) Unit sample sequence $\delta(n)$, (b) unit step sequence $u(n)$, (c) ramp sequence $r(n)$, (d) real valued exponential sequence $x(n) = (0.8)^n u(n)$ for $0 \leq n \leq 50$.

2. Write a program to compute the convolution sum of a rectangle signal (or gate function) with itself for N = 5
$$x(n) = rect\left(\frac{n}{2N}\right) = \Pi\left(\frac{n}{2N}\right) = \begin{cases} 1 & -N \leq n \leq N \\ 0 & otherwise \end{cases}$$

3. An LTI system is specified by the difference equation
$$y(n) = 0.8y(n-1) + x(n)$$
(a) Determine $H\left(e^{jw}\right)$
(b) Calculate and plot the steady state response $y_{ss}(n)$ to
$$x(n) = \cos(0.5\pi n)u(n)$$

4. Given a casual system
$$y(n) = 0.9y(n-1) + x(n)$$
(a) Find $H(z)$ and sketch its pole-zero plot

(b) Plot the frequency response $\left|H\left(e^{jw}\right)\right|$ and $\angle H\left(e^{jw}\right)$
5. Design a digital filter to eliminate the lower frequency sinusoid of
$x(t) = \sin 7t + \sin 200t$. The sampling frequency is $f_s = 500\,Hz$. Plot its pole zero diagram, magnitude response, input and output of the filter.

6. Let $x(n)$ be a 4-point sequence:
$$x(n) = \begin{matrix} \{1,1,1,1\} \\ \uparrow \end{matrix} = \begin{cases} 1 & 0 \leq n \leq 3 \\ 0 & otherwise \end{cases}$$

Compute the DTFT $X\left(e^{jw}\right)$ and plot its magnitude
(a) Compute and plot the 4 point DFT of $x(n)$
(b) Compute and plot the 8 point DFT of $x(n)$ (by appending 4 zeros)

(c) Compute and plot the 16 point DFT of $x(n)$ (by appending 12 zeros)

7. Let $x(n)$ and $h(n)$ be the two 4-point sequences,

$$x(n) = \overset{\{1,2,2,1\}}{\underset{\uparrow}{}}$$

$$h(n) = \overset{\{1,-1,-1,1\}}{\underset{\uparrow}{}}$$

Write a program to compute their linear convolution using circular convolution.

8. Using a rectangular window, design a FIR low-pass filter with a pass-band gain of unity, cut off frequency of 1000 Hz and working at a sampling frequency of 5 KHz. Take the length of the impulse response as 17.

9. Design an FIR filter to meet the following specifications:
passband edge $F_p = 2\,KHz$
stopband edge $F_s = 5\,KHz$
Passband attenuation $A_p = 2\,dB$
Stopband attenuation $A_s = 42\,dB$
Sampling frequency $F_s = 20\,KHz$

10. The frequency response of a linear phase digital differentiator is given by

$$H_d\left(e^{jw}\right) = jwe^{-j\tau w}\,|w| \leq \pi$$

Using a Hamming window of length M = 21, design a digital FIR differentiator. Plot the amplitude response.

References:

1. Digital Signal Processing, Tarun Kumar Rawat, Oxford University Press, India.
2. A Guide to MATLAB, B.R. Hunt, R.L. Lipsman, J.M. Rosenberg, 2014, 3rd Edn., Cambridge University Press
3. Fundamentals of Digital Signal processing using MATLAB, R.J. Schilling and S.L. Harris, 2005, Cengage Learning.
4. Getting started with MATLAB, Rudra Pratap, 2010, Oxford University Press.
5. Digital Signal Processing, S. K. Mitra, McGraw Hill, India.
6. Fundamentals of signals and systems, P.D. Cha and J.I. Molinder, 2007, Cambridge University Press.

DSE: Physics of Earth (32227624)
Credit : 06 (Theory-05, Tutorial-01)
Theory : 75 Hours
Tutorial : 15 Hours

Course Objective

This course familiarizes the students with the origin of universe and role of earth in the solar system.

Course 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
- In the tutorial section, through literature survey on the various aspects of health of Earth, project work / seminar presentation, the students will be able to appreciate need to 'save' Earth.

Unit 1

The Earth and the Universe:

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

(b) General characteristics and origin of the Universe. The Big Bang Theory. Age of the universe and Hubble constant. Formation of Galaxies. The Milky Way galaxy, Nebular Theory, solar system, Earth's orbit and spin, the Moon's orbit and spin. The terrestrial and Jovian planets. Titius-Bode law. Asteroid belt. Asteroids: origin types and examples. Meteorites & Asteroids. Earth in the Solar system ,origin, size, shape, mass, density, rotational and revolution parameters and its age.

(c) Energy and particle fluxes incident on the Earth. (d) The Cosmic Microwave Background.

(17 Lectures)

Unit 2

Structure:
(a) The Solid Earth: Mass, dimensions, shape and topography, internal structure, magnetic field, geothermal energy. How do we learn about Earth's interior?
(b) The Hydrosphere: The oceans, their extent, depth, volume, chemical composition. River systems.
(c) The Atmosphere: layers, variation of temperature with altitude, adiabatic lapse rate, variation of density and pressure with altitude, cloud formation.
(d) The Cryosphere: Polar caps and ice sheets. Mountain glaciers, permafrost.

(18 Lectures)

Unit 3

Dynamical Processes:
(a) The Solid Earth: Origin of the magnetic field. Source of geothermal energy. Convection in Earth's core and production of its magnetic field. Mechanical layering of the Earth. Introduction to geophysical methods of earth investigations. Concept of plate tectonics; types of plate movements, hotspots; sea-floor spreading and continental drift. Geodynamic elements of Earth: Mid Oceanic Ridges, trenches, transform faults and island arcs. Origin of oceans, continents, mountains and rift valleys. Earthquake and earthquake belts. Seismic waves, Richter scale, geophones. Volcanoes: types products and distribution.
(b) The Hydrosphere: Ocean circulations. Oceanic current system and effect of coriolis forces. Concepts of eustasy, tend – air-sea interaction; wave erosion and beach processes. Tides. Tsunamis.
(c) The Atmosphere: Atmospheric circulation. Weather and climatic changes. Earth's heat budget. Cyclones and anti-cyclones.
Climate: i. Earth's temperature and greenhouse effect. ii. Paleoclimate and recent climate changes. iii. The Indian monsoon system.
(d) Biosphere: Water cycle, Carbon cycle. The role of cycles in maintaining a steady state.

(18 Lectures)

Unit 4

Evolution:

Stratigraphy: Introduction and types, Standard stratigraphic time scale and introduction to the concept of time in geological studies. Time line of major geological and biological events. Introduction to geochronological methods and their application in geological

studies. Radiometric dating: Advantages & disadvantages of various isotopes. History of development of concepts of uniformitarianism, catastrophism and neptunism. Various laws of stratigraphy. Introduction to the geology and geomorphology of Indian subcontinent. Origin of life on Earth, Role of the biosphere in shaping the environment. Future of evolution of the, Earth and solar system: Death of the Earth (Probable causes).

(18 Lectures)

Unit 5

Disturbing the Earth – Contemporary dilemmas (a) Human population growth. (b) Atmosphere: Green house gas emissions, climate change, air pollution. (c) Hydrosphere: Fresh water depletion. (d) Geosphere: Chemical effluents, nuclear waste. (e) Biosphere: Biodiversity loss. Deforestation. Robustness and fragility of ecosystems.

(4 Lectures)

References

1. Planetary Surface Processes, H. Jay Melosh, 2011, Cambridge University Press.
2. Consider a Spherical Cow: A course in environmental problem solving, John Harte, University Science Books
3. Holme's Principles of Physical Geology, 1992, Chapman & Hall.
4. Planet Earth, Cosmology, Geology and the Evolution of Life and Environment, C. Emiliani, 1992, Cambridge University Press.
5. The Blue Planet: An Introduction to Earth System Science, Brian J. Skinner, Stephen C. Portere, 1994, John Wiley & Sons.
6. Physics of the Earth, Frank D. Stacey, Paul M. Davis, 2008, Cambridge University Press.
7. Fundamentals of Geophysics, William Lowrie, 1997, Cambridge University Press.
8. The Solid Earth: An Introduction to Global Geophysics, C. M. R. Fowler, 1990, Cambridge University Press.
9. The Earth: A Very Short Introduction, Martin Redfern, 2003, Oxford University Press.
10. Galaxies: A Very Short Introduction, John Gribbin, 2008, Oxford University Press.
11. Climate Change: A Very Short Introduction, Mark Maslin, 3 rd Edition, 2014, Oxford University Press.
12. The Atmosphere: A Very Short Introduction, Paul I. Palmer, 2017, Oxford University Press.
13. IGNOU Study material: PHE 15 Astronomy and Astrophysics Block 2

DSE: Advanced Mathematical Physics-II (32227625)
Credit : 06 (Theory-05, Tutorial-01)
Theory : 75 Hours
Tutorial : 15 Hours

Course Objective

The course is intended to develop new mathematical tools in terms of Calculus of Variation, Group Theory and Theory of Probability in the repertoire of the students to apply in Theoretical and Experimental Physics.

Course Learning Outcomes

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

* Understand variational principle and apply it to calculate: (i)   Geodesics in two and three dimensions (ii) Euler Lagrange Equation and apply it simple problems in one and two dimensions.
* Acquire basic concept of Hamiltonian, Hamilton's principle and Hamiltonian equation of motion, Poisson and Lagrange brackets.
* Learn elementary group theory, i.e., definition and properties of groups, subgroups, Homomorphism, isomorphism, normal and conjugate groups, representation of groups, Reducible and Irreducible groups.
* Learn the theory of probability, Random variables and probability distributions, Expectation values and variance. Various examples of probability distributions used in physics. The principle of least squares.

Unit 1

Variable Calculus: Variational Principle, Euler's Equation and its Application to Simple Problems. Geodesics. Calculus of Variations. Concept of Lagrangian: Generalized co-ordinates. Definition of canonical moment, Euler-Lagrange's Equations of Motion and its Applications to Simple Problems (e.g., Simple Pendulum and One dimensional harmonic oscillator). Definition of Canonical Momenta. Canonical Pair of Variables. Definition of Generalized Force: Definition of Hamiltonian (Legendre Transformation). Hamilton's Principle. Poisson Brackets and their properties. Lagrange Brackets and their properties.

(25 Lectures)

Unit 2

Group Theory: Review of sets, Mapping and Binary Operations, Relation, Types of Relations. Groups: Elementary properties of groups, uniqueness of solution, Subgroup, Centre of a group, Co-sets of a subgroup, cyclic group, Permutation/Transformation. Homomorphism and Isomorphism of group. Normal and conjugate subgroups, Completeness and Kernel. Some special groups : SO(2), SO(3), SU(2), SU(3).

(25 Lectures)

Unit 3

Advanced Probability Theory: Fundamental Probability Theorems. Conditional Probability, Bayes' Theorem, Repeated Trials, Binomial and Multinomial expansions. Random Variables and probability distributions, Expectation and Variance, Special Probability distributions: The binomial distribution, The poisson distribution, Continuous distribution: The Gaussian (or normal) distribution, The principle of least squares.

(25 Lectures)

References

1. Mathematical Methods for Physicists: Weber and Arfken, 2005, Academic Press.
2. Mathematical Methods for Physicists: A Concise Introduction: Tai L. Chow, 2000, Cambridge Univ. Press.
3. Elements of Group Theory for Physicists by A. W. Joshi, 1997, John Wiley.
4. Group Theory and its Applications to Physical Problems by Morton Hamermesh, 1989, Dover
5. Introduction to Mathematical Physics: Methods & Concepts: Chun Wa Wong, 2012, Oxford University Press
6. Introduction to Mathematical Probability, J. V. Uspensky, 1937, Mc Graw-Hill.

DSE: Classical Dynamics (32227626)
Credit : 06 (Theory-05, Tutorial-01)
Theory : 75 Hours
Tutorial : 15 Hours

Course Objective

This course on classical dynamics trains the student in problem solving ability and develops understanding of physical problems. The course begins with the review of Newton's Laws of Motion and ends with the Special The of Relativity by 4-vector approach and fluids. Students will also learn the Lagrangian and Hamiltonian Mechanics. The emphasis of this course is to enhance the understanding of Classical Mechanics (Lagrangian

and Hamiltonian Approach). By the end of this course, students should be able to solve the seen or unseen problems/numericals in classical mechanics.

Course Learning Outcomes

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

- Understand the physical principle behind the derivation of Lagrange and Hamilton equations, and the advantages of these formulations.
- Translate physical problems into appropriate mathematical language and apply appropriate mathematical tools – particularly, calculus, differential equations, linear algebra, and the calculus of variations – to analyze and solve the resulting equations.
- Apply Lagrangian & Hamiltonian methods to complex motion problems.
- One will be able to relate symmetries to conservation laws in physical systems, and apply these concepts to practical situations.
- Understand the intricacies of motion of particle in central force field. Critical thinking and problem-solving skills
- Review the retarded potentials, potentials due to a moving charge, Lienard Wiechert potentials, electric and magnetic fields due to a moving charge, power radiated, Larmor's formula and its relativistic generalization.
- Recapitulate and learn the special theory of relativity- postulates of the special theory of relativity, Lorentz transformations on space-time and other four vectors, four-vector notations, space-time invariant, length contraction, time dilation, mass-energy relation, Doppler effect, light cone and its significance, problems involving energy- momentum conservations.
- Learn the basics of fluid dynamics, streamline and turbulent flow, Reynolds's number, coefficient of viscosity and Poiseuille's equation.
- Upon taking the classical dynamics course students will be able to integrate competently the knowledge and skills acquired in post-undergraduate studies.

Unit 1

Classical Mechanics of Point Particles: Review of Newtonian Mechanics; Application to the motion of a charge particle in external electric and magnetic fields- motion in uniform electric field, magnetic field- gyroradius and gyro-frequency, motion in crossed electric and magnetic fields. Degrees of freedom of a system, Generalized coordinates and velocities. Hamilton's Principle, Lagrangian and Lagrange's equations of motion of one- dimensional simple harmonic oscillators, falling body in uniform gravity. Cyclic coordinates. Canonical momenta & Hamiltonian. Hamilton's equations of motion. Comparison of Newtonian, Lagrangian and Hamiltonian mechanics. Applications of Hamiltonian mechanics: Hamiltonian for a simple harmonic oscillator, solution of Hamilton's equations for simple harmonic oscillations (1-D), particle in a Central Force Field – conservation of angular momentum and energy.

(25 Lectures)

Unit 2

Small Amplitude Oscillations: Minima of potential energy and points of stable equilibrium, small amplitude oscillations about the minimum, normal modes of longitudinal simple harmonic oscillations (maximum 3 masses connected by 4 springs). Kinetic energy

(T) and potential energy (V) in terms of normal co-ordinates. T and V matrices: finding eigen-frequencies and eigen-vectors using these matrices.

(15 Lectures)

Unit 3

Special Theory of Relativity: Postulates of Special Theory of Relativity. Lorentz Transformations. Minkowski space. The invariant interval, light cone and world lines. Space-time diagrams: Time-dilation, Length contraction, Simultaneity.

Four -vectors: space-like, time-like and light-like. Four-displacement four velocity, four-acceleration four-space. Four-momentum and energy-momentum relation. Doppler effect from a 4-vector perspective. Application to two-body decay of an unstable particle. Metric tensor and alternating tensors and their properties.

(25 Lectures)

Unit 4

Fluid Dynamics: Density ρ and pressure P in a fluid, an element of fluid and its velocity, continuity equation and mass conservation, stream-lined motion, laminar flow, Poiseuille's equation for flow of a liquid through a pipe. Analogy between liquid flow and current flow, rate of liquid flow through capillaries in series and in parallel combination. Navier Stoke's equation, Reynolds number.

(10 Lectures)

References

1. Classical Mechanics, H.Goldstein, C.P. Poole, J.L. Safko, 3rdEdn. 2002,Pearson Education. Mechanics, L. D. Landau and E. M. Lifshitz, 1976, Pergamon.
2. Classical Mechanics, P.S. Joag, N.C. Rana, 1st Edn., McGraw Hall.
3. Classical Mechanics, R. Douglas Gregory, 2015, Cambridge University Press.
4. Solved Problems in classical Mechanics, O.L. Delange and J. Pierrus, 2010, Oxford Press
5. Classical Mechanics, Tai L. Chow, CRC Press.
6. An Introduction to Fluid Dynamics, G. K. Batchelor, Cambridge University Press, 2002.

DSE: Dissertation (32227627)
Credit:06

Course Objective

Dissertation involves project work with the intention of exposing the student to research /development. It involves open ended learning based on student ability and initiative, exposure to scientific writing and inculcation of ethical practices in research and communication.

Course Learning Outcomes
- Exposure to research methodology
- Picking up skills relevant to dissertation project, such as experimental skills in the subject, computational skills, etc.
- Development of creative ability and intellectual initiative
- Developing the ability for scientific writing
- Becoming conversant with ethical practices in acknowledging other sources, avoiding plagiarism, etc.

Guidelines for dissertation:

1. The dissertation work should not be a routine experiment or project at the under graduate level. It should involve more than text book knowledge. Referring text books for preparation and understanding concepts is allowed; however one component of the dissertation must include study of research papers or equivalent research material and/or open ended project.
2. The total number of dissertations allowed should be limited to 5% of the total strength of the students in the programme. However, students having national scholarships like NTSE, KVPY, INSPIRE, etc. can be considered above this quota. The selection criterion is at the discretion of the college. The student should not have any academic backlog (Essential Repeat). The sole/single supervisor must have a Ph.D. degree. Not more than two candidates would be enrolled under same supervisor.
3. At the time of submission of teaching work-load of the teachers by the college to the Department (Department of Physics and Astrophysics, Delhi University), the supervisor shall submit the proposal (200-300 words; not more than one full A4 page) of the proposed dissertation. Along with that four names of the external examiners from any college of Delhi University (other than the own college of the supervisor) or any department of Delhi University can be suggested. The committee of courses of the department may appoint any one teacher as an external examiner from the proposed list of external examiners.

4. No topic would be repeated from the topics allotted by the supervisor in the previous years, so that the work or dissertation could be distinct every time. The 'proposal' should include the topic, plan of work, and clearly state the expected deliverables. The topic must be well defined. The abstract should clearly explain the significance of the suggested problem. It must emphasize the specific skills which the student shall be learning during the course of dissertation, for example, some computational skill or literature survey, etc. Both internal (supervisor) and external examiners will assess the student at the end of the semester and award marks jointly, according to the attached scheme.

5. Other than the time for pursuing dissertation work, there must be at least 2 hours of interaction per week, of the student with the supervisor. The student has to maintain a "Log Book" to summarize his/ her weekly progress which shall be duly signed by the supervisor. Experimental work should be carried out in the parent college or any other college or the Department in Delhi University with the consent of a faculty member there. Unsupervised work carried out at research institutions / laboratories is to be discouraged.

6. The dissertation report should be of around 30 pages. It must have minimum three chapters namely (1) Introduction, (2) the main work including derivations / experimentation and Results, and (3) Discussion and Conclusion. At the end, adequate references must be included. Plagiarism should be avoided by the student and this should be checked by the supervisor.

7. It is left to the discretion of the college if it can allow relaxation of two teaching periods (at the most two periods per week to the supervisor, irrespective of the number of students enrolled under him / her for dissertation). The evaluation/presentation of the dissertation must be done within two weeks after the exams are over. For the interest of the students it is advised that college may organize a workshop for creating awareness amongst students. Any teacher who is not Ph.D. holder can be Co-supervisor with the main supervisor.

Assessment of dissertation

MARKING SCHEME for Dissertation:

- 30 marks: Internal assessment based on performance like sincerity, regularity, etc. Awarded by: Supervisor
- 40 marks: Written Report (including content and quality of work done). Awarded by: Supervisor and External Examiner.
- 30 marks: Presentation*. Awarded by: Supervisor and External Examiner.

* All Dissertation presentations should be open. Other students / faculty should be encouraged to attend.

DSE: Verilog and FPGA based system design (32227628)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

* This paper provides a review of combinational and sequential circuits such as multiplexers, demultiplexers, decoders, encoders and adder circuits.
* Evolution of Programmable logic devices such as PAL, PLA and GAL is explained.
* At the end of the syllabus, students will be able to understand the modeling of combinational and sequential circuits (including FSM and FSMD) with Verilog Design.

Course Learning Outcomes

This paper discusses the fundamental Verilog concepts in-lieu of today's most advanced digital design techniques. At the end of this course, students will be able to develop following learning outcomes:

* Understand the steps and processes for design of logic circuits and systems.
* Be able to differentiate between combinational and sequential circuits.
* Be able to design various types of state machines.
* Be able to partition a complex logic system into elements of data-path and control path.
* Understand various types of programmable logic building blocks such as CPLDs and FPGAs and their tradeoffs.
* Be able to write synthesizable Verilog code.
* Be able to write a Verilog test bench to test various Verilog code modules.
* Be able to design, program and test logic systems on a programmable logic device (CPLD or FPGA) using Verilog.

Unit 1

Digital logic design flow. Review of combinational circuits. Combinational building blocks: multiplexors, demultiplexers, decoders, encoders and adder circuits. Review of sequential circuit elements: flip-flop, latch and register. Finite state machines: Mealy and Moore. Other sequential circuits: shift registers and counters. FSMD (Finite State Machine with Datapath): design and analysis. Microprogrammed control. Memory basics and timing. Programmable Logic devices.

(20 lectures)

Unit 2

Evolution of Programmable logic devices. PAL, PLA and GAL. CPLD and FPGA architectures. Placement and routing. Logic cell structure, Programmable interconnects, Logic blocks and I/O Ports. Clock distribution in FPGA. Timing issues in FPGA design. Boundary scan.

(20 lectures)

Unit 3

Verilog HDL: Introduction to HDL. Verilog primitive operators and structural Verilog Behavioral Verilog. Design verification. Modeling of combinational and sequential circuits (including FSM and FSMD) with Verilog Design examples in Verilog.

(20 lectures)

Practical : 60 Hours
PRACTICALS-DSE LAB: Verilog and FPGA based system design Lab

Session on the construction and use of CRO, and other experimental apparatuses used in the lab, including necessary precautions.

Sessions on the review of experimental data analysis and its application to specific experiments done in the lab.

At least 06 Experiments from the following

1. Write code to realize basic and derived logic gates.
2. Half adder, Full Adder using basic and derived gates.
3. Half subtractor and Full Subtractor using basic and derived gates.
4. Design and simulation of a 4 bit Adder.
5. Multiplexer (4x1) and Demultiplexer using logic gates.
6. Decoder and Encoder using logic gates.
7. Clocked D, JK and T Flip flops (with Reset inputs)
8. 3-bit Ripple counter
9. To design and study switching circuits (LED blink shift)
10. To design traffic light controller.
11. To interface a keyboard
12. To interface a LCD using FPGA
13. To interface multiplexed seven segment display.
14. To interface a stepper motor and DC motor.
15. To interface ADC 0804.

References
1. Lizy Kurien and Charles Roth. Principles of Digital Systems Design and VHDL. Cengage Publishing. ISBN-13:978-8131505748
2. Palnitkar, Samir, Verilog HDL. Pearson Education; Second edition (2003).
3. Ming-Bo Lin. Digital System Designs and Practices: Using Verilog HDL and FPGAs. Wiley India Pvt Ltd. ISBN-13: 978-8126536948
4. Zainalabedin Navabi. Verilog Digital System Design. TMH; 2nd edition. ISBN-13: 978-0070252219

5. Wayne Wolf. FPGA Based System Design. Pearson Education. S. K. Mitra, Digital Signal processing, McGraw Hill, 1998
6. VLSI design, Deba prasad Das, 2nd Edition, 2015, Oxford University Press.
7. D.J. Laja and S. Sapatnekar, Designing Digital Computer Systems with Verilog, Cambridge University Press, 2015.
8. U. Meyer Baese, Digital Signal Processing with FPGAs, Springer, 2004
9. Verilog HDL primer- J. Bhasker. BSP, 2003 II edition

DSE: Advanced Quantum Mechanics (xxx4)
Credit : 06 (Theory-05, Tutorial-01)
Theory : 75 Hours
Tutorial : 15 Hours

Course Objective

This course aims to describe quantum phenomena in terms of linear vector space formalism. The students will be able to learn to represent quantum states by ket vectors
and physical observables as operators and their time evolution. Commutation relations between observables will be studied since it is fundamental to understanding uncertainty principle as well as deriving the eigen values of angular momenta. The complete set of commuting observables will be introduced. An understanding of identical particles like bosons and fermions will be developed. At the end of the syllabus, students will be able to learn angular momenta algebra and the computation of Clebsch-Gordan coefficients.

Course Learning Outcomes

This course will aim the B.Sc.(Hons.) physics students with modern analytical techniques so that they can easily apply them to research areas involving lasers interacting with atoms/molecules, manipulate entangled quantum states like qubits, so necessary in the field of quantum information theory and quantum computation, deal effectively with superconductors and superfluidity, etc.

- The world is marching towards attainment of quantum computers, which in turn is likely to revolutionize the field of Artificial Intelligence (AI).
- After learning this course properly, our students would be adequately prepared to participate and innovate in the coming AI revolution.
- As this course starts with an introduction to linear vector spaces and inner product of two vectors that results in a complex number, aided by problem solving exercises, students will imbibe a critical understanding of the general mathematical structures of complex analysis, vector spaces, basis and orthogonality, which form the underlying principles of diverse topics like Fourier transform, matrices and their diagonalisation, Laurent series and calculus of residues, etc. which in turn constitute the bedrock of signal processing, Wiener-Khinchin theorem, Match filtering, etc. that are extremely useful in communication, radar techniques, detection of weak signals, gravitational wave data analysis, operation research, etc.
- Intense problem-solving sessions will enable the students to develop analytical and mathematical imagination that are necessary to be creative in physical sciences as well as engineering research areas.

- The quantum dynamics of two-level systems will help the students to understand the principles of NMR, ESR and MRI. Such systems are also very useful as far as comprehension and implementation of qubit structures that are of paramount importance to future quantum computers.

Unit 1

Motivation for developing a linear vector space formulation to describe quantum phenomena.
Brief review of linear vector spaces with ket notation: Inner product, norm, Schwarz inequality, linear operators, eigenvalue and eigenvector, adjoint of a linear operator, Hermitian or self-adjoint operators and their properties. Orthonormal basis – discrete and continuous. Unitary operators and change of basis. Completeness, closure relation. The position and momentum representations, Relation between wave functions and kets, given an orthonormal basis. Bra vectors.

(17 lectures)

Unit 2

Representation of quantum states by ket vectors and physical observables by Hermitian operators. Unitary time-evolution and Schrodinger equation in ket notation. Measurement of an observable. Expectation value of an observable. Canonical commutation relations - commutators of position and momentum, commutators for orbital and spin angular momentum.

(14 lectures)

Unit 3

Compatible and incompatible observables: Commutator brackets and their properties, the uncertainty principle. Ehrenfest's theorem and the classical limit. Correspondence of unitary evolution of ket vectors with Schrodinger wave mechanics.

(6 lectures)

Unit 4

Identical particles: direct product of kets, symmetric and antisymmetric states. Systems of identical non-interacting particles. Bosons and Fermions; Pauli's exclusion principle.
Dynamics of two-level systems (e.g. electron in an external magnetic field). Entangled states, Qubits; One dimensional Harmonic oscillator, its energy eigen values and eigen states using ladder operators.

(15 lectures)

Unit 5

Addition of orbital and spin angular momenta, $J = L+S$. Commutators of J_x , J_y and J_z ; Ladder operators, recursion relations, eigenvalues and eigenstates of total angular momentum operators. Composite system of two spin-half particles – singlet and triplet states. Clebsch-Gordan coefficients: formalism, computation (up to $l \oplus 1/2$)

(13 lectures)

Unit 6

Variational Method: Basic idea, application to some simple systems like rigid box problem and one dimensional simple harmonic oscillator; Estimation of Hydrogen atom

ground state energy using variational method. Helium atom ground state energy.

(10 lectures)

References

1. Modern Quantum Mechanics, J.J Sakurai, Revised Edition, 1994, Addision-Wesley.
2. The Principles of Quantum Mechanics, P. A. M. Dirac, Clarendon Press, 2004
3. Introduction to Quantum Mechanics, David J. Griffiths, Second Edition, 2006, Pearson Education.
4. Quantum Mechanic Concepts and Applications, Nouredine Zettili, Second Edition,2001, John Wiley & Sons, Ltd.
5. A Text book of Quantum Mechanics, P.M.Mathews& K.Venkatesan, 2nd Ed., 2010, McGraw Hill.
6. Quantum Mechanics, Brian H. Bransden and C. Charles Jean Joachain, 2000, Prentice Hall.

Additional Resources:

1. Introduction to Quantum Mechanics, Volume-I, C. Cohen-Tannoudgi, B. Diu, F. Laloe, 1977, Wiley-VCH. Quantum Theory, David Bohm, Dover Publications, 1979.
2. QUANTUM MECHANICS: Theory and Applications, (2019), (Extensively revised 6th Edition), Ajoy Ghatak and S. Lokanathan, Laxmi Publications, New Delhi.
3. Lectures on Quantum Mechanics: Fundamentals and Applications, eds. A. Pathak and Ajoy Ghatak, Viva Books Pvt. Ltd., 2019
4. Introduction to Quantum Mechanics, R. H. Dicke and J. P. Wittke, Addison-Wesley Publications, 1966
5. Quantum Mechanics, Leonard I. Schiff, 3rd Edn. 2010, Tata McGraw Hill.
6. Quantum Mechanics, Eugene Merzbacher, 2004, John Wiley and Sons, Inc.

9.3. Skill-Enhancement Elective Course - (SEC)

SEC: Physics Workshop Skills (32223901)
Credit:04 (Theory-02, Practical-02)
Theory: 30 Hours
Practical : 60 Hours

Course Objective

The aim of this course is to enable the students to familiar and experience with various mechanical and electrical tools through hands-on mode. This course enable students to understand working of various measuring devices and different type of errors student can encounter in the measurement process. This course also develop the mechanical skills of the students by direct exposure to different machines and tools by demonstration and experimental technique.

Teacher may give long duration project based on this paper.

Course Learning Outcomes

After completing this course, student will be able to :
- Learning measuring devices like Vernier callipers, Screw gauge, travelling microscope and Sextant for measuring various length scales.
- Acquire skills in the usage of multimeters, soldering iron, oscilloscopes, power supplies and relays.

- Developing mechanical skill such as casting, foundry, machining, forming and welding and will become familiar with common machine tools like lathe, shaper, drilling, milling, surface machines and Cutting tools.

- Getting acquaintance with prime movers: Mechanism, gear system, wheel, Fixing of gears with motor axle. Lever mechanism. Lifting of heavy weight using lever. braking systems, pulleys.

Unit 1

Introduction: Measuring devices: Vernier calliper, Screw gauge and travelling microscope. Measure the dimension of a solid block, volume of cylindrical beaker/glass, diameter of a thin wire, thickness of metal sheet, etc. Use of Sextant to measure height of buildings, mountains, etc.

(6 lectures)

Unit 2

Mechanical Skill: Overview of manufacturing methods: casting, foundry, machining, forming and welding. Types of welding joints and welding defects. Concept of machine processing, introduction to common machine tools like lathe, shaper, drilling, milling and surface machines. Cutting tools, lubricating oils. Cutting of a metal sheet using blade. Smoothening of cutting edge of sheet using file. Drilling of holes of different diameter in metal sheet and wooden block. Use of bench vice and tools for fitting. Make funnel using metal sheet.

(14 Lectures)

Unit 3

Introduction to prime movers: Mechanism, gear system, wheel, Fixing of gears with motor axel. Lever mechanism, Lifting of heavy weight using lever. braking systems, pulleys, working principle of power generation systems. Demonstration of pulley experiment.

(10 Lectures)

Practical: 60 Hours
PRACTICALS-SEC LAB: Physics Workshop Skills Lab

Sessions on the use of equipment used in the workshop, including necessary precautions.

Sessions on the review of experimental data analysis and its application to the specific experiments done in the lab.

Main emphasis is on taking observations, calculations, graph and result. Perform at least three practicals from the following.

1. Comparison of diameter of a thin wire using screw gauge and travelling microscope.
2. Drilling of Hole in metal, wood and plastic.
3. Cutting of metal sheet.
4. Cutting of glass sheet
5. Lifting of heavy weights using simple pulley/lever arrangement.

References

1. A text book in Electrical Technology - B L Theraja – S. Chand and Company.
2. Performance and design of AC machines – M.G. Say, ELBS Edn.
3. Mechanical workshop practice, K.C. John, 2010, PHI Learning Pvt. Ltd.
4. Workshop Processes, Practices and Materials, Bruce J Black 2005, 3rd Edn., Editor Newnes [ISBN: 0750660732] New Engineering Technology, Lawrence Smyth/Liam Hennessy, The Educational Company of Ireland [ISBN0861674480].

SEC: Computational Physics Skills (32223902)
Credit:04 (Theory-02, Practical-02)
Theory: 30 Hours
Practical : 60 Hours

Course Objectives

This course is intended to give an insight to computer hardware and computer applications. Students will familiarize with use of computer to solve physics problems. They will learn
- a programming language namely fortran.
- will also learn to visualize at data graphically using gnu plot.
- further will learn to prepare long formatted document using latex.

Teacher may give long duration project based on this paper.

Course Learning Outcomes

- Learn the importance of computers in solving problems in Physics.

- Learn to write the algorithm for solving a problem by drawing the flowchart of simple problems like roots of quadratic equations etc.

- Have a working knowledge about the Linux system: the necessary commands.

- Learn to write and execute FORTRAN programs in the Linux system. They should attempt the simple numerical exercises: product of matrices, sum of finite series and area under a curve, plotting trajectory of a projectile, find roots of a quadratic equation, numerical solution of equation of motion of simple harmonic oscillator and plot the outputs for visualization etc.

- Learn to use GUI windows, Linux commands, familiarity with DOS commands and working in an editor to write sources codes in FORTRAN.

- The students should also learn "Scientific Word Processing", particularly, how to use the LaTeX software in writing articles and papers which include mathematical equations and diagrams.

- The students should learn the basics of Gnuplot. He should be able to create an input Gnuplot file for plotting a data and saving the output for seeing on the screen, saving it as an eps file and as a pdf file etc.

Unit 1

Introduction: Importance of computers in Physics, paradigm for solving physics problems for solution. Usage of linux as an Editor.

Algorithms and Flowcharts: Algorithm: Definition, properties and development. Flowchart: Concept of flowchart, symbols, guidelines, types. Examples: Cartesian to Spherical Polar Coordinates, Roots of Quadratic Equation, Sum of two matrices, Sum and Product of a finite series, calculation of sin(x) as a series, algorithm for plotting (1) lissajous figures and (2) trajectory of a projectile thrown at an angle with the horizontal.

(4 Lectures)

Scientific Programming: Some fundamental Linux Commands (Internal and External commands). Development of FORTRAN, Basic elements of FORTRAN: Character Set, Constants and their types, Variables and their types, Keywords, Variable Declaration and concept of instruction and program. Operators: Arithmetic, Relational, Logical and Assignment Operators. Expressions: Arithmetic, Relational, Logical, Character and Assignment Expressions. Fortran Statements: I/O Statements (unformatted/formatted), Executable and Non-Executable Statements, Layout of Fortran Program, Format of writing Program and concept of coding, Initialization and Replacement Logic. Examples from physics problems.

(5 Lectures)

Unit 2

Control Statements: Types of Logic(Sequential, Selection, Repetition), Branching Statements (Logical IF, Arithmetic IF, Block IF, Nested Block IF, SELECT CASE and ELSE IF Ladder statements), Looping Statements (DO- CONTINUE, DO-ENDDO, DO-WHILE, Implied and Nested DO Loops), Jumping Statements (Unconditional GOTO, Computed GOTO, Assigned GOTO) Subscripted Variables (Arrays: Types of Arrays, DIMENSION Statement, Reading and Writing Arrays), Functions and Subroutines (Arithmetic Statement Function, Function Subprogram and Subroutine), RETURN, CALL, COMMON and EQUIVALENCE Statements), Structure, Disk I/O Statements, open a file, writing in a file, reading from a file. Examples from physics problems Programming:

1. Exercises on syntax on usage of FORTRAN
2. Usage of GUI Windows, Linux Commands, familiarity with DOS commands and working in an editor to write sources codes in FORTRAN.
3. To print out all natural even/ odd numbers between given limits.
4. To find maximum, minimum and range of a given set of numbers.
5. Calculating Euler number using exp(x) series evaluated at x=1

(6 Lectures)

Unit 3

Scientific word processing: Introduction to LaTeX: TeX/LaTeX word processor, preparing a basic LaTeX file, Document classes, Preparing an input file for LaTeX, Compiling LaTeX File, LaTeX tags for creating different environments, Defining LaTeX commands and environments, Changing the type style, Symbols from other languages. Equation representation: Formulae and equations, Figures and other floating bodies, Lining in columns- Tabbing and tabular environment, Generating

table of contents, bibliography and citation, Making an index and glossary, List making environments, Fonts, Picture environment and colors, errors.

(6 Lectures)

Unit 4

Visualization: Introduction to graphical analysis and its limitations. Introduction to Gnuplot.importance of visualization of computational and computational data, basic Gnuplot commands: simple plots, plotting data from a file, saving and exporting, multiple data sets per file, physics with Gnuplot (equations, building functions, user defined variables and functions), Understanding data with Gnuplot

Practicals/Hands on exercises:
PRACTICALS-SEC LAB: Computational Physics Skills Lab

1. To compile a frequency distribution and evaluate mean, standard deviation etc.
2. To evaluate sum of finite series and the area under a curve.
3. To find the product of two matrices
4. To find a set of prime numbers and Fibonacci series.
5. To write program to open a file and generate data for plotting using Gnuplot.
6. Plotting trajectory of a projectile projected horizontally.
7. Plotting trajectory of a projectile projected making an angle with the horizontally.
8. Creating an input Gnuplot file for plotting a data and saving the output for seeing on the screen. Saving it as an eps file and as a pdf file.
9. To find the roots of a quadratic equation.
10. Motion of a projectile using simulation and plot the output for visualization.
11. Numerical solution of equation of motion of simple harmonic oscillator and plot the outputs for visualization.
12. Motion of particle in a central force field and plot the output for visualization.

(9 Lectures)

References

1. Introduction to Numerical Analysis, S.S. Sastry, 5th Edn., 2012, PHI Learning Pvt. Ltd.
2. Computer Programming in Fortran 77". V. Rajaraman (Publisher:PHI).
3. LaTeX–A Document Preparation System", Leslie Lamport (Second Edition, Addison-Wesley, 1994).
4. Gnuplot in action: understanding data with graphs, Philip K Janert, (Manning 2010).
5. Schaum's Outline of Theory and Problems of Programming with Fortran, S Lipsdutz and A Poe, 1986Mc-Graw Hill Book Co.
6. Computational Physics: An Introduction, R. C. Verma, et al. New Age International Publishers, New Delhi(1999).
7. Elementary Numerical Analysis, K.E.Atkinson,3rd Edn., 2007, Wiley India Edition.

SEC: Electrical circuits and Network Skills (32223903)
Credit:04 (Theory-02, Practical-02)
Theory: 30 Hours
Practical : 60 Hours

Course Objectives:

This is a course to expose basic circuit concepts, circuit modeling and methods of circuit analysis in time domain and frequency domain for solving simple and multi dimensional circuits including DC and AC circuit theory and network theorems.

Teacher may give long duration project based on this paper.

Course Leaning Outcomes:

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

- They would be able to demonstrate good comprehension of basic principles of electricity including ideas about voltage, current and resistance.

- They would also be proficient in identifying different combinations of circuit elements besides having sound knowledge about varying types of voltage & current - alternating and direct.

- Their familiarization with basic tenets of electrical circuits like measurement of resistance, current and voltages in different circuits would be complete.

- They would be able to analyse complicated AC and DC electrical circuits.

- They would have the ability to calculate real, imaginary and complex power components of AC sources.

- They would become proficient in power factor calculation and hence would be able to design circuits exhibiting enhanced efficiency.

- The students would develop the capacity to analyse and evaluate schematics of electrical circuits including those of power and control while demonstrating insight into tracking of interconnections within elements while identifying current flow and voltage drop.

- The students would gain knowledge about generators, transformers as also electric motors including single and three phase AC and DC. The knowledge would be inclusive to interfacing aspects besides consumer defined control of speed and power.

- The students would acquire capacity to work theoretically and practically with solid-state devices including resistors, inductors and capacitors as also diodes and rectifiers in series or shunt configurations.

- The students would also be able to delve into practical aspects related to electrical wiring like varying types of conductors and cables. basics of wiring-Star and delta connections, voltage drop and losses.

Post extensive hands-on training (laboratory exercises) the students would be able to achieve the following learning outcomes:

- They would acquire ability to measure current, voltage, power in DC and AC circuits.

- They would assimilate proficiency in fabrication of regulated power supply besides preparation of extension board

- They would be enabled to choose relevant diodes (signal or power) and design rectifiers.

- They would develop capacity to identify and suggest types and sizes of solid & stranded cables, conduit lengths, cable trays. Splices, crimps, terminal blocks and solder

Unit 1

Basic Electricity Principles: Voltage, Current, Resistance, and Power. Ohm's law. Series, parallel, and series-parallel combinations. AC and DC Electricity. Familiarization with multimeter, voltmeter and ammeter.

(3 Lectures)

Electrical Circuits: Basic electric circuit elements and their combination. Rules to analyze DC sourced electrical circuits. Current and voltage drop across the DC circuit elements. Single-phase and three-phase alternating current sources. Rules to analyze AC sourced electrical circuits. Real, imaginary and complex power components of AC source. Power factor. Saving energy and money.

(4 Lectures)

Electrical Drawing and Symbols: Drawing symbols. Blueprints. Reading Schematics. Ladder diagrams. Electrical Schematics. Power circuits. Control circuits. Reading of circuit schematics. Tracking the connections of elements and identify current flow and voltage drop.

(4 Lectures)

Generators and Transformers: DC Power sources. AC/DC generators. Inductance, capacitance, and impedance. Operation of transformers.

(2 Lectures)

Electric Motors: Single-phase, three-phase & DC motors. Basic design. Interfacing DC or AC sources to control heaters and motors. Speed & power of ac motor.

(3 Lectures)

Unit 2

Solid-State Devices: Resistors, inductors and capacitors. Diode and rectifiers. Components in Series or in shunt. Response of inductors and capacitors with DC or AC sources.

(3 Lectures)

Electrical Protection: Relays. Fuses and disconnect switches. Circuit breakers. Overload devices. Ground-fault protection. Grounding and isolating. Phase reversal. Surge protection. Relay protection device.

(3 Lectures)

Electrical Wiring: Different types of conductors and cables. Basics of wiring-Star and delta connection. Voltage drop and losses across cables and conductors. Instruments to measure current, voltage, power in DC and AC circuits. Insulation. Solid and stranded cable. Conduit. Cable trays. Splices: wirenuts, crimps, terminal blocks, and solder. Preparation of extension board.

(5 Lectures)

Network Theorems:(1) Thevenin theorem (2) Norton theorem (3) Superposition theorem (4) Maximum Power Transfer theorem.

(3 Lectures)

Practical : 60 Hours
PRACTICALS-SEC LAB: Electrical circuits and Network Skills Lab

Sessions on the construction and use of specific measurement instruments and experimental apparatuses used in the physics lab, including necessary precautions.

Sessions on the review of experimental data analysis and its application to the specific experiments done in the lab.

At least 08 Experiments from the following

1. Series and Parallel combinations: Verification of Kirchoff's law.
2. To verify network theorems: (I) Thevenin (II) Norton (III) Superposition theorem
   (IV) Maximum power transfer theorem
3. To study frequency response curve of a Series LCR circuit.
4. To verify (1) Faraday's law and (2) Lenz's law.
5. Programming with Pspice/NG spice.
6. Demonstration of AC and DC generator.
7. Speed of motor
8. To study the characteristics of a diode.
9. To study rectifiers (I) Half wave (II) Full wave rectifier (III) Bridge rectifier
10. Power supply (I) C-filter, (II) π- filter
11. Transformer – Step up and Step down
12. Preparation of extension board with MCB/fuse, switch, socket-plug, Indicator.
13. Fabrication of Regulated power supply.

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 practicals enumerated above.

References

1. Electrical Circuits, K.A. Smith and R.E. Alley, 2014, Cambridge University Press
2. A text book in Electrical Technology - B L Theraja - S Chand & Co.
3. A text book of Electrical Technology - A K Theraja
4. Performance and design of AC machines - M G Say ELBS Edn.
5. Electrical Circuit Analysis, K. Mahadevan and C. Chitran, 2nd Edition, 2018, PHI learning Pvt. Ltd.

SEC: Basic Instrumentation Skills (32223904)
Credit:04 (Theory-02, Practical-02)
Theory : 30 Hours
Practical : 60 Hours

Course Objective

• This course is to get exposure with various aspects of instruments and their usage through hands-on mode.
• Students will obtain a thorough understanding of basics of measurement, measurement devices such as electronic voltmeter, Oscilloscope, signal and pulse generators, Impedance bridges, digital instruments etc.

Teacher may give long duration project based on this paper.

Course Learning Outcomes

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

• 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 familizes about each and every specification of a multimeter, multimeters, multivibrators, rectifiers, amplifiers, oscillators and high voltage probes and their significance with hands on mode.
• Explanation of the Specifications 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 mode Understanding and usage of analog & digital instruments.

- Hands-on mode for working of digital multimeter and frequency counter.

Unit 1

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

(4 Lectures)

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

(4 Lectures)

Unit 2

Oscilloscope: Block diagram of basic CRO. CRT, electrostatic focusing and acceleration (Explanation only– no mathematical treatment), brief discussion on screen phosphor, visual persistence. Time base operation, synchronization.Front panel controls. Specifications of CRO and their significance.

(6 Lectures)

Use of CRO: for the measurement of voltage (dc and ac), frequency and time period. Special features of dual trace, introduction to digital oscilloscope, probes. Digital storage Oscilloscope: principle of working.

(3 Lectures)

Unit 3

Signal and pulse Generators: Block diagram, explanation and specifications of low frequency signal generator and pulse generator. Brief idea for testing, specifications. Distortion factor meter, wave analysis.

(4 Lectures)

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

(3 Lectures)

Unit 4

Digital Instruments: Comparison of analog & digital instruments. Characteristics of a digital meter. Working principles of digital voltmeter.

(3 Lectures)

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

(3 Lectures)

Practical : 60 Hours
PRACTICALS-SEC LAB: Basic Instrumentation Skills Lab

Session on the construction and use of CRO, and other experimental apparatuses used in the lab, including necessary precautions.

Sessions on the review of experimental data analysis and its application to specific experiments done in the lab.

The test of lab skills will be of the following test items:

1. Use of an oscilloscope.
2. Oscilloscope as a versatile measuring device.
3. Circuit tracing of Laboratory electronic equipment,
4. Use of Digital multimeter/VTVM for measuring voltages
5. Circuit tracing of Laboratory electronic equipment,
6. Winding a coil / transformer.
7. Study the layout of receiver circuit.
8. Trouble shooting a circuit
9. Balancing of bridges

Practicals:

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 a Q- meter.
4. Measurement of voltage, frequency, time period and phase using Oscilloscope.
5. Measurement of time period, frequency, average period using universal counter/ frequency counter.
6. Measurement of rise, fall and delay times using a Oscilloscope.
7. Measurement of distortion of a RF signal generator using distortion factor meter.
8. Measurement of R,L and C using a LCR bridge/ universal bridge.

Open Ended Experiments:

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

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 practicals enumerated above.

References

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

3. Digital Circuits and systems, Venugopal, 2011, Tata McGraw Hill.
4. Logic circuit design, Shimon P. Vingron, 2012, Springer.
5. Digital Electronics, Subrata Ghoshal, 2012, Cengage Learning.
6. Electronic Devices and circuits, S. Salivahanan & N. S.Kumar, 3rd Ed., 2012, Tata Mc-Graw Hill

SEC: Renewable Energy and Energy harvesting (32223905)
Credit:04 (Theory-02, Practical-02)
Theory : 30 Hours
Practical : 60 Hours

Course Objective

Energy drives life, movements and changes. Human beings have been dependent on fossil fuels to extract energy for a long time. But in today's world, availability of fossil fuels is increasingly becoming scarcer, and hence, one needs to plan for the distant future and for the generations yet to come and live in a decent manner. Therefore, one needs to look into and study various alternate energy sources. The aim of this course is not just to impart theoretical knowledge to the students but to provide them with exposure and hands-on learning wherever possible. Similarly, water, a vital ingredient for the survival of all species, is no longer abundant. One needs to think seriously about rain water harvesting. This paper describes the ways of harvesting energy using wind, solar, mechanical, ocean, geothermal energy and so on. This paper provides a review and working of various energy harvesting systems which are installed worldwide.

Teacher may give long duration project based on this paper.

Course Learning Outcomes

- Significance of renewable energy and details concerning various sources of energy will be imparted to the students. The students are expected to learn not only the theories of the renewable sources of energy, but also to have hands-on experiences on them wherever possible.

- Some of the renewable sources of energy which should be studied here are: (i) off-shore wind energy, (ii) tidal energy, (iii) solar energy, (iv) biogas energy and (v) hydroelectricity.

- Knowledge of various sources of energy for harvesting will be given
- Understand the need of energy conversion and the various methods of energy storage
- Students will have a good understanding of various renewable energy systems, and its components.

- They will be able to gain knowledge about renewable energy technologies, different storage technologies, distribution grid, smart grid including sensors, regulation and their control.
- Student will understand the concept of direct energy conversion systems and their applications.
- Students will able to identify and design the model for sending the wind energy or solar energy plant.
- The students should observe practical demonstrations of (i) training modules of solar energy, wind energy etc., (ii) Conversion of vibration into voltage using piezoelectric materials, (iv) conversion of thermal energy into voltage using thermoelectric modules.

Unit 1

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

(3 Lectures)

Unit 2

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

(6 Lectures)

Unit 3

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

(3 Lectures)

Unit 4

Ocean Energy: Ocean Energy Potential against Wind and Solar, Wave Characteristics
and Statistics, Wave Energy Devices.
Tide characteristics and Statistics, Tide Energy Technologies, Ocean Thermal Energy, Osmotic   Power, Ocean Bio-mass.
Geothermal Energy: Geothermal Resources, Geothermal Technologies.
Hydro Energy: Hydropower resources, hydropower technologies, environmental impact of hydro power sources. Rain water harvesting.

(9 Lectures)

Unit 5

Piezoelectric Energy harvesting: Introduction, Physics and characteristics of piezoelectric effect, materials and mathematical description of piezo-electricity,

Piezoelectric parameters and modeling piezoelectric generators, Piezoelectric energy harvesting applications, Human power

Electromagnetic Energy Harvesting: Linear generators, physical/mathematical models, recent applications Carbon captured technologies, cell, batteries, power consumption Environmental issues and Renewable sources of energy, sustainability. Merits of Rain Water harvesting

(9 Lectures)

Practical : 60 Hours
PRACTICALS-SEC LAB: Renewable Energy and Energy Harvesting Lab

Sessions on the use of equipment used in the workshop, including necessary precautions.

Sessions on the review of experimental data analysis and its application to the specific experiments done in the lab.

Demonstrations and Experiments:

1. Demonstration of Training modules on Solar energy, wind energy, etc.
2. Conversion of vibration to voltage using piezoelectric materials
3. Conversion of thermal energy into voltage-driven thermo-electric modules.

References

1.   Non-conventional energy sources, B.H. Khan, McGraw Hill 60
2.   Solar energy, Suhas P Sukhative, Tata McGraw - Hill Publishing Company Ltd.
3.   Renewable Energy, Power for a sustainable future, Godfrey Boyle, 3rd Edn., 2012, Oxford University Press.
4.   Solar Energy: Resource Assessment Handbook, P Jayakumar, 2009
5.   J.Balfour, M.Shaw and S. Jarosek, Photo-voltaics, Lawrence J Goodrich (USA).

Additional Resources:

1.   http://en.wikipedia.org/wiki/Renewable_energy

SEC: Engineering Design and Prototyping/Technical Drawing(32223906)
Credit:04 (Theory-02, Practical-02)
Theory: 30 Hours
Practical : 60 Hours

Course Objective

The objective of this course is to introduce the students to modern visualization techniques and their applications in diverse areas including computer aided design.

Course Learning Outcomes

This course learning will enable the student to be proficient in:
- Understanding the concept of a sectional view – visualizing a space after being cut by a plane. How The student will be able to draw and learn proper techniques for drawing an aligned sections

- Understanding the use of spatial visualization by constructing an orthographic multi view drawing

- Drawing simple curves like ellipse, cycloid and spiral, Orthographic projections of points, lines and of solids like cylinders, cones, prisms and pyramids etc.

- Exposure to Computer Aided Design (CAD) and Auto CAD techniques and hence will make the student technologically savvy.

Teacher may give long duration project based on this paper.

Unit 1

Introduction: Fundamentals of Engineering design, design process and sketching: Scales and dimensioning, Designing to Standards (ISO Norm Elements/ISI), Engineering Curves: Parabola, hyperbola, ellipse and spiral.

(4 Lectures)

Unit 2

Projections: Principles of projections, Orthographic projections: straight lines, planes and solids. Development of surfaces of right and oblique solids. Section of solids. Intersection and Interpenetration of solids. Isometric and Oblique parallel projections of solids.

(10 Lectures)

Unit 3

CAD Drawing: Introduction to CAD and Auto CAD, precision drawing and drawing aids, Geometric shapes, Demonstrating CAD specific skills (graphical user interface, create, retrieve, edit, and use symbol libraries). Use of Inquiry commands to extract drawing data. Control entity properties. Demonstrating basic skills to produce 2-D drawings. Annotating in Auto CAD with text and hatching, layers, templates and design centre, advanced plotting (layouts, viewports), office standards, dimensioning, internet and collaboration, Blocks, Drafting symbols, attributes, extracting data. Basic printing and editing tools, plot/print drawing to appropriate scale.

(10 Lectures)

Unit 4

Computer Aided Design and Prototyping: 3D modeling with AutoCAD (surfaces and solids), 3D modeling with Sketchup, 3D designs, Assembly: Model Editing; Lattice and surface optimization; 2D and 3D packing algorithms, Additive Manufacturing Ready Model Creation (3D printing), Technical drafting and Documentation.

(6 Lectures)

Practicals : 60 Hours
PRACTICALS-SEC LAB: Engineering Design and Prototyping/Technical Lab

Five experiments based on the above theory.
Teacher may design at least five experiments based on the above syllabus.

References

1. Engineering Drawing, N.S. Parthasarathy and Vele Murali, 1st Edition, 2015, Oxford University Press
2. Engineering Graphic, K. Venugopal and V. Raja Prabhu, New Age International
3. Engineering Drawing, Dhananjay A Jolhe, McGraw-Hill
4. AutoCAD 2014 and AutoCAD 2014/Donnie Gladfelter/Sybex/ISBN:978-1-118-57510-9
5. Don S. Lemons, Drawing Physics, MIT Press, M A Boston, 2018, ISBN:9780262535199
6. Norton, Robert L. Design of Machinery: An Introduction to the Synthesis and
7. Analysis of Mechanisms and Machines, M A Boston, McGraw-Hill, 2007.
8. James A. Leach, AutoCAD 2017 Instructor, SDC publication, Mission, KS 2016. ISBN: 978163057029.
9. Architectural Design with Sketchup/Alexander Schreyer/John Wiley & Sons/ISBN:978-1-118-12309-6

SEC: Radiation Safety (32223907)
Credit:04 (Theory-02, Practical-02)
Theory : 30 Hours
Practical : 60 Hours

Course Objective

It is a course focused 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 the radiation exposure. It imparts all the skills required by a radiation safety officer or any job dealing with radiation such as X-ray operators, nuclear medicine dealing jobs: chemotherapists, PET MRI CT scan, gamma camera etc. operators etc.

Teacher may give long duration project based on this paper.

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.
- Learning the basic aspects of the atomic and nuclear Physics, specially the radiations that originate from the atom and the nucleus.
- 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 devises to detect and measure radiation, such as the Geiger-Mueller counter and scintillation counter.
- Learning radiation safety management, biological effects of ionizing radiation, operational limits and basics of radiation hazards evaluation and control, radiation protection standards, 'International Commission on Radiological Protection' (ICRP) its principles, justification, optimization, limitation, introduction of safety and risk management of radiation. nuclear waste and disposal management, brief idea about 'Accelerator driven Sub-critical System' (ADS) for waste management.
- Learning about the devices which apply radiations in medical sciences, such as MRI, PET.
- Understanding and performing experiments like Study the background radiation levels using Radiation meter, Study the Characteristics of Geiger Muller (GM) Counter, getting the plateau curve and the operating voltage and the statistical distribution of beta or gamma ray emitted from a radioactive source, Determination of gamma ray linear and mass absorption coefficient of a given material and drawing the mass absorption coefficient vs. energy curve for a given material with a number of gamma ray sources, study of beta ray energy spectrum for a given source etc.

Unit 1

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

(6 Lectures)

Unit 2

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

(7 Lectures)

Unit 3

Radiation detection and monitoring devices: 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). Radiation detection: Basic concept and working principle of gas detectors (Ionization Chambers, Proportional Counter, Multi-Wire Proportional Counters (MWPC) and Geiger Muller Counter), Scintillation Detectors (Inorganic and Organic Scintillators), Solid States Detectors and Neutron Detectors, Thermo luminescent Dosimetry.

Radiation detection: Basic concept and working principle of gas detectors (Ionization Chambers, Proportional Counter and Geiger Muller Counter), Scintillation Detectors (Inorganic and Organic Scintillators), Solid States Detectors and Neutron Detectors, Thermoluminescent Dosimetry.

(7 Lectures)

Unit 4

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

(5 Lectures)

Unit 5

Application of nuclear techniques: Application in medical science (e.g., MRI, PET, Projection Imaging Gamma Camera, radiation therapy), Archaeology, Art, Crime

detection, Mining and oil. Industrial Uses: Tracing, Gauging, Material Modification, Sterilization, Food preservation.

(5 Lectures)

Practical : 60 Hours
PRACTICALS-SEC LAB: Radiation Safety Lab

Sessions on the construction and use of specific measurement instruments and experimental apparatuses used in the physics lab, including necessary precautions.

Sessions on the review of experimental data analysis and its application to the specific experiments done in the lab.

Experiments:

Minimum five experiments need to be performed from the following,

1. Estimate the energy loss of different projectiles/ions in Water and carbon, using SRIM/TRIM etc. simulation software.
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. (Data may be taken from the Department of Physics & Astrophysics, University of Delhi and 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. KSO_4etc.). 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. Detection of α particles using reference source & determining its half life using spark counter.
13. Gamma spectrum of Gas Light mantle (Source of Thorium).

References

1. Nuclear Physics: Principles and Applications by J Lilley, Wiley Publication, 2006.
2. Nuclear and Particle Physics by W E Burcham and M Jobes, Harlow Longman Group, 1995.
3. Basic ideas and concepts in Nuclear Physics: An introductory approach by K Heyde, third edition, IOP Publication, 1999.
4. Nuclear Physics by S N Ghoshal, First edition, S. Chand Publication, 2010.
5. Radiation detection and measurement by G F Knoll, 4th Edition, Wiley Publications, 2010.
6. Techniques for Nuclear and Particle Physics experiments by W R Leo, Springer, 1994.
7. Thermoluminescence dosimetry by A F Mcknlay, Bristol, Adam Hilger (Medical Physics Hand book 5.
8. Fundamental Physics of Radiology by W J Meredith and J B Massey, John Wright and Sons, UK, 1989.
9. An Introduction to Radiation Protection by A Martin and S A Harbisor, John Willey & Sons, Inc. New York, 1981.
10. Medical Radiation Physics by W R Hendee, Year book Medical Publishers, Inc., London, 1981.
11. Physics and Engineering of Radiation Detection by S N Ahmed, Academic Press Elsevier, 2007.

Books for Numericals:

1. Schaum's Outline of Modern Physics, McGraw-Hill, 1999.
2. Schaum's Outline of College Physics, by E. Hecht, 11th edition, McGraw Hill, 2009.
3. Modern Physics by K Sivaprasath and R Murugeshan, S Chand Publication, 2010.

Additional Resources:

1. 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).
2. AERB Safety Guide (Guide No. AERB/RF-RS/SG-1), Security of radioactive sources in radiation facilities, 2011
3. AERB Safety Standard No. AERB/SS/3 (Rev. 1), Testing and Classification of sealed Radioactivity Sources., 2007.

SEC: Applied Optics (32223908)
Credit:04 (Theory-02, Practical-02)
Theory: 30 Hours
Practical : 60 Hours

Course Objective

The quest to understand the 'nature of light' is a favorite inquiry of mankind since ancient times. By the advent lasers, holography, and optical fibres in twentieth century the optics now-a-days finds application in several branches of science and engineering. This paper provides the conceptual understanding of these branches of modern optics to the students.

Course Learning Outcomes

This course will help students to
- Understand basic lasing mechanism qualitatively, types of Lasers, characteristics of Laser Light, types of Lasers, and its applications in developing LED, Holography.
- Learn concept of Fourier optics and fourier transform spectroscopy.
- Understanding of basic principle and theory of Holography.
- Concept of total internal reflection.
- Characteristics of optical fibre.

Teacher may give long duration project based on this paper.

Unit 1

Photo-sources and Detectors

Lasers: an introduction, Planck's radiation law (qualitative idea), Energy levels, Absorption process, Spontaneous and stimulated emission processes, Theory of laser action, Population of energy levels, Einstein's coefficients and optical amplification, properties of laser beam, Ruby laser, He-Ne laser, and semiconductor lasers; Light Emitting Diode (LED) and photo-detectors.

(9 lectures)

Unit 2

Fourier Optics and Fourier Transform Spectroscopy (Qualitative explanation) Concept of Spatial frequency filtering, Fourier transforming property of a thin lens, Fourier Transform Spectroscopy (FTS): measuring emission and absorption spectra,

with wide application in atmospheric remote sensing, NMR spectrometry, and forensic science.

(6 lectures)

Unit 3

Holography
Introduction: Basic principle and theory: recording and reconstruction processes, Requirements of holography- coherence, etc. Types of holograms: The thick or volume hologram, Multiplex hologram, white light reflection hologram; application of holography in microscopy, interferometry, and character recognition.

(6 lectures)

Unit 4

Photonics: Fibre Optics
Optical fibres: Introduction and historical remarks, Total Internal Reflection, Basic characteristics of the optical fibre: Principle of light propagation through a fibre, the coherent bundle, The numerical aperture, Attenuation in optical fibre and attenuation limit; Single mode and multimode fibres, Fibre optic sensors: Fibre Bragg Grating.

(9 lectures)

Practical : 60 Hours
PRACTICALS-SEC LAB: Applied Optics Lab

Sessions on the construction and use of specific measurement instruments and experimental apparatuses used in the 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.

Experiments on Lasers:

a. To determine the grating radial spacing of the Compact Disc (CD) by reflection using He-Ne or solid state laser. b. To find the width of the wire or width of the slit using diffraction pattern obtained by a He-Ne or solid state laser.
c. To find the polarization angle of laser light using polarizer and analyzer d. Thermal expansion of quartz using laser
e. To determine the wavelength and angular spread of laser light by using plane diffraction grating.

Experiments on Semiconductor Sources and Detectors:
a. V-I characteristics of LED
b. Study the characteristics of solid state laser c. Study the characteristics of LDR
d. Characteristics of Photovoltaic Cell/ Photodiode. e. Characteristics of IR sensor

Experiments on Fourier Optics:
a. Optical image addition/subtraction b. Optical image differentiation

c. Fourier optical filtering

d. Construction of an optical 4f system

Experiments on Fourier Transform Spectroscopy

To study the interference pattern from a Michelson interferometer as a function of mirror separation in the interferometer. The resulting interferogram is the Fourier transform of the power spectrum of the source. Analysis of experimental interferograms allows one to determine the transmission characteristics of several interference filters. Computer simulation can also be done.

Experiments on Holography and interferometry:

a. Recording and reconstruction of holograms (Computer simulation can also be done). b. To construct a Michelson interferometer or a Fabry Perot interferometer.

c. To determine the wavelength of sodium light by using Michelson's interferometer.

d. To measure the refractive index of air.

Experiments on Fibre Optics

a. To measure the numerical aperture of an optical fibre

b. To measure the near field intensity profile of a fibre and study its refractive index profile c. To study the variation of the bending loss in a multimode fibre

d. To determine the power loss at a splice between two multimode fibre

e. To determine the mode field diameter (MFD) of fundamental mode in a single-mode fibre by measurements of its far field Gaussian pattern

References

1. LASERS: Fundamentals & applications, K.Thyagrajan & A.K.Ghatak, 2010, Tata McGraw Hill
2. Introduction to Fourier Optics, Joseph W. Goodman, The McGraw- Hill, 1996.
3. Introduction to Fiber Optics, A. Ghatak & K. Thyagarajan, Cambridge University Press.
4. Fibre optics through experiments, M.R.Shenoy, S.K.Khijwania, et.al. 2009, Viva Books
5. Optical Electronics, Ajoy Ghatak and K. Thyagarajan, 2011, Cambridge University Press
6. Optics, Karl Dieter Moller, Learning by computing with model examples, 2007, Springer.
7. Optoelectronic Devices and Systems, S.C. Gupta, 2005, PHI Learning Pvt. Ltd.

SEC: Weather Forecasting (32223909)
Credit:04 (Theory-02, Practical-02)
Theory: 30 Hours
Practical : 60 Hours

Course Objective
The aim of this course is not just to impart theoretical knowledge to the students but to enable them to develop an awareness and understanding regarding the causes and effects of different weather phenomenon and basic forecasting techniques

Course Learning Outcomes

- Acquire basic knowledge of the elements of the atmosphere, its composition at various heights, variation of pressure and temperature with height.
- To learn basic techniques to measure temperature and its relation with cyclones and anti-cyclones.
- Knowledge of simple techniques to measure wind speed and its directions, humidity and rainfall.
- Absorption, emission and scattering of radiations in atmosphere. Radiation laws.
- Knowledge of global wind systems, jet streams, local thunderstorms, tropical cyclones, tornadoes and hurricanes.
- Knowledge of climate and its classification. Understanding various causes of climate change like global warming, air pollution, aerosols, ozone depletion, acid rain.
- Develop skills needed for weather forecasting, mathematical simulations, weather forecasting methods, types of weather forecasting, role of satellite observations in weather forecasting, weather maps etc. Uncertainties in predicting weather based on statistical analysis.
- Develop ability to do weather forecasts using input data.
- In the laboratory course, students should be able to learn: Principle of the working of a weather Station, Study of Synoptic charts and weather reports, Processing and analysis of weather data, Reading of Pressure charts, Surface charts, Wind charts and their analysis.

Teacher may give long duration project based on this paper.

Unit 1

Introduction to atmosphere: Elementary idea of atmosphere: physical structure and composition; compositional layering of the atmosphere; variation of pressure and

temperature with height; air temperature; requirements to measure air temperature; temperature sensors: types; atmospheric pressure: its measurement

(9 Periods)

Unit 2

Measuring the weather: Wind; forces acting to produce wind; wind speed direction: units, its direction; measuring wind speed and direction; humidity, clouds and rainfall, radiation: absorption, emission and scattering in atmosphere; radiation laws.

(4 Periods)

Unit 3

Weather systems: Global wind systems; air masses and fronts: classifications; jet streams; local thunderstorms; tropical cyclones: classification; tornadoes; hurricanes.

(3 Periods)

Unit 4

Climate and Climate Change: Climate: its classification; causes of climate change; global warming and its outcomes; air pollution and its measurement, particulate matters PM 2.5, PM 10. Health hazards due to high concentration of PM2.5; aerosols, ozone depletion

(6 Periods)

Unit 5

Basics of weather forecasting: Weather forecasting: analysis and its historical background; need of measuring weather; types of weather forecasting; weather forecasting methods; criteria of choosing weather station; basics of choosing site and exposure; satellites observations in weather forecasting; weather maps; uncertainty and predictability; probability forecasts.

(8 Periods)

Practical : 60 Hours
PRACTICALS-SEC LAB: Weather Forecasting Lab

Real time demonstration of clouds location and their movements based on short-time animation. Satellite, for instance INSAT-3D products, can be displayed. Water vapour, cloud imagery and 3D overview of wind pattern can be demonstrated. Different wavelength channels (infra-red and visible) operations can be shown to distinguish the features. Profiles of different atmospheric parameters (temperature, humidity, wind component, etc.) can be demonstrated based on radiosonde daily launch.

Demonstrations and Experiments:
1. Study of synoptic charts & weather reports, working principle of weather station.
2. Processing and analysis of weather data:
      (a) To calculate the sunniest time of the year.
      (b) To study the variation of rainfall amount and intensity.
      (c) To observe the sunniest/driest day of the week.
      (d) To examine the maximum and minimum temperature throughout the year.
      (e) To evaluate the relative humidity of the day.
      (f) To examine the rainfall amount month wise.
3. Exercises in chart reading: Plotting of constant pressure charts, surfaces charts, upper wind charts and its analysis.

4. Formats and elements in different types of weather forecasts/ warning (both aviation and non-aviation).
5. Simulation of weather system
6. Field visits to India Meteorological department and National center for medium range weather forecasting

References

1. Aviation Meteorology, I.C. Joshi, 3rd edition 2014, Himalayan Books
2. The weather Observers Hand book, Stephen Burt, 2012, Cambridge University Press.
3. Meteorology, S.R. Ghadekar, 2001, Agromet Publishers, Nagpur.
4. Text Book of Agrometeorology, S.R. Ghadekar, 2005, Agromet Publishers, Nagpur.
5. Atmosphere and Ocean, John G. Harvey, 1995, The Artemis Press.

SEC: Introduction to Physical Computing (xxx1)
Credit:04 (Theory-02, Practical-02)
Theory: 30 Hours
Practical : 60 Hours

Course Objective

Physical computing is an interactive physical system that senses, processes and responds to our analog world. An embedded computer together with sensors and actuators to connect with the physical environment including human interaction, represents a common method of implementing a physical computing system.

Embedded computers have revolutionized our world. Embedded computers are much lower in cost and size and ser a single dedicated function of implementing and improving the function of the gadget. The study of elements of physical computing using embedded computers would be very beneficial towards implementing experimental setup in physics.

Course Learning Outcomes

- Understand the evolution of the CPU from microprocessor to microcontroller and embedded computers from a historical perspective.
- Understand the operation of basic electronic components and analog electronics and digital electronics building blocks including power supply and batteries.
- Be able to use CAD software to create schematic diagrams and printed circuit board layout.
- Understand how to use basic laboratory measurement equipment and instrumentation.
- Understand the Arduino ecosystem and to write simple Arduino programs (called sketches)

- Understand sensor characteristics and how to select a suitable sensor for various applications.
- Be able to read digital and analog data and produce digital and analog outputs from an embedded computer.
- Understand how to interface an embedded computer to the physical environment.
- Be able to visualize the needs of a stand alone embedded computer and to implement a simple system using Arduino.
- Be able to build and test such an embedded physical computing system.

Teacher may give long duration project based on this paper.

Unit 1

Brief overview of a computer. Evolution from CPU to Microprocessor to microcontroller. Introduction to Arduino. Overview of basic electronic components (R, L, C, diode, BJT, Mosfet etc.) and circuits, 555 timer, logic gates, logic function ICs, power supply and batteries.

(4 Lectures)

Unit 2
Capturing schematic diagrams.
   (i) Using free software such as Eagle CAD.
   (ii) Using basic lab instruments – DMM, oscilloscope, signal generator etc.

(6 Lectures)

Unit 3
Understanding Arduino programming. Downloading and installing Arduino IDE.
Writing an Arduino sketch.
Programming fundamentals: program initialization, conditional statements, loops, functions, global variables.

(5 Lectures)

Unit 4

 a) Digital Input and Output
 b) Measuring time and events. Pulse Width Modulation.

(6 Lectures)

Unit 5

a)   Analog Input and Output.
b)   Physical Interface: sensors and actuators.

(6 Lectures)

Unit 6

a)   Communication with the outside world.
b)   System Integration and debugging.

(**3 Lectures)**

Practical : 60 Hours
PRACTICALS-SEC LAB: Introduction to Physical Computing Lab

Sessions on the construction and use of specific equipment and experimental apparatuses used in the physics lab, including necessary precautions.

Sessions on the review of experimental data analysis and its application to the specific experiments done in the lab.

1. Hello LED: Connect a LED to a digital output pin and turn it on and off.
2. Hello Switch: Read a switch a toggle an LED when the switch is pressed and released.
3. Hello ADC: Connect a potentiometer to an ADC input and print the analog voltage on the serial monitor.
4. Hello Blink: Read a switch and changing the LED blink rate every time the switch is pressed and released.
5. Hello PWM: Write a Pulse Width Modulation code in software and vary the LED intensity.
6. Hello Random: Read a switch and every time the switch is pressed and released, generate and print a random number on the serial monitor.
7. Hello Random2: Connect a Seven Segment Display (SSD) and print the random number on this display each time a switch is pressed and released. Collect large data sample and plot relative frequency of occurrence of each 'random' number
8. Hello LCD: Connect a (16X2) LCD to an Arduino and print 'Hello World'.
9. Hello LCD2: Connect a temperature sensor to an ADC input and print the temperature on the LCD
10. Hello PWM2: Connect a RGB LED and 3 switches. Use hardware PWM feature of the Arduino and change the relative intensity of each of the LEDs of the RGB LED and generate large number of colors.

Mini Projects:

1. Connect 2 SSDs and every time a switch is pressed and released, print 2 random numbers on the two SSDs
2. Connect a switch and 4 RGB LEDs in a 'Y' configuration. Change the LED lighting patterns each time a
   (i) switch is pressed and released (total 4095 patterns possible). Arrange acrylic mirrors in a triangle and make a LED kaleidoscope using the RGB LEDs as the light source.
   (ii) Connect a photo-gate mechanism to a bar pendulum. Verify that the period of oscillation is independent of the amplitude for small amplitudes. What happens when the amplitude is large?
   (iii) Connect 8 switches and a small speaker and an audio amplifier and make a piano.
   (iv) Connect 2 sets of 3 switches for two players. Connect LCD and implement a 'rock-paper-scissors' game.

References

1. Learn Electronics with Arduino: An Illustrated Beginner's Guide to Physical Computing. Jody Culkin and Eric Hagan. Shroff Publishers. ISBN: 9789352136704.
2. Programming Arduino: Getting Started with Sketches, Second Edition. Simon Monk. McGraw-Hill Education. ISBN-10: 1259641635.
3. Physical Computing: Sensing and Controlling the Physical World with Computers, 1st Edition. Thomson. ISBN-10: 159200346X.

SEC: Numerical Analysis (xxx2)
Credit:04 (Theory-02, Practical-02)
Theory : 30 Hours
Practical : 60 Hours

Course Objective

- 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.
- 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

Theory:

After completing this course, student will be able to :
- approximate single and multi-variable function by Taylor's Theorem.
- Solve first order differential equations and apply it to physics problems.
- solve linear second order homogeneous and non-homogeneous differential equations with constant coefficients.
- Calculate partial derivatives of function of several variables
- Understand the concept of gradient of scalar field and divergence and curl of vector fields. perform line, surface and volume integration
- Use Green's, Stokes' and Gauss's Theorems to compute integrals

Practical:

After completing this course, student will be able to :
- design, code and test simple programs in C++ learn Monte Carlo techniques,
- fit a given data to linear function using method of least squares find roots of a given non-linear function
- Use above computational techniques to solve physics problems

Teacher may give long duration project based on this paper.

Unit 1

Errors and iterative Methods: Truncation and Round-off Errors. Floating Point Computation, Overflow and underflow. Single and Double Precision Arithmetic, Iterative Methods.

(2 Lectures)

Solutions of Algebraic and Transcendental Equations: (1) Fixed point iteration method, (2) Bisection method, (3) Secant Method, (4) Newton Raphson method, (5) Generalized Newton's method. Comparison and error estimation

(6 Lectures)

Unit 2

Interpolation: Forward and Backward Differences. Symbolic Relation, Differences of a polynomial. Newton's Forward and Backward Interpolation Formulas

(5 Lectures)

Unit 3

Least Square fitting: (1) Fitting a straight line. (2) Non-linear curve fitting: (a) Power function, (b) Polynomial of nth degree, and (c) Exponential Function. (3) Linear Weighed Least square Approximation

(5 Lectures)

Unit 4

Numerical Differentiation: (1) Newton's interpolation Formulas & (2) Cubic Spline Method, Errors in Numeric Differentiation. Maximum and Minimum values of a Tabulated Function

(4 Lectures)

Numerical Integration: Generalized Quadrature Formula. Trapezoidal Rule. Simpson's 1/3 and 3/8 Rules. Weddle's Rule, Gauss-Legendre Formula.

(4 Lectures)

Solution of Ordinary Differential Equations: First Order ODE's: solution of Initial Value problems: (1) Euler's Method, (2) Modified Euler's method

(4 Lectures)

Practical : 60 Hours
PRACTICALS-SEC LAB: Numerical Analysis Lab

Sessions on the review of experimental data analysis and its application to the specific experiments done in the lab.

At least 08 Experiments from the following

Algebraic and transcendental equation:
1. To find the roots of an algebraic equation by Bisection method.
2. To find the roots of an algebraic equation by Secant method.
3. To find the roots of an algebraic equation by Newton-Raphson method.
4. To find the roots of a transcendental equation by Bisection method.

5. 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.
6. 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.
7. 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).
8. 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.
    d. To evaluate a definite integral by Gauss Quadrature rule.
9. Differential Equations
    a. To solve differential equations by Euler's method
    b. To solve differential equations by modified Euler's method

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. A first course in Numerical Methods, U.M. Ascher & C. Greif, 2012, PHI Learning.
4. Schaum's Outline of Programming with C++. J. Hubbard, 2000, McGraw Hill Pub.
5. Numerical Recipes in C++: The Art of Scientific Computing, W.H. Press et.al., 2nd Edn., 2013, Cambridge University Press.
6. An introduction to Numerical methods in C++, Brian H. Flowers, 2009, Oxford University Press.

9.4. Generic Elective-(GE)

GE: Electricity and Magnetism (32225101)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

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

- Demonstrate Gauss law, Coulomb's law for the electric field, and apply it to systems of point charges as well as line, surface, and volume distributions of charges.
- Explain and differentiate the vector (electric fields, Coulomb's law) and scalar (electric potential, electric potential energy) formalisms of electrostatics.
- Apply Gauss's law of electrostatics to solve a variety of problems.
- Articulate knowledge of electric current, resistance and capacitance in terms of electric field and electric potential.
- Demonstrate a working understanding of capacitors
- Calculate the magnetic forces that act on moving charges and the magnetic fields due to currents (Biot- Savart and Ampere laws)
- Have brief idea of dia-, para= and ferro-magnetic materials
- Understand the concepts of induction and self-induction, to solve problems using Faraday's and Lenz's laws
- Have an introduction to Maxwell's equations.

Unit 1

Vector Analysis: Vector algebra (Scalar and Vector product), gradient, divergence, Curl and their significance, Vector Integration, Line, surface and volume integrals of Vector fields, Gauss-divergence theorem and Stoke's theorem of vectors (statement only).

(20 Lectures)

Unit 2

Electrostatics: Electrostatic Field, electric flux, Gauss's theorem of electrostatics. Applications of Gauss theorem- Electric field due to point charge, infinite line of charge, uniformly charged spherical shell and solid sphere, plane charged sheet, charged conductor. Electric potential as line integral of electric field, potential due to a point charge, electric

dipole, uniformly charged spherical shell and solid sphere. Calculation of electric field from potential. Capacitance of an isolated spherical conductor. Parallel plate, spherical and cylindrical condenser. Energy per unit volume in electrostatic field. Dielectric medium, Polarisation, Displacement vector. Gauss's theorem in dielectrics. Parallel plate capacitor completely filled with dielectric.

(22 Lectures)

Unit 3
Magnetism:
Magnetostatics: Biot-Savart's law and its applications- straight conductor, circular coil, solenoid carrying current. Divergence and curl of magnetic field. Magnetic vector potential. Ampere's circuital law.
Magnetic properties of materials: Magnetic intensity, magnetic induction, permeability, magnetic susceptibility. Brief introduction of dia-, para- and ferro-magnetic materials.

(10 Lectures)

Unit 4

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

(6 Lectures)

Introduction to Maxwell`s equations.

(2 Lectures)

Practical : 60 Hours
PRACTICALS-GE LAB: Electricity and Magnetism Lab

Dedicated demonstration cum laboratory sessions on the construction, functioning and uses of different electrical bridge circuits, and electrical devices like the ballistic galvanometer.

Sessions on the review of scientific laboratory report writing, and on experimental data analysis, least square fitting, and computer programme to find slope and intercept of straight line graphs of experimental data.

At least 05 experiments from the following:

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

References for Theory :

1. Vector analysis – Schaum's Outline, M.R. Spiegel, S. Lipschutz, D. Spellman, 2nd Edn., 2009, McGraw- Hill Education.
2. Electricity and Magnetism, Edward M. Purcell, 1986, McGraw-Hill Education.
3. Electricity & Magnetism, J.H. Fewkes & J.Yarwood. Vol. I, 1991, Oxford Univ.Press
4. Electricity and Magnetism, D C Tayal, 1988, Himalaya Publishing House.
5. University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole.
6. D.J. Griffiths, Introduction to Electrodynamics, 3rd Edn, 1998, Benjamin Cummings.

References for Practical:

1. Advanced Practical Physics for students, B.L.Flint & 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 & Ramakrishna, 11th Ed.2011, Kitab Mahal.
4. An Advanced Course in Practical Physics, D. Chattopadhyay & P. C. Rakshit, 2013, New Book Agency (P) Ltd.
5. Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press
6. B.Sc. Practical Physics, H. Singh & P. S. Hemne, 2011, S Chand and Company Ltd
7. B.Sc. Practical Physics, C. L. Arora, 2011, S Chand and Company Ltd.

GE: Mathematical Physics (32225102)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

- 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.
- 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

Theory:

After completing this course, student will

- Learn to plot and interpret graph of the functions using the concepts of calculus.
- Be able to solve first order differential equations and apply it to physical problems.
- Have ability to solve linear second order homogeneous and non-homogeneous differential equations with constant coefficient
- Understand Vector Algebra: scalar and vector product, scalar triple product and their physical significance.
- Understand the concept of vector differentiation: gradient of scalar field, divergence and curl of vector fields. Del and Laplacian Operators
- Learn to find line, surface and volume integration
- Have understanding of Green's, Stokes' and Gauss's theorems to compute integrals.
- Apply curvilinear coordinates to problems with spherical and cylindrical symmetries.
- Understand elementary probability theory and the properties of discrete and continuous distribution functions.

Practical: 60 Hours
PRACTICALS- GE LAB: Mathematical Physics Lab

After completing this course, student will be able to :
- design, code and test simple programs in C++ learn Monte Carlo techniques,
- fit a given data to linear function using method of least squares find roots of a given non-linear function
- Use above computational techniques to solve physics problems

Unit 1

Calculus

Functions: Recapitulate the concept of functions. Plot and interpret graphs of functions using the concepts of calculus.

(2 Lectures)

First Order Differential Equations: First order differential Equations: Variable separable, homogeneous, non-homogeneous, exact and inexact differential equations and Integrating Factor. Application to physics problems.

(5 Lectures)

Second Order Differential equations: Homogeneous Equations with constant coefficients. Wronskian and general solution. Particular Integral with operator method, method of undetermined coefficients and variation method of parameters. Euler differential equation and simultaneous differential equations of First and Second order.

(13 Lectures)

Unit 2
Vector Analysis
Vector Algebra: Properties of vectors. Scalar product and vector product, Scalar triple product and their interpretation in terms of area and volume respectively. Scalar and Vector fields.

(5 lectures)

Vector Differentiation: Directional derivatives and normal derivative. Gradient of a scalar field and its geometrical interpretation. Divergence and curl of a vector field. Del and Laplacian operators. Vector identities.

(8 Lectures)

Vector Integration: Ordinary Integrals of Vectors. Double and Triple integrals, change of order of integration, Jacobian. Notion of infinitesimal line, surface and volume elements. Line, surface and volume integrals of Vector fields. Flux of a vector field. Gauss' divergence theorem, Green's and Stokes Theorems and their verification (no rigorous proofs).

(14 Lectures)

Orthogonal Curvilinear Coordinates: Orthogonal Curvilinear Coordinates. Derivation of Gradient, Divergence, Curl and Laplacian in Cartesian, Spherical and Cylindrical Coordinate Systems.

(6 Lectures)

Unit 3
Probability and statistics:
Independent and dependent event, Conditional Probability. Bayes' Theorem, Independent random variables, Probability distribution functions, special distributions: binomial, Poisson and Normal. Sample mean and variance and their confidence intervals for Normal distribution.

(7 lectures)

Practical: 60 Hours
PRACTICALS-GE LAB: Mathematical Physics Lab

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.

- Highlights the use of computational methods to solve physics problems
- The course will consist of lectures (both theory and practical) in the Lab. The recommended group

size is not more than 15 students.

- Evaluation to be done not on the programming but 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.

Topics	Descriptions with Applications
Introduction and Overview	Computer architecture and organization, memory and Input/output devices,

Basics of scientific computing	Binary and decimal arithmetic, Floating point numbers, single and double precision arithmetic, underflow and overflow - emphasize the importance of making equations in terms of dimensionless variables, Iterative methods
Algorithms and Flow charts	Purpose, symbols and description,
Introduction to C++	Introduction to Programming: Algorithms: Sequence, Selection and Repetition, Structured programming, basic idea of Compilers. Data Types, Enumerated Data, Conversion & 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. 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
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: • To find roots of a quadratic equation if…else And if…else if..else • To find largest of three numbers • To check whether a number is prime or not • To list Prime numbers up to 1000
Random Number generator	Generating pseudo random numbers To find value of pi using Monte Carlo simulations. To integrate using Monte Carlo Method
Arrays and Functions	Sum and average of a list of numbers, largest of a given list of numbers and its location in the list, sorting of numbers in ascending descending order using Bubble sort and Sequential sort, Binary search, 2-dimensional arrays, matrix operations (sum, product, transpose etc)
Solution of Algebraic and Transcendental equations by Bisection, Newton Raphson and Secant methods	Solution of linear and quadratic equation, solving $x = \tan\alpha; I = I_0 \left(\dfrac{\sin\alpha}{\alpha} \right)^2$ in optics, square root of a number.

Data Analysis and Least Square Fitting (Linear case)	Uncertainty, error and precision, mean, standard deviation and error in the mean. Combining uncertainties, Least squares method for fitting data: linear (y=ax+b), power law(y=ax^b) and exponential (y=ae^{bx}). To find parameters a,b and errors in them using method of least squares.Ohms law- calculate R, Hooke's law - Calculate spring constant.
Numerical differentiation (Forward and Backward and central difference formulae – Using basic definition)	Given Position with equidistant time data calculate velocity and acceleration

References for Theory:

1. An introduction to ordinary differential equations, E.A.Coddington, 2009, PHI learning. Differential Equations, George F. Simmons, 2007, McGraw Hill.
2. Advanced Engineering Mathematics,D.G.Zill and W.S.Wright, 5 Ed.,2012,Jones and Bartlett Learning. Mathematical Physics, Goswami, 1st edition, Cengage Learning.
3. Engineering Mathematics, S.Pal and S.C. Bhunia, 2015, Oxford University Press.
4. Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India.
5. Mathematical Physics, A.K. Ghatak, I.C. Goyal and S.J. Chua, Laxmi Publications Private Limited (2017)
6. Vector Analysis: Schaum Outline Series, M. Spiegel, McGraw Hill Education (2017).

References for Practical:

C++ How to Program', Paul J. Deitel and Harvey Deitel, Pearson (2016)
1. 'Schaum's Outline of Programming with C++', J.Hubbard, 2000, McGraw-Hill Education
2. Introduction to Numerical Analysis, S.S. Sastry, 5th Edn., 2012, PHI Learning Pvt. Ltd.
3. An introduction to Numerical methods in C^{++}, Brian H. Flowers, 2009, Oxford University Press.
4. A first course in Numerical Methods, U.M. Ascher & C. Greif, PHI Learning (2012).
5. Computational Physics, Darren Walker, 1st Edn., Scientific International Pvt. Ltd (2015).
6. Applied numerical analysis, Cutis F. Gerald and P.O. Wheatley, Pearson Education, India (2007).

Additional References for Practical

1. 'The C++ Programming Language, Bjarne Stroustrup, Addison-Wesley Professional (2013)
2. Numerical Recipes in C^{++}: The Art of Scientific Computing, W.H. Press et.al., 2ndEdn., Cambridge University Press (2013).
3. An Introduction to Computational Physics, T. Pang, Cambridge University Press (2010).
4. Elementary Numerical Analysis, K.E. Atkinson, 3rd Edn., 2007, Wiley India Edition.

GE: Digital,Analog and Instrumentation
(32225103)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

- This paper aims to cover the basic digital and analog electronic systems. The concept of Boolean algebra is discussed in detail and arithmetic circuits are described.
- Students will learn the physics of semiconductor devices such as p-n junction, rectifier diodes and bipolar junction transistors.
- By the end of the syllabus, students will also have an understanding of operational amplifiers and instrumentation including CRO, power supply etc.

Course Learning Outcomes

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

- To differentiate between Analog and Digital circuits, acquire knowledge of the concepts of binary numbers, their addition, subtraction and conversion into decimal numbers.
- To explains the concepts of logic states and logic gates AND, OR, NOT, NAND, NOR, XOR and XNOR as fundamental, universal and derived gates with its utility.
- To learn how to write logical Boolean statements using the truth table, its simplification using Boolean Algebra, De-Morgan's Theorem and Karnaugh Maps specially the Sum of Products method and realize the corresponding logic circuit.
- To realize addition and subtraction of binary numbers using electronic circuits.
- To introduce the structure and operation of PN junction diodes and Bipolar Junction transistors. Also understand characteristics of different configurations, various current components and related parameters.
- To learn about the DC load line, quiescent point and biasing of voltage divider circuit.
- To analyze CE transistor amplifier using h-parameter model of the transistor.
- To distinguish ideal and practical op-amps and their electrical parameters.
- To understand various operating modes of Op-amps and its linear and non-linear application and acquire skill to design circuits for different OP-amp applications.
- To comprehend the criterion for sustained oscillations and its application in frequency determination for RC
- phase shift oscillator.
- To impart understanding of working of CRO and its usage in measurements of voltage, current, frequency and phase measurement.
- To describe working of rectifier circuits and quantitatively explain effect of capacitance filter, line and load regulation
- To explain the working of timer circuits using IC 555 and use them to develop multivibrators.
- At the successful completion of the laboratory course the student is expected to acquire hands on skills/ knowledge on the following:- Measurement of voltage and frequency

of a periodic waveform using CRO, construct all logic gates using NAND as a building block, synthesize digital circuits and simplify them using Boolean algebra, construct adders/subtractors and binary adders and Adder-Subtractors, design – amplifier using transistor, Op-Amp, Multivibrator using 555 Timer

Unit 1

Digital Circuits:

Difference between Analog and Digital Circuits. Binary Numbers. Decimal to Binary and Binary to Decimal Conversion, AND, OR and NOT Gates. NAND and NOR. Gates as Universal Gates. XOR and XNOR Gates.

(5 Lectures)

De Morgan's Theorems. Boolean Laws. Simplification of Logic Circuit using Boolean Algebra. Fundamental Products. Minterms and Maxterms. Conversion of a Truth Table into an Equivalent Logic Circuit by (1) Sum of Products Method and (2) Karnaugh Map.

(6 Lectures)

Binary Addition. Binary Subtraction using 2's Complement Method). Half Adders andFull Adders and Subtractors, 4-bit binary Adder-Subtractor.

(4 Lectures)

Unit 2

Semiconductor Devices and Amplifiers:

Semiconductor Diodes: P and N type semiconductors. PN junction and its characteristics. Static and dynamic Resistance.

(2 Lectures)

Bipolar Junction transistors: n-p-n and p-n-p Transistors. Characteristics of CB, CE and CC Configurations. Active, Cutoff & Saturation regions. Current gains α and β. Relations between α and β. Load Line analysis of Transistors. DC Load line & Q-point. Voltage Divider Bias Circuit for CE Amplifier. h-parameter Equivalent Circuit of transistor. Analysis of single-stage CE amplifier using hybrid Model. Input and output Impedance. Current and Voltage gains.

(12 Lectures)

Unit 3

Operational Amplifiers (Black Box approach):

Characteristics of an Ideal and Practical Op-Amp (IC 741), Open-loop and closed-loop Gain. CMRR, concept of Virtual ground. Applications of Op-Amps: (1) Inverting and non-inverting Amplifiers, (2) Adder, (3) Subtractor, (4) Differentiator,(5) Integrator, (6) Zero crossing detector.

(14 Lectures)

Sinusoidal Oscillators: Barkhausen's Criterion for Self-sustained Oscillations. Determination of Frequency of RC Phase-shift Oscillator.

(5 Lectures)

Unit 4

Instrumentations:

Introduction to CRO: Block diagram of CRO. Applications of CRO: (1) Study of waveform, (2) Measurement of voltage, current, frequency, and phase difference.

(3 Lectures)

Power Supply: Half-wave Rectifiers. Centre-tapped and Bridge Full-wave Rectifiers Calculation of Ripple Factor and Rectification Efficiency, Basic idea about capacitor filter, Zener Diode and Voltage Regulation.

(6 Lectures)

Timer IC: IC 555 Pin diagram and its application as Astable and Monostable Multivibrator.

(3 Lectures)

Practical : **60 Hours**
PRACTICALS-GE LAB: Digital, Analog and Instrumentation Lab

Session on the construction and use of CRO, and other experimental apparatuses used in the lab, including necessary precautions.

Sessions on the review of experimental data analysis and its application to specific experiments done in the lab.

At least 06 Experiments from the following

1. To measure (a) Voltage, and (b) Frequency of a periodic waveform using CRO
2. To minimize a given (a) logic circuit and (b) Boolean equation.
3. Half adder, Full adder and 4-bit Binary Adder.
4. To design an astable multivibrator of given specifications using 555 Timer.
5. To design a monostable multivibrator of given specifications using 555 Timer.
6. To study IV characteristics of (a) PN diode, (b) Zener diode and (3) LED.
7. To study the characteristics of a Transistor in CE configuration.
8. To design a CE amplifier of given gain (mid-gain) using voltage divider bias.
9. (a) To design an inverting amplifier of given gain using Op-amp 741 and study its frequency response.
   (b) To design a non-inverting amplifier of given gain using Op-amp 741 and study its Frequency Response.
10. To study Differential Amplifier of given I/O specification using Op-amp.
11. To investigate a differentiator made using op-amp.
12. To design a Wien Bridge Oscillator using an op-amp.

References

1.   Integrated Electronics, J. Millman and C.C. Halkias, 1991, Tata Mc-Graw Hill.
2.   Fundamentals of Digital Circuits, Anand Kumar, 4nd Edn, 2018, PHI Learning Pvt. Ltd.
3.   Electronic devices & circuits, S. Salivahanan & N.S. Kumar, 2012, Tata Mc-Graw Hill
4.   Microelectronic Circuits, M.H. Rashid, 2nd Edn., 2011, Cengage Learning.

5. Modern Electronic Instrumentation and Measurement Tech., Helfrick and Cooper,1990, PHI Learning
6. Digital Principles and Applications, A.P.Malvino, D.P.Leach and Saha, 8th Ed., 2018, Tata McGraw Hill Education
7. Microelectronic circuits, A.S. Sedra, K.C. Smith, A.N. Chandorkar, 2014, 6th Edn., Oxford University Press.
8. OP-AMP & Linear Digital Circuits, R.A. Gayakwad, 2000, PHI Learning Pvt. Ltd.
9. Electronic Devices and circuits, B. Kumar, S.B. Jain, 2nd Edition, 2015, PHI Learning Pvt. Ltd.
10. Basic Electronics: A text lab manual, P.B.Zbar, A.P.Malvino, M.A.Miller, 1994, Mc-Graw Hill.
11. Electronics: Fundamentals and Applications, J.D. Ryder, 2004, Prentice Hall.

GE: Applied Dynamics
(32225104)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

Most processes encountered in nature are inherently nonlinear. 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. Specific topics include maps and flows in one and two dimensions, phase portraits, bifurcations, chaos, fractals and elementary fluid dynamics. Students will obtain familiarity with conce and methods in the field of dynamical systems, apply those concepts and methods to analyze dynamic models analytically and computationally, and will learn how to interpret and critically evaluate the results of those analyses. 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. Students will also appreciate the introduction to chaos and fractals. The emphasis of this course is to enhance the understanding of the basics of applied dynamics. By the end of this course, students should be able to solve the seen or unseen problems/numericals in applied dynamics.

Course Learning Outcomes

Upon successful course completion, a student will be able to:

- Demonstrate understanding of the concepts that underlay the study of dynamical systems. Use the analytical and computational methods covered in this course to analyze dynamical systems models.
- Understand fractals as self-similar structures by giving examples from nature and develop mathematical models for simple fractal structures.
- Understand various forms of dynamics and different routes to chaos.
- Analyze the behavior of dynamical systems (e.g. find periodic orbits and assess their stability, draw phase portraits, etc.).
- Understand basic Physics of fluids and its dynamics theoretically and experimentally and by computational simulations: Basic properties of fluids including viscosity, thermal conductivity, mass diffusivity, equation of state. Also, Physics of different types of fluid flow phenomena as well as fluid flow visualizations like streamlines, pathlines and streakline flows.
- Apply the techniques of nonlinear dynamics to physical processes drawn from a variety of scientific and engineering disciplines.
- Analyze uniform and non uniform oscillators (flows on circle)
- Draw phase portraits and interpret them in several applications from biology, physics, chemistry and engineering.

In the Lab course, students will be able to perform Simulations/Lab experiments on: Determination of the coupling Coefficients of Coupled pendulums and other coupled Oscillators, Simulation of Simple Population Models, Experimental growth and Decay, Logistic growth, Species Competition, Predator-Prey Dynamics, Simple genetic circuits, Solve rate equations numerically for some simple chemical reactions, Simulation of Fractal Formation in Deterministic Fractals, Self Similar Fractals and Fractals in nature like Trees, Coastlines and Earthquakes,Simulation of some Fluid Flow Models like Streamlines, Pathlines, and Streakline flows

Unit 1

Introduction to Dynamical systems: Definition of a continuous first order dynamical system. The idea of phase space, flows and trajectories. 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.

(22 Lectures)

Unit 2

Introduction to Chaos and Fractals: Chaos in nonlinear equations - Logistic map and Lorenz equations: Dynamics from time series. Parameter dependence- steady, periodic and chaotic states.Cobweb iteration.Fixed points. Defining chaos- aperiodic, bounded, deterministic and sensitive dependence on initial conditions.

Self-similarity and fractal geometry: Fractals in nature – trees, coastlines, earthquakes, etc. Need for fractal dimension to describe self-similar structure. Deterministic fractal vs. self-similar fractal structure.

(18 Lectures)

Unit 3

Elementary Fluid Dynamics: Importance of fluids: Fluids in the pure sciences, fluids in technology. Study of fluids: Theoretical approach, experimental fluid dynamics, computational 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, other fluid properties and equation of state; Flow phenomena- flow dimensionality, steady and unsteady flows, uniform and non-uniform flows, viscous and inviscid flows, incompressible and compressible flows, laminar and turbulent flows, rotational and irrotational flows, separated and unseparated flows.

(20 Lectures)

Practical :60 Hours
PRACTICALS- GE LAB: APPLIED DYNAMICS

Computing and visualizing trajectories using software such as Scilab, Maple, Octave, XPPAUT based on Applied Dynamics problems like (at least 06 experiments)
1. To determine the coupling coefficient of coupled pendulums.
2. To determine the coupling coefficient of coupled oscillators.
3. To determine the coupling and damping coefficient of damped coupled oscillator.
4. To study population models e.g. exponential growth and decay, logistic growth, predator-prey dynamics.
5. To study rate equations for chemical reactions e.g. auto catalysis, bistability.
6. To study examples from game theory.
7. To study period doubling route to chaos in logistic map.
8. To study various attractors of Lorenz equations.
9. Computational visualization of fractal formations of Deterministic fractal.
10. Computational visualization of fractal formations of self-similar fractal.
11. Computational visualization of fractal formations of Fractals in nature – trees, coastlines, earthquakes.
12. Computational Flow visualization - streamlines, pathlines, Streaklines.

References For Theory:

1. Nonlinear Dynamics and Chaos, S.H. Strogatz, Levant Books, Kolkata, 2007.
2. Understanding Nonlinear Dynamics, Daniel Kaplan and Leon Glass, Springer.
3. Nonlinear Dynamics: Integrability, Chaos and Patterns, M. Lakshmanan and S. Rajasekar, Springer, 2003.
4. An Introduction to Fluid Dynamics, G.K.Batchelor, Cambridge Univ. Press, 2002.
5. Fluid Mechanics, 2nd Edition, L. D. Landau and E. M. Lifshitz, Pergamon Press, Oxford, 1987.

References For Practicals:

1. Nonlinear Dynamics and Chaos, Steven H. Strogatz, Levant Books, Kolkata, 2007
2. Understanding Nonlinear Dynamics, Daniel Kaplan and Leon Glass, Springer.
3. An Introduction to Fluid Dynamics, G.K.Batchelor, Cambridge Univ. Press, 2002
4. Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific and Engi neering Applications: A. Vande Wouwer, P. Saucez, C. V. Fernández. 2014 Springer

GE: Medical Physics (32225105)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

This course introduces a student to the basics of Medical Physics.

Course Learning Outcomes

This course will enable the student to
- Focus on the application of Physics to clinical medicine.
- Gain a broad and fundamental understanding of Physics while developing particular expertise in medical applications.
- Learn about the human body, its anatomy, physiology and BioPhysics, exploring its performance as a physical machine.
- Learn diagnostic and therapeutic applications like the ECG, Radiation Physics, X-ray technology, ultrasound and magnetic resonance imaging.
- Gain knowledge with reference to working of various diagnostic tools, medical imaging techniques
- Understand interaction of ionizing radiation with matter - its effects on living organisms and its uses as a therapeutic technique and also radiation safety practices.
- Imparts functional knowledge regarding need for radiological protection and the sources of an approximate level of radiation exposure for treatment purposes.
- In the laboratory course, the student will be exposed to the workings of various medical devices and getting familiarized with various detectors used in medical imaging, medical diagnostics. The hands-on experience will be very useful for the students from job perspective.

Unit 1

PHYSICS OF THE BODY-I

Basic Anatomical Terminology: Standard Anatomical Position, Planes. Familiarity with terms like- Superior, Inferior, Anterior, Posterior, Medial, Lateral, Proximal and Distal. Mechanics of the body: Skeleton, forces, and body stability. Muscles and dynamics of body movement. Physics of Locomotors Systems: joints and movements, Stability and Equilibrium. Energy household of the body: Energy balance in the body, Energy consumption of the body, Heat losses of the body, Thermal Regulation. Pressure system of body: Physics of breathing, Physics of cardiovascular system. Basics of CPR.

(8 Lectures)

Unit 2

PHYSICS OF THE BODY-II

Acoustics of the body: Nature and characteristics of sound, Production of speech, Physics of the ear, Diagnostics with sound and ultrasound. Optical system of the body: Physics of the eye. Electrical system of the body: Physics of the nervous system, Electrical signals and information transfer.

(10 Lectures)

Unit 3

PHYSICS OF DIAGNOSTIC AND THERAPEUTIC SYSTEMS-I

X-RAYS: Electromagnetic spectrum, production of x-rays, x-ray spectra, Brehmsstrahlung, Characteristic x-ray. X-ray tubes & types: Coolidge tube, x-ray tube design, tube cooling stationary mode, Rotating anode x-ray tube, Tube rating, quality and intensity of x-ray. X-ray generator circuits, half wave and full wave rectification, filament circuit, kilo voltage circuit, types of X-Ray Generator, high frequency generator, exposure timers and switches, HT cables, HT generation.

(7 Lectures)

RADIATION PHYSICS: Radiation units exposure, absorbed dose, units: rad, gray, relative biological effectiveness, effective dose, inverse square law. Interaction of radiation with matter Compton & photoelectric effect, Rem & Sievert, linear attenuation coefficient. Radiation Detectors: Thimble chamber, condenser chambers, Geiger Muller counter, Scintillation counters and Solid State detectors, ionization chamber, Dosimeters, survey methods, area monitors, TLD, Semiconductor detectors.

(7 Lectures)

Unit 4

MEDICAL IMAGING PHYSICS: Evolution of Medical Imaging, X-ray diagnostics and imaging, Physics of nuclear magnetic resonance (NMR), NMR imaging, MRI Radiological imaging, Ultrasound imaging, Physics of Doppler with applications and modes, Vascular Doppler. Radiography: Filters, grids, cassette, X-ray film, film processing, fluoroscopy. Computed tomography scanner- principle & function, display, generations, mammography. Thyroid uptake system and Gamma camera (Only Principle, function and display).

(9 Lectures)

RADIATION ONCOLOGY PHYSICS: External Beam Therapy (Basic Idea): Telecobalt, Conformal Radiation Therapy (CRT), 3DCRT, IMRT, Image Guided Radiotherapy, EPID, Rapid Arc, Proton Therapy, Gamma Knife, Cyber Knife. Contact Beam Therapy (Basic Idea): Brachytherapy-LDR and HDR, Intra Operative Brachytherapy. Radiotherapy, kilo voltage machines, deep therapy machines, Telecobalt machines ,Medical linear accelerator. Basics of Teletherapy units, deep x- ray, Telecobalt units, medical linear accelerator, Radiation protection, external beam characteristics, dose maximum and build up – bolus, percentage depth dose, tissue maximum ratio and tissue phantom ratio, Planned target Volume and Gross Tumour Volume.

(9 Lectures)

Unit 5

RADIATION AND RADIATION PROTECTION: Principles of radiation protection, protective materials-radiation effects , somatic, genetic stochastic and deterministic effect. Personal monitoring devices: TLD film badge , pocket dosimeter, OSL dosimeter. Radiation dosimeter. Natural radioactivity, Biological effects of radiation, Radiation monitors. Steps to reduce radiation to Patient, Staff and Public. Dose Limits for Occupational workers and Public. AERB: Existence and Purpose.

(5 Lectures)

Unit 6

PHYSICS OF DIAGNOSTIC AND THERAPEUTIC SYSTEMS-II

Diagnostic nuclear medicine: Radiopharmaceuticals for radioisotope imaging, Radioisotope imaging equipment, Single photon and positron emission tomography. Therapeutic nuclear medicine: Interaction between radiation and matter Dose andisodose in radiation treatment. Medical Instrumentation: Basic Ideas of Endoscope and Cautery, Sleep Apnea and Cpap Machines, Ventilator and its modes.

(5 Lectures)

Practical : 60 Hours
PRACTICALS- GE LAB: Medical Physics Lab

Sessions on the construction and use of specific measurement instruments and experimental apparatuses used in the lab, including necessary precautions.

Sessions on the review of experimental data analysis and its application to the specific experiments done in the lab.

1. Understanding the working of a manual Hg Blood Pressure monitor, Stethoscope and to measure the Blood Pressure.
2. Basic Process of doing CPR
3. Understanding the working of a manual optical eye-testing machine and to learn eye testing procedure.
4. Correction of Myopia (short sightedness) using a combination of lenses on an optical bench/breadboard.
5. Correction of Hypermetropia/Hyperopia (long sightedness) combination of lenses on an optical bench/breadboard.
6. To learn working of Thermo luminescent dosimeter (TLD) badges and measure the background radiation.
7. Familiarization with Geiger-Muller (GM) Counter & to measure background radiation
8. Familiarization with Radiation meter and to measure background radiation.
9. Familiarization with the Use of a Vascular Doppler.

References

1. Medical Physics, J.R. Cameron and J.G. Skofronick, Wiley (1978)
2. Basic Radiological Physics Dr. K.Thayalan- Jayapee Brothers Medical Publishing Pvt. Ltd. New Delhi (2003)
3. Christensen's Physics of Diagnostic Radiology: Curry, Dowdey and Murry - Lippincot Williams and Wilkins (1990)

4. Physics of the human body, Irving P. Herman, Springer (2007).
5. Physics of Radiation Therapy: F M Khan - Williams and Wilkins, 3 rd edition (2003)
6. The essential physics of Medical Imaging: Bushberg, Seibert, Leidholdt and Boone Lippincot Williams and Wilkins, Second Edition (2002)
7. Handbook of Physics in Diagnostic Imaging: R.S. Livingstone: B.I. Publication Pvt Ltd.

GE: Mechanics (32225201)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

This course begins with the review of Vectors and Differential equations and ends with the Special Theory of Relativity. Students will also appreciate the Gravitation, Rotational Motion and Oscillations. The emphasis of this course is to enhance the basics of mechanics. By the end of this course, students should be able to solve the seen or unseen problems/numericals in vectors, differential equations and mechanics.

Course Learning Outcomes

Upon completion of this course, students are expected to understand the following concepts which would help them to appreciate the application of the fundamental concepts to the analysis of simple, practical situations related to the real world:

- Understand the role of vectors and coordinate systems in Physics.
- Learn to solve Ordinary Differential Equations: First order, Second order Differential Equations with constant coefficients'
- Understand laws of motion and their application to various dynamical situations.
- Learn the concept of Inertial reference frames and Galilean transformations. Also, the concept of conservation of energy, momentum, angular momentum and apply them to basic problems.
- Understand the analogy between translational and rotational dynamics, and application of both motions simultaneously in analyzing rolling with slipping.
- Understand variable mass system and dynamics of a system of particles.
- Able to write the expression for the moment of inertia about the given axis of symmetry for different uniform mass distributions.
- Understand the phenomena of elastic and in-elastic collisions
- Understand angular momentum of a system of particle.
- Apply Kepler's law to describe the motion of planets and satellite in circular orbit through the study of law of Gravitation.

- Understand concept of Geosynchronous orbits
- Explain the phenomenon of simple harmonic motion.
- Understand special theory of relativity - special relativistic effects and their effects on the mass and energy of a moving object.
- In the laboratory course, after acquiring knowledge of how to handle measuring instruments (like screw gauge, vernier callipers, Travelling microscope) student shall embark on verifying various principles learnt in theory. Measuring 'g' using Bar Pendulum, Kater pendulum and measuring elastic constants of materials, viscous properties of liquids etc.

Unit 1

Vectors: Vector algebra. Derivatives of a vector with respect to a parameter. Scalar and vector products of two, three and four vectors. Gradient, divergence and curl of vectors fields. Polar and Axial vectors.

(5 Lectures)

Ordinary Differential Equations:1st order homogeneous differential equations, exact and non-exact differential equations, 2nd order homogeneous and non-homogenous differential equations with constant coefficients (Operator Method Only).

(8 Lectures)

Unit 2

Laws of Motion: Review of Newton's Laws of motion. Dynamics of a system of particles. Concept of Centre of Mass, determination of center of mass for discrete and continuous systems having cylindrical and spherical symmetry (1-D, 2-D, 3-D objects).

(6 Lectures)

Work and Energy: Motion of rocket. Work-Energy theorem for conservative forces. Force as a gradient of Potential Energy. Conservation of momentum and energy. Elastic and in-elastic Collisions.

(5 Lectures)

Unit 3

Rotational Dynamics: 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, 2-D and 3-D). Kinetic energy of rotation. Motion involving both translation and rotation.

(10 Lectures)

Unit 4

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

(5 Lectures)

Unit 5

Oscillations: Simple harmonic motion. Differential equation of SHM and its solutions. Kinetic and Potential Energy, Total Energy and their time averages. Compound pendulum. Differential equations of damped oscillations and its solution.

(7 Lectures)

Unit 6

Special Theory of Relativity: Frames of reference. Gallilean Transformations. Inertial and Non-inertial frames. Outcomes of Michelson Morley's Experiment. Postulates of Special Theory of Relativity. Length contraction. Time dilation. Relativistic transformation of velocity. Relativistic variation of mass. Mass-energy equivalence. Transformation of Energy and Momentum.

(14 Lectures)

Note: Students are not familiar with vector calculus. Hence all examples involve differentiation either in one dimension or with respect to the radial coordinate.

Practical: 60 Hours
PRACTICALS- GE LAB: Mechanics Lab

Demonstration cum laboratory sessions on the construction and use of Vernier callipers, screw gauge and travelling microscope, and necessary precautions during their use.

Sessions and exercises on the least count errors, their propagation and recording in final result up to correct significant digits, linearization of data and the use of slope and intercept to determine unknown quantities.

Session on the writing of scientific laboratory reports, which may include theoretical and practical significance of the experiment performed, apparatus description, relevant theory, necessary precautions to be taken during the experiment, proper recording of observations, data analysis, estimation of the error and explanation of its sources, correct recording of the result of the experiment, and proper referencing of the material taken from other sources (books, websites, research papers, etc.)

At least 05 experiments from the following:

1. Measurements of length (or diameter) using Vernier calliper, screw gauge and travelling microscope.
2. To study the random error in observations.
3. To determine the height of a building using a Sextant.
4. To study the motion of the spring and calculate (a) Spring constant and, (b) g.
5. To determine the Moment of Inertia of a Flywheel.
6. To determine g and velocity for a freely falling body using Digital Timing Technique.
7. To determine Coefficient of Viscosity of water by Capillary Flow Method (Poiseuille's method).
8. To determine the Young's Modulus of a Wire by Optical Lever Method.
9. To determine the Modulus of Rigidity of a Wire by Maxwell's needle.
10. To determine the elastic constants of a wire by Searle's method.
11. To determine the value of g using Bar Pendulum.
12. To determine the value of g using Kater's Pendulum.

References for Theory:

1. University Physics.FW Sears, MW Zemansky & HD Young13/e, 1986.
2. Addison-Wesley Mechanics Berkeley Physics course, vol.1
3. Charles Kittel,et.al. 2007, Tata McGraw-Hill Physics.
4. Resnick, Halliday & Walker 9/e, 2010, Wiley.
5. Engineering Mechanics, Basudeb Bhattacharya, 2nd ed., 2015, Oxford University Press.
6. University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole.

References for Practical:

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, New Delhi.
3. Engineering Practical Physics, S. Panigrahi and B.Mallick, 2015, Cengage Learning India Pvt. Ltd.
4. An Advanced Course in Practical Physics, D. Chattopadhyay & P. C. Rakshit, 2013, New Book Agency (P) Ltd.
5. Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press
6. B.Sc. Practical Physics, H. Singh & P. S. Hemne, 2011, S Chand and Company Ltd
7. B.Sc. Practical Physics, C. L. Arora, 2011, S Chand and Company Ltd.

GE: Elements of Modern Physics (32225202)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

This course introduces modern development in Physics that ushered in relativity and quantum physics which not only revolutionized mankind's understanding of time, space, atomic and sub-atomic structures that make up the matter around us, but also led to fascinating developments in technology that are being witnessed all around us. Beginning with technological marvels like electronics, spectroscopy, semiconductor based devices, IC chips, lasers, harnessing of nuclear energy, satellite communication, atomic clocks, GPS, space travel, scanni tunneling microscope, nano-materials, nano- technology, CCDs, etc. modern physics brought forth useful tools in our daily lives like laptop computers, mobile phones, laser pointers, LEDs, LCD screens, so on and so forth. Therefore, the objective of this course is to teach the physical and mathematical foundations necessary for learning various topics in modern physics. Starting from Planck's law, this course introduces experimental observation of photo-ejection of electrons, ide of wave-particle duality as well as Bohr model of atoms and, then it develops the formulation of Schrodinger equation and the idea of probability interpretation associated with wave-functions. It also introduces basic underlying concepts involved in laser physics as well as that in nuclear physics, so cruci for high energy physics, nuclear technology and astrophysics.

Course Learning Outcomes

After getting exposure to this course, the following topics would be learnt:

- Main aspects of the inadequacies of classical mechanics and understand historical development of quantum mechanics and ability to discuss and interpret experiments that reveal the dual nature of matter.
- The theory of quantum measurements, wave packets and uncertainty principle.
- The central concepts of quantum mechanics: wave functions, momentum and energy operator, the Schrodinger equation, time dependent and time independent cases, probability density and the normalization techniques, skill development on problem solving e.g. one dimensional rigid box, tunneling through potential barrier, step potential, rectangular barrier.
- The properties of nuclei like density, size, binding energy, nuclear forces and structure of atomic nucleus, liquid drop model and nuclear shell model and mass formula.
- To calculate the decay rates and lifetime of radioactive decays like alpha, beta, gamma decay. Neutrinos and its properties and role in theory of beta decay.
- Fission and fusion well as nuclear processes to produce nuclear energy in nuclear reactor and stellar energy in stars.
- The spontaneous and stimulated emission of radiation, optical pumping and population inversion. Three level and four level lasers. Ruby laser and He-Ne laser in details. Basic lasing.
- In the laboratory course, the students will get opportunity to measure

(i) Planck's constant by more than one method, verify photoelectric effect and determination of the work Function of a metal, determine e/m of electron.

(ii) Ionization potential of atoms, wavelength of the emission lines in the spectrum of Hydrogen atom, absorption lines in the rotational spectrum of molecules.

(iii) The wavelength of Laser sources by single and Double slit experiment and the wavelength and angular spread of He-Ne Laser using plane diffraction grating

Unit 1

Planck's quantum, Planck's constant and light as a collection of photons; Blackbody Radiation: 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. Double-slit experiment with electrons. Probability. Wave amplitude and wave functions.

(12 Lectures)

Unit 2

Position measurement : gamma ray microscope thought experiment; Wave-particle duality leading to Heisenberg uncertainty principle; Uncertainty relations involving canonical pair of variables: Derivation from Wave Packets; Impossibility of a particle following a trajectory; Estimating minimum energy of a confined particle using uncertainty principle; Energy-time uncertainty principle: origin of natural width of emission lines as well as estimation of the mass of the virtual particle that mediates a force from the observed range of the force

(7 Lectures)

Unit 3

Two-slit interference experiment with photons, atoms and particles; linear superposition principle as a consequence; Schrodinger equation for non-relativistic particles; Momentum and Energy operators; stationary states; physical interpretation of a wave function, probabilities and normalization; Probability and probability current densities in one dimension.

(10 Lectures)

Unit 4

One dimensional infinitely rigid box : energy eigenvalues, eigenfunctions and their normalization; Quantum dot as an example; Quantum mechanical scattering and tunneling in one dimension : across a step potential & across a rectangular potential barrier. Lasers: Metastable states. Spontaneous and Stimulated emissions. Optical Pumping and Population Inversion.

(14 Lectures)

Unit 5

Size and structure of atomic nucleus and its relation with atomic weight; Impossibility of an electron being in the nucleus as a consequence of the uncertainty principle. Nature of nuclear force, N-Z graph, Liquid Drop model: semi-empirical mass formula and binding energy.

(6 Lectures)

Unit 6

Radioactivity: stability of the nucleus; Law of radioactive decay; Mean life and half-life; Alpha decay; Beta decay: energy released, spectrum and Pauli's prediction of neutrino; Gamma ray emission, energy-momentum conservation: electron-positron pair creation by gamma photons in the vicinity of a nucleus. Fission and fusion: mass deficit, relativity and generation of energy; Fission : nature of fragments and emission of neutrons. Fusion and thermonuclear reactions driving stellar evolution (brief qualitative discussions).

(11 Lectures)

Practical : 60 Hours
PRACTICALS- GE LAB: Elements of Modern Physics Lab

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.

At least 06 experiments from the following:

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 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 H-alpha emission line of Hydrogen atom.
6. To determine the ionization potential of mercury.
7. To determine the absorption lines in the rotational spectrum of Iodine vapour.
8. To determine the value of e/m by (a) Magnetic focusing or (b) Bar magnet.
9. To setup the Millikan oil drop apparatus and determine the charge of an electron.
10. To show the tunneling effect in tunnel diode using I-V characteristics.
11. To determine the wavelength of laser source using diffraction of single slit.
12. To determine the wavelength of laser source using diffraction of double slits.
13. To determine angular spread of He-Ne laser using plane diffraction grating

References for Theory :

1. Concepts of Modern Physics, Arthur Beiser, 2002, McGraw-Hill.
2. Introduction to Modern Physics, Rich Meyer, Kennard, Coop, 2002, Tata McGraw Hill.
3. Physics for scientists and Engineers with Modern Physics, Jewett and Serway, Cengage Learning 2010.
4. Quantum Physics, Berkeley Physics, Vol.4. E.H.Wichman, 1971, Tata McGraw-Hill Co.
5. Theory and Problems of Modern Physics, Schaum`s outline, R. Gautreau and W. Savin, 2nd Edn, Tata McGraw-Hill Publishing Co. Ltd.
6. Modern Physics, G.Kaur and G.R. Pickrell, 2014, McGraw Hill.

References for Practical:

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, I.Prakash & amp; Ramakrishna, 11 th Edn, 2011,Kitab Mahal.
4. An Advanced Course in Practical Physics, D. Chattopadhyay & P. C. Rakshit, 2013, New Book Agency (P) Ltd.
5. Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press
6. B.Sc. Practical Physics, H. Singh & P. S. Hemne, 2011, S Chand and Company Ltd
7. B.Sc. Practical Physics, C. L. Arora, 2011, S Chand and Company Ltd.

Additional Resources:

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. Lectures on Quantum Mechanics: Fundamentals and Applications, eds. A. Pathak and Ajoy Ghatak, Viva Books Pvt. Ltd., 2019
4. Quantum Theory, David Bohm, Dover Publications, 1979
5. Introduction to Quantum Mechanics, David J. Griffith, 2005, Pearson Education.

GE: Solid State Physics (32225203)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

This syllabus begins with introduction to the basic concepts and principles to understand the various properties exhibited by condensed matter, especially solids. These properties depend on the chemical constituents making the particular solid and their arrangement in the crystal. A semi-classical approach is used to introduce various models, from toy model to a higher level, suitable to explain the particular property exhibited by the solid. The syllabus is specifically designed to guide the students to learn how to create a theoretical model for a particular property and appreciate the beauty that lies in these solids through their properties.

Course Learning Outcomes

On successful completion of the module students should be able to

- Elucidate the concept of lattice, crystals and symmetry operations.
- Explain the concepts such as the reciprocal lattice and the Brillouin zone and the dynamics of atoms and electrons in solids.
- Explain diffraction of X-rays by solids to determine the crystal structure.
- Understand the elementary lattice dynamics and its influence on the properties of materials.
- Describe the main features of the physics of electrons in solids.
- Understand the origin of energy bands, and how they influence electronic behavior.
- 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 phase transitions and the preliminary concept and experiments related to superconductivity in solid.
- To 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.

Unit 1

Crystal Structure and Elementary Lattice Dynamics: State of matter: Gas, Liquid, Solid. Solids: Amorphous and Crystalline Materials. Lattice Translation Vectors. Lattice with a Basis. Unit Cell. Types of Lattices. Miller Indices. Reciprocal Lattice. Diffraction of X-rays by Crystals. Bragg's Law. Lattice Vibrations: Linear Monoatomic and Diatomic Chains.

(12 Lectures)

Unit 2

Elementary band theory: Band Gap. Conductors, Semiconductors and insulators. P-and N- type Semiconductors. Conductivity of Semiconductors, mobility, Hall Effect, Hall coefficient.

(10 Lectures)

Unit 3

Magnetic Properties of Matter: Dia-, Para-, Ferri- and Ferro- magnetic materials. Classical Langevin Theory of dia– and Para- magnetic Domains.Curie's law, Weiss's Theory of Ferromagnetism and Ferromagnetic Domains. Discussion of B-H Curve. Hysteresis and Energy Loss.

(12 Lectures)

Unit 4

Dielectric Properties of Materials: Polarization. Local Electric Field at an Atom. Depolarization Field. Electric Susceptibility.Polarizability.Clausius Mossotti Equation. Classical Theory of Electric Polarizability

(8 Lectures)

Unit 5

Applications: Piezoelectric, Pyroelectric, Ferroelectric, Ferromagnetic materials

(3 Lectures)

Unit 6

Superconductivity: Experimental Results. Critical Temperature. Critical magnetic field. Meissner effect. Type I and type II Superconductors.

(5 Lectures)

Practical : 60 Hours
PRACTICALS- GE LAB: Solid State Physics Lab

Sessions on the construction and use of specific measurement instruments and experimental apparatuses used in the solid state 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.
At least 06 experiments from the following:

1. Measurement of susceptibility of paramagnetic solution (Quinck's Tube Method).
2. To measure the Magnetic susceptibility of solids.
3. To determine the Coupling Coefficient of a piezoelectric crystal.
4. To study the dielectric response of materials with frequency.
5. To determine the complex dielectric constant and plasma frequency of a metal using Surface Plasmon Resonance (SPR) technique.
6. To determine the refractive index of a dielectric material using SPR technique.
7. To study the PE Hysteresis loop of a Ferroelectric Crystal.

8. To draw the BH curve of Iron (Fe) using solenoid & determine the energy loss from Hysteresis loop.
9. To measure the resistivity of a semiconductor (Ge) with temperature (up to 150^0C) by four-probe method and determine its band gap.
10. To determine the Hall coefficient of a semiconductor sample.
11. Analysis of X-Ray diffraction data in terms of unit cell parameters and estimation of particle size.
12. Measurement of change in resistance of a semiconductor with magnetic field.

References for Theory:

1. Introduction to Solid State Physics, Charles Kittel, 8th Ed.,2004, Wiley India Pvt. Ltd.
2. Elements of Solid State Physics, J.P. Srivastava, 2nd Ed.,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. Elementary Solid State Physics, M.Ali Omar, 2006, Pearson
6. Solid State Physics, M.A. Wahab, 2011, Narosa Publications.

Reference for Practical:

1. Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.
2. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers
3. Elements of Solid State Physics, J.P. Srivastava, 2nd Ed., 2006, Prentice-Hall of India
4. An Advanced Course in Practical Physics, D. Chattopadhyay & P. C. Rakshit, 2013, New Book Agency (P) Ltd.
5. Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press
6. B.Sc. Practical Physics, H. Singh & P. S. Hemne, 2011, S Chand and Company Ltd
7. B.Sc. Practical Physics, C. L. Arora, 2011, S Chand and Company Ltd.

GE: Embedded System: Introduction to Microcontroller (32225204)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

- In this course, students will learn about the 8051 I/O port programming, various addressing modes.
- Students will have a thorough understanding of Timer and counter programming, Serial port programming with and without interrupt and interfacing 8051 microcontroller to peripherals.

Course Learning Outcomes

This is a course to familiarize/ introduce students to designing and developing embedded systems. It provides the students with an introductory coverage of embedded systems. The learning outcomes of the course are:

- Knowledge of the major components that constitute an embedded system.
- Understand what is a microcontroller, microcomputer embedded system.
- Description of the architecture of a 8051 microcontroller.
- Write simple programs for 8051 microcontroller in C language.
- Understand key concepts of 8051 microcontroller systems like I/O operations, interrupts, programming of timers and counters.
- Interfacing of 8051 microcontroller with peripherals
- Understand and explain concepts and architecture of embedded systems
- Implement small programs to solve well-defined problems on an embedded platform.
- Develop familiarity with tools used to develop an embedded environment
- Learning to use the Arduino Uno (an open source microcontroller board) in simple applications.

Unit 1

Embedded system introduction: Introduction to embedded systems and general purpose computer systems, architecture of embedded system, classifications, applications and purpose of embedded systems, challenges and design issues in embedded systems, operational and non-operational quality attributes of embedded systems, elemental description of embedded processors and microcontrollers.

(4 Lectures)

8051 microcontroller: Introduction and block diagram of 8051 microcontroller, architecture of 8051, overview of 8051 family, 8051 assembly language programming, Program Counter and ROM memory map, Data types and directives, Flag bits and Program Status Word (PSW) register, Jump, loop and call instructions.

(12 Lectures)

Unit 2

8051 I/O port programming: Introduction of I/O port programming, pin out diagram of 8051 microcontroller, I/O port pins description and their functions, I/O port programming in 8051, (Using Assembly Language), I/O programming: Bit manipulation.

(4 Lectures)

Programming of 8051: 8051 addressing modes and accessing memory using various addressing modes, assembly language instructions using each addressing mode, arithmetic & logic instructions, 8051 programming in C:- for time delay and I/O operations and manipulation, for arithmetic & logic operations, for ASCII and BCD conversions.

(12 Lectures)

Unit 3

Timer & counter programming: Programming 8051 timers, counter programming.

(3 Lectures)

Serial port programming with and without interrupt: Introduction to 8051 interrupts, programming timer interrupts, programming external hardware interrupts and serial communication interrupt, interrupt priority in the 8051.

(6 Lectures)

Interfacing 8051 microcontroller to peripherals: Parallel and serial ADC, DAC interfacing, LCD interfacing.

(2 Lectures)

Unit 4

Programming Embedded Systems: Structure of embedded program, infinite loop, compiling, linking and locating, downloading and debugging.

(3 Lectures)

Embedded system design and development: Embedded system development environment, file types generated after cross compilation, disassembler/ decompiler, simulator, emulator and debugging, embedded product development life-cycle, trends in embedded industry.

(8 Lectures)

Unit 5

Introduction to Arduino: Pin diagram and description of Arduino UNO. Basic programming and applications.

(6 Lectures)

Practical :60 Hours
PRACTICALS- GE LAB: Embedded System: Introduction to Microcontroller Lab

Sessions on the use of specific equipment and experimental apparatuses used in the physics lab, including necessary precautions.

Sessions on the review of experimental data analysis and its application to the specific experiments done in the lab.

At least 06 experiments based on 8051 microcontroller from the following:

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 segment 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, some information on LCD display, interfacing a keyboard.

References

1. Embedded Systems: Architecture, Programming & Design, Raj Kamal, 2008, Tata McGraw Hill
2. The 8051 Microcontroller and Embedded Systems Using Assembly and C, M.A.Mazidi, J.G. Mazidi, and R.D. McKinlay, 2nd Ed., 2007, Pearson Education
3. Embedded Systems: Design & applications, S.F. Barrett, 2008, Pearson Education
4. Embedded Microcomputer systems: Real time interfacing, J.W.Valvano 2011, Cengage Learning
5. Embedded Systems & Robots, Subrata Ghoshal, 2009, Cengage Learning
6. Embedded System, B.K. Rao, 2011, PHI Learning Pvt. Ltd.
7. Microprocessors and Microcontrollers, Krishna Kant, 2nd Edition, 2016. PHI learning Pvt. Ltd.

GE: Biological Physics (32225205)
Credit : 06 (Theory-05, Tutorial-01)
Theory : 75 Hours
Tutorial : 15 Hours

Course Objective

- To familiarize the students with the basic facts and ideas of biology from a quantitative perspective.
- To show them how ideas and methods of physics enrich our understanding of biological systems at diverse length and time scales.
- To give them a flavour of the interface between biology, chemistry, physics and mathematics.

Course 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.
- Gain a systems level perspective on organisms and appreciate how networks of interactions of many components give rise to complex behavior.
- Perform mathematical and computational modelling of certain aspects of living systems.
- Acquire mastery of the fundamental principles and applications of various branches of Physics in understanding biological systems.
- Learn relevance of chemistry principles and thermodynamics in understanding energy transfer mechanism and protein folding in 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
- Get exposure to models of evolution.

Unit 1

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. Allometric scaling laws.

(6 Lectures)

Unit 2

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.

(18 Lectures)

Unit 3

Molecular motion in cells:
Random walks and applications to biology: Diffusion; models of macromolecules. Entropic forces: Osmotic pressure; polymer elasticity. Chemical forces: Self assembly of amphiphiles. Molecular motors: Transport along microtubules. Flagellar motion: bacterial chemotaxis.

(22 Lectures)

Unit 4

The complexity of life:
At the level of a cell: The numbers of distinct metabolites, genes and proteins in 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. Brain as an information processing system. At the level of an ecosystem and the biosphere: Foodwebs. Feedback cycles and self- sustaining ecosystems.

(20 Lectures)

Unit 5

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. Examples.

(9 Lectures)

References

1. Biological Physics: Energy, Information, Life; Philip Nelson (W H Freeman &Co, NY, 2004)
2. Physical Biology of the Cell (2nd Edition); Rob Phillips et al (Garland Science, Taylor & Francis Group, London & NY, 2013)
3. An Introduction to Systems Biology; Uri Alon (Chapman and Hall/CRC, Special Indian Edition, 2013)
4. Evolution; M. Ridley (Blackwell Publishers, 2009, 3rd edition)

GE: Waves and Optics (32225310)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

The physics and mathematics of wave motion underlie many important phenomena. The water wave on the sea, the vibration of a violin string, etc. can all be described in a similar way. Light too, often displays properties that are wave-like. The course is aimed at equipping the students with the general treatment of waves. This begins with explaining ideas of oscillations and simple harmonic motion and go on to look at the physics of travelling and standing wav This understanding applies to have a more elaborate analysis for sound waves and this further considers a numb of phenomena in which the wave properties of light are important such as interference, diffraction, and polarization with emphasis of examples as seen in daily life.

Course 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 the importance of classical wave equation in transverse and longitudinal waves and solving a range of physical systems on its basis.
- Understand different types of waves and their velocities: Plane, Spherical, Transverse, Longitudinal.
- Understand Concept of normal modes in transverse and longitudinal waves: their frequencies and configurations
- Understand the concept of temporal and spatial coherence.
- 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's Mirror, Newton's Rings.
- Demonstrate basic concepts of Diffraction: Superposition of wavelets diffracted from apertures
- Understand Fraunhoffer Diffraction from a slit.
- 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, Fresnel Biprism etc. Resolving power of optical equipment can be learnt first hand.

- The motion of coupled oscillators, study of Lissajous figures and behaviour of transverse, longitudinal waves can be learnt in this laboratory course.

Unit 1

Superposition of Two Collinear Harmonic oscillations: Simple harmonic motion (SHM). Linearity and Superposition Principle. (1) Oscillations having equal frequencies and (2) Oscillations having different frequencies (Beats).

(6 Lectures)

Superposition of Two Perpendicular Harmonic Oscillations: Graphical and Analytical Methods. Lissajous Figures (1:1 and 1:2) and their uses.

(2 Lectures)

Unit 2

Waves Motion- General: Transverse waves on a string. Travelling and standing waves on a string. Normal Modes of a string. Group velocity, Phase velocity. Plane waves. Spherical waves, Wave intensity.

(8 Lectures)

Unit 3

Sound: Sound waves, production and properties. Intensity and loudness of sound. Decibels. Intensity levels. General idea of musical notes and musical scale. Acoustics of buildings (General idea).

(6 Lectures)

Unit 4

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

(14 Lectures)

Unit 5

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

(14 Lectures)

Unit 6

Polarization: Transverse nature of light waves. Plane polarized light – production and analysis. Circular and elliptical polarization (General idea).

(7 Lectures)

Practical : 60 Hours
PRACTICALS- GE LAB: Waves and Optics Lab

Dedicated demonstration cum laboratory session on the construction, and use of spectrometer and lasers, and necessary precautions during their use.

Session on experimental data analysis, theory of random errors and the standard error in the mean. Use of error bars in graphs and errors in slope and intercept.

At least 05 experiments from the following:

1. To investigate the motion of coupled oscillators
2. To determine the Frequency of an Electrically Maintained Tuning Fork by Melde's Experiment and to verify $\lambda 2 - T$ Law.
3. To study Lissajous Figures
4. Familiarization with Schuster`s focussing; determination of angle of prism.
5. To determine the Refractive Index of the Material of a Prism using Sodium Light.
6. To determine Dispersive Power of the Material of a Prism using Mercury Light
7. To determine the value of Cauchy Constants.
8. To determine the Resolving Power of a Prism.
9. To determine wavelength of sodium light using Fresnel Biprism.
10. To determine wavelength of sodium light using Newton's Rings.
11. To determine the wavelength of Laser light using Diffraction of Single Slit.
12. To determine wavelength of (1) Sodium and (2) Spectral lines of the Mercury light using plane diffraction Grating.
13. To determine the Resolving Power of a Plane Diffraction Grating. To determine the wavelength of laser light using diffraction grating.

References for Theory :

1. Vibrations and Waves, A.P. French, 1stEd., 2003, CRC press.
2. The Physics of Waves and Oscillations, N.K. Bajaj, 1998, Tata McGraw Hill.
3. OPTICS, (2017), 6th Edition, Ajoy Ghatak, McGraw-Hill Education, New Delhi;
4. Fundamentals of Optics, F.A Jenkins and H.E White, 1976, McGraw-Hill
5. Principles of Optics, B.K. Mathur, 1995, Gopal Printing
6. Fundamentals of Optics, A. Kumar, H.R. Gulati and D.R. Khanna, 2011, R. Chand Publications
7. University Physics. F.W. Sears, M.W. Zemansky and H.D. Young. 13/e, 1986. Addison-Wesley.

References for Practical:

1. Advanced Practical Physics for students, B.L.Flint and H.T.Worsnop, 1971, Asia Publishing House.
2. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann
3. Educational Publishers

4. A Text Book of Practical Physics, Indu Prakash and Ramakrishna, 11th Edition, 2011, Kitab Mahal, New Delhi.
5. An Advanced Course in Practical Physics, D. Chattopadhyay & P. C. Rakshit, 2013, New Book Agency (P) Ltd.
6. Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press
7. B.Sc. Practical Physics, H. Singh & P. S. Hemne, 2011, S Chand and Company Ltd
8. B.Sc. Practical Physics, C. L. Arora, 2011, S Chand and Company Ltd.

GE: Quantum Mechanics (32225311)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

After learning the elements of modern physics, students would be poised to learn more advanced topics like ho to solve the Schrodinger equation for spherically symmetric potentials. Then, in this course, eigenvalues and eigen functions of the Hamiltonian as well as the orbital angular momentum would be studied. Furthermore, application of Schrodinger equation to various quantum mechanical problems would be taken up. The spin angular momentum of electrons would also be introduced in the course. It is recommended that students crediting this course should taken have taken earlier the courses - (1)"Mathematical Physics" and (2) "Elements of Modern Physics" , in order to perform well in this course.

Course Learning Outcomes

The Students will be able to learn the following from this course:

*   Familiarization with quantum mechanics formulation.
*   After an exposition of inadequacies of classical mechanics in explaining microscopic phenomena, quantum theory formulation is introduced through Schrodinger equation.
*   The interpretation of wave function of quantum particle and probabilistic nature of its location and subtler points of quantum phenomena are exposed to the student.
*   Methods to solve time-dependent and time-independent Schrodinger equation
*   Through understanding the behavior of quantum particle encountering a barrier potential, the student gets exposed to solving non-relativistic hydrogen atom, for its spectrum and eigenfunctions.
*   Physics of atomic interactions with electric and magnetic field - Space quantization, electron spin, spin angular momentum, Larmor's theorem, Zeeman effect etc.

- Concept of spectral notations, LS-, JJ- coupling, symmetric & antisymmetric wave functions and Pauli's exclusion principle in in many electron atomic systems
- Application to atomic systems
- In the laboratory course, with the exposure in computational programming in the computer lab, the student will be in a position to solve Schrodinger equation for ground state energy and wave functions of various simple quantum mechanical one-dimensional and three dimensional potentials.

Unit 1

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

(12 Lectures)

Unit 2

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

(12 Lectures)

Unit 3

General discussion of bound states in an arbitrary potential: continuity of wave function, boundary condition and emergence of discrete energy levels; application to one-dimensional problem-square well potential; Quantum mechanics of simple harmonic oscillator: energy levels and energy eigenfunctions using Frobenius method; Hermite polynomials; ground state, zero point energy & uncertainty principle.

(10 Lectures)

Unit 4

Quantum theory of hydrogen-like atoms: time independent Schrodinger equation in spherical polar coordinates; separation of variables for second order partial differential equation; angular momentum operator & quantum numbers; Radial wavefunctions from Frobenius method; shapes of the probability densities for ground and first excited states; Orbital angular momentum quantum numbers l and m; s, p, d shells.

(10 Lectures)

Unit 5

Atoms in Electric and Magnetic Fields: Electron angular momentum. Angular momentum quantization. Electron Spin and Spin Angular Momentum. Larmor's Theorem. Spin Magnetic Moment. Stern-Gerlach Experiment. Normal Zeeman Effect: Electron Magnetic Moment and Magnetic Energy.

Unit 6

Many electron atoms: Pauli's Exclusion Principle. Symmetric and Anti-symmetric Wave Functions. Spin orbit coupling. Spectral Notations for Atomic States. Total angular momentum. Spin-orbit coupling in atoms-L-S and J-J couplings.

(8 Lectures)

Practical : 60 Hours
PRACTICALS- GE LAB: Quantum Mechanics Lab

Use C/C ++ /Scilab for solving the following problems based on Quantum Mechanics like:

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

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

where m is the reduced mass of the electron. Obtain the energy eigenvalues and plot the corresponding wavefunctions. Remember that the ground state energy of the hydrogen atom is $\approx$ -13.6 eV. Take e = 3.795 (eVÅ)$^{1/2}$, ℏc = 1973 (eVÅ) and m = 0.511x10^6 eV/c^2.

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

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

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

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

Find the energy (in eV) of the ground state of the atom to an accuracy of three significant digits. Also, plot the corresponding wavefunction. Take e = 3.795 (eVÅ)$^{1/2}$, m = 0.511x10^6 eV/c^2, and a = 3 Å, 5 Å, 7 Å. In these units ℏc = 1973 (eVÅ). The ground state energy is expected to be above -12 eV in all three cases.

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

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

For the anharmonic oscillator potential

$$V(r) = \frac{1}{2} k r^2 + \frac{1}{3} b r^3$$

for the ground state energy (in MeV) of particle to an accuracy of three significant digits. Also, plot the corresponding wave function. Choose m = 940 MeV/c^2, k = 100 MeV fm^{-2},

b = 0, 10, 30 MeV fm^{-3}. In these units, c$\hbar$ = 197.3 MeV fm. The ground state energy is expected to lie between 90 and 110 MeV for all three cases.

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

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

Where μ is the reduced mass of the two-atom system for the Morse potential

$$V(r) = D\left(e^{-2ar'} - e^{-ar'}\right), r' = \frac{r - r_0}{r}$$

Find the lowest vibrational energy (in MeV) of the molecule to an accuracy of three significant digits. Also plot the corresponding wave function.
Take: m = 940x10^6 eV/c^2, D = 0.755501 eV, α = 1.44, r_0 = 0.131349 Å

Where μ is the reduced mass of the two-atom system for the Morse potential

Find the lowest vibrational energy (in MeV) of the molecule to an accuracy of three significant digits. Also plot the corresponding wave function.
Take: m = 940x10^6 eV/c^2, D = 0.755501 eV, α = 1.44, r_o = 0.131349 Å

Additional laboratory based experiments: (optional)

5. Study of Electron spin resonance- determine magnetic field as a function of the resonance frequency
6. Study of Zeeman effect: with external magnetic field; Hyperfine splitting

References

1. Modern Quantum Mechanics, J.J Sakurai, Revised Edition, 1994, Addision-Wesley.
2. Introduction to Quantum Mechanics, David J. Griffiths, Second Edition, 2006, Pearson Education.
3. QUANTUM MECHANICS: Theory and Applications, (2019), (Extensively revised 6th Edition), Ajoy Ghatak and S. Lokanathan, Laxmi Publications, New Delhi.
4. Quantum Mechanic Concepts and Applications, Nouredine Zettili, Second Edition 2001, John Wiley & Sons, Ltd.
5. Introduction to Quantum Mechanics, Volume-I, C. Cohen-Tannoudgi, B. Diu, F. Laloe, 1977, Wiley-VCH.

Reference Books for the practicals:

1. Schaum & Outline of Programming with C++. J.Hubbard, 2000, McGraw-Hill Pub.
2. Numerical Recipes in C: The Art of Scientific Computing, W.H. Press et.al., 3 rd Edn., 2007, Cambridge University Press.
3. A Guide to MATLAB, B.R. Hunt, R.L. Lipsman, J.M. Rosenberg, 2014, 3 rd Edn., 122 Cambridge University Press
4. Elementary Numerical Analysis, K.E. Atkinson, 3 rd Ed. 2007,Wiley India Edition

5. Simulation of ODE/PDE Models with MATLAB®, OCTAVE and SCILAB: Scientific & Engineering Applications: A.V. Wouwer, P. Saucez, C.V. Fernández.2014 Springer
6. Quantum Mechanics, Leonard I. Schiff, 3 rd Edn. 2010, Tata McGraw Hill.
7. A Text book of Quantum Mechanics, P.M.Mathews& K.Venkatesan, 2nd Ed., 2010, McGraw Hill.
8. Quantum Mechanics, Brian H. Bransden and C. Charles Jean Joachain, 2000, Prentice Hall.

Additional Resources:

1. Lectures on Quantum Mechanics: Fundamentals and Applications, eds. A. Pathak and Ajoy Ghatak, Viva Books Pvt. Ltd., 2019
2. Introduction to Quantum Mechanics, R. H. Dicke and J. P. Wittke, Addison-Wesley Publications, 1966.

GE: Communication System (32225312)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

- 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 and mobile telephony system are introduced.

Course 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 analyze 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.
- They will study the concept of Mobile radio propagation, cellular system design and understand mobile technologies like GSM and CDMA.
- Students will understand evolution of mobile communication generations 2G, 3G, and 4G with their characteristics and limitations.
- This paper will essentially connect the text book knowledge with the most popular communication technology in real world.
- Students will apply the theory that they have learned in the theory class to gain hands on experience in building modulation and demodulation circuits; Transmitters and Receivers for AM and FM. Also to construct TDM, PAM, PWM, PPM and ASK, PSK and FSK modulator and verify their results.

Unit 1

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.

(4 Lectures)

Analog Modulation: Amplitude Modulation, modulation index and frequency spectrum. Generation of AM (Emitter Modulation), Amplitude Demodulation (diode detector), Single Sideband (SSB) systems, advantages of SSB transmission, Concept of Single side band generation and detection. Frequency Modulation (FM) and Phase Modulation (PM), modulation index and frequency spectrum, equivalence between FM and PM, Generation of FM using VCO, FM detector (slope detector), Qualitative idea of Super heterodyne receiver.

(12 Lectures)

Unit 2

Analog Pulse Modulation: Channel capacity, Sampling theorem, Basic Principles- PAM, PWM, PPM, modulation and detection technique for PAM only, Multiplexing (time division multiplexing and frequency division multiplexing).

(9 Lectures)

Unit 3

Digital Pulse Modulation: Need for digital transmission, Pulse Code Modulation, Digital Carrier Modulation Techniques, Sampling, Quantization and Encoding. Concept of Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK), Phase Shift Keying (PSK), and Binary Phase Shift Keying (BPSK).

(10 Lectures)

Unit 4

Satellite Communication– Introduction, need, 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 earth station.

(10 Lectures)

Unit 5

Mobile Telephony System– Basic concept of mobile communication, frequency bands used in mobile communication, concept of cell sectoring and cell splitting, SIM number, IMEI number, need for data encryption, architecture (block diagram) of mobile communication network, idea of GSM, CDMA, TDMA and FDMA technologies, simplified block diagram of mobile phone handset, 2G, 3G and 4G concepts (qualitative only). GPS navigation system (qualitative idea only)

(15 Lectures)

Practical: 60 Hours

PRACTICALS- GE LAB: Communication System Lab

Session on the construction and use of CRO, and other experimental apparatuses used in the lab, including necessary precautions.

Sessions on the review of experimental data analysis and its application to specific experiments done in the lab.

At least 05 experiments from the following

1. To design an Amplitude Modulator using Transistor
2. To study envelope detector for demodulation of AM signal
3. To study FM - Generator and Detector circuit
4. To study AM Transmitter and Receiver
5. To study FM Transmitter and Receiver
    (i) To study Time Division Multiplexing (TDM)
    (ii) To study Pulse Amplitude Modulation (PAM)
    (iii) To study Pulse Width Modulation (PWM)
    (iv) To study Pulse Position Modulation (PPM)
    (v) To study ASK, PSK and FSK modulators

References

1. Electronic Communications, D. Roddy and J. Coolen, Pearson Education India.
2. Advanced Electronics Communication Systems- Tomasi, 6th Edn.Prentice Hall.
3. Modern Digital and Analog Communication Systems, B.P. Lathi, 4th Edition, 2011, Oxford University Press.
4. Electronic Communication systems, G. Kennedy, 3rd Edn., 1999, Tata McGraw Hill.
5. Principles of Electronic communication systems – Frenzel, 3rd edition, McGraw Hill
6. Communication Systems, S. Haykin, 2006, Wiley India
7. Electronic Communication system, Blake, Cengage, 5th edition.
8. Wireless communications, Andrea Goldsmith, 2015, Cambridge University Press
9. Introduction to Communication systems, U. Madhow, 1st Edition, 2018, Cambridge University Press

GE: Verilog and FPGA based system design (32225313)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

- This paper provides a review of combinational and sequential circuits such as multiplexers, demultiplexers, decoders, encoders and adder circuits.
- Evolution of Programmable logic devices such as PAL, PLA and GAL is explained.
- At the end of the syllabus, students will be able to understand the modeling of combinational and sequential circuits (including FSM and FSMD) with Verilog Design.

Course Learning Outcomes

This paper discusses the fundamental Verilog concepts in-lieu of today's most advanced digital design techniques. At the end of this course, students will be able to develop following learning outcomes:

- Understand the steps and processes for design of logic circuits and systems.
- Be able to differentiate between combinational and sequential circuits.
- Be able to design various types of state machines.
- Be able to partition a complex logic system into elements of data-path and control path.
- Understand various types of programmable logic building blocks such as CPLDs and FPGAs and their tradeoffs.
- Be able to write synthesizable Verilog code.
- Be able to write a Verilog test bench to test various Verilog code modules.

- Be able to design, program and test logic systems on a programmable logic device (CPLD or FPGA) using Verilog.

Unit 1

Digital logic design flow. Review of combinational circuits. Combinational building blocks: multiplexors, demultiplexers, decoders, encoders and adder circuits. Review of sequential circuit elements: flip-flop, latch and register. Finite state machines: Mealy and Moore. Other sequential circuits: shift registers and counters. FSMD (Finite State Machine with Datapath): design and analysis. Microprogrammed control. Memory basics and timing. Programmable Logic devices.

(**20 Lectures**)

Unit 2

Evolution of Programmable logic devices. PAL, PLA and GAL. CPLD and FPGA architectures. Placement and routing. Logic cell structure, Programmable interconnects, Logic blocks and I/O Ports. Clock distribution in FPGA. Timing issues in FPGA design. Boundary scan.

(**20 Lectures**)

Unit 3

Verilog HDL: Introduction to HDL. Verilog primitive operators and structural Verilog Behavioral Verilog. Design verification. Modeling of combinational and sequential circuits (including FSM and FSMD) with Verilog Design examples in Verilog.

(**20 lectures**)

Practical: 60 Hours

PRACTICALS- GE LAB: Verilog and FPGA based System Design Lab

Session on the construction and use of experimental apparatuses used in the lab, including necessary precautions.

Sessions on the review of experimental data analysis and its application to specific experiments done in the lab

At least 08 experiments from following.

1. Write code to realize basic and derived logic gates.
2. Half adder, Full Adder using basic and derived gates.
3. Half subtractor and Full Subtractor using basic and derived gates.
4. Design and simulation of a 4 bit Adder.
5. Multiplexer (4x1) and Demultiplexer using logic gates.
6. Decoder and Encoder using logic gates.
   (i)   Clocked D, JK and T Flip flops (with Reset inputs)
   (ii) 3-bit Ripple counter
   (iii) To design and study switching circuits (LED blink shift)
   (iv) To design traffic light controller.
   (v)   To interface a keyboard
   (vi) To interface a LCD using FPGA
   (vii) To interface multiplexed seven segment display.

(viii) To interface a stepper motor and DC motor.

(ix) To interface ADC 0804.

References

1. Lizy Kurien and Charles Roth. Principles of Digital Systems Design and VHDL.Cengage Publishing. ISBN-13: 978-8131505748
2. Palnitkar, Samir, Verilog HDL. Pearson Education; Second edition (2003).
3. Ming-Bo Lin. Digital System Designs and Practices: Using Verilog HDL and FPGAs. Wiley India Pvt Ltd. ISBN-13: 978-8126536948
4. Zainalabedin Navabi. Verilog Digital System Design. TMH; 2nd edition.ISBN-13: 978-0070252219
5. Wayne Wolf. FPGA Based System Design. Pearson Education.
6. S. K. Mitra, Digital Signal processing, McGraw Hill, 1998
7. VLSI design, Debaprasad Das, 2nd Edition, 2015, Oxford University Press.
8. D.J. Laja and S. Sapatnekar, Designing Digital Computer Systems with Verilog, Cambridge University Press, 2015.
9. U. Meyer Baese, Digital Signal Processing with FPGAs, Springer, 2004
10. Verilog HDL primer- J. Bhasker. BSP, 2003 II edition

GE: Nano Materials and Applications (32225314)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

This course introduces briefly the basic concepts of Quantum Mechanics, essential for this course. Schrodinger wave equation and its applications to simple problems are discussed. The concepts were then used to understand the idea of quantum confinement which is central to the understanding of the optical properties and electron transport phenomenon in nanostructures. Synthesis, characterization and applications of nanomaterials are discussed.

The main prerequisite is an introductory course in Solid State Physics and Quantum Mechanics.

Course Learning Outcomes

On successful completion of the module students should be able to

- Explain the difference between nanomaterials and bulk materials and their properties.
- 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 various characterization tools required to study the structural, optical and electrical properties of nanomaterials.
- Analyze the data obtained from the various characterization techniques.
- 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.
- Explain the Interger Quantum Hall Effect and the concept of Landau Levels, and edge states in 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.
- Explain why nanomaterials exhibit properties which are sometimes very opposite, like magnetic, to their bulk counterparts.

Unit 1

Brief Historical achievements: Use of nanoparticle by artisans or craftsman's in glass wares, pottery etc. Introduction to naturally occurring nanoparticles/nanostructures (explore the surroundings). Discussion on Michael Faraday's experiment with the gold films.

Discussion on the visionary articles: (1) There's Plenty of Room at the Bottom: An Invitation to Enter a New Field of Physics by Prof. Richard P. Feynman, (2) Room at the Bottom, Plenty of Tyranny at the Top by Prof. Karl Hess.

(8 Lectures)

Unit 2

Basic Quantum Mechanics: Idea about particles as wave, electron interference experiment, superposition principle, position (or amplitude), and momentum. Wave-particle duality, uncertainty principle, energy quantization, Schrodinger equation. Applications of Schrodinger equation (**qualitative**): The free particle, potential step, rectangular potential barrier and the tunnel effect, free and bound states of a particle in square well potential, particle in a box (3D) problem.

(10 Lectures)

Unit 3

Basic Introduction to solids and Nanoscale Systems: Classification of solids into crystalline and amorphous materials, classification based on conductivity (range of values) as metals, semiconductors and insulators, idea of bandgap and its consequences on optical and electrical properties, electrons as free particles for current conduction (I = nevA), introduce bulk (3D) and nanomaterials {thin films (2D), nanowires (1D) nanodots or quantum dots (0D)} with an example of the colour of say Gold metals and its nanoparticles. Bulk materials Density of states function and its implication on electrical properties, Band structure and density of states function for nanoscale materials (Quantitative for 2D, 1D, 0D), Applications of quantum confinement of carriers in 3D, 2D, 1D nanostructures and its consequences on electronic and optical properties.
(DOS function can be introduced through the population census survey, the plot of no. of persons (in millions) vs age)

(17 Lectures)

Unit 4

Synthesis and Characterization (Qualitative): Top down and Bottom up approach, Photolithography. Ball milling. Spin coating, Vacuum deposition: Physical vapor deposition (PVD): Thermal evaporation, Sputtering, Pulsed Laser Deposition (PLD), electric arc deposition for CNT, C_{60}, grapheme, Chemical vapor deposition (CVD). Preparation through colloidal methods (Metals, Metal Oxide nanoparticles), MBE growth of quantum dots. **Structure and Surface morphology:** X-Ray Diffraction (XRD). Scanning Electron Microscopy (SEM), Scanning Tunnel Microscopy (STM) (must discuss Quantum Corral). Transmission Electron Microscopy (TEM). **Spectroscopy:** UV-Vis spectroscopy. (Emphasis should be on to discuss data and plots gathered from these techniques)

(10 Lectures)

Unit 5

Optical and Electron Transport Properties: Bandgap tuning as a function of particle size (discuss results of oxide and metal nanoparticles) Radiative processes: General formalization-absorption, emission and luminescence. Defects and impurities. Idea about time and length scale, diffusive and ballistic transport of electrons in nanostrcutures, Discuss interesting experiments (no derivations) (1) Charging effect, Coulomb blockade effect (2) Single electron device.

Unit 6

Applications (Qualitative): based on optical, electrical and magnetic properties of nanoparticles, nanowires and thin films in electronic industry, medical industry, beauty products, Micro Electromechanical Systems (MEMS).

(5 Lectures)

Practical: 60 Hours
PRACTICALS- GE LAB: Nano Materials and Applications Lab

Sessions on the construction and use of specific measurement instruments and experimental apparatuses used in the nano physics lab, including necessary precautions.

Sessions on the review of experimental data analysis and its application to the specific experiments done in the lab.

At least 06 experiments from the following:

1. Synthesis of metal (Au/Ag) nanoparticles by chemical route and study/observe its optical absorption properties.
2. Synthesis of semiconductor (CdS/ZnO/TiO2/Fe2O3etc) nanoparticles and study/observe its optical absorption properties.
3. Study the XRD pattern of nanoparticles and estimation the particle size.
4. Surface Plasmon study of metal nanoparticles by UV-Visible spectrophotometer.
5. To study/observe the effect of size on color of nanomaterials.
6. To prepare composite of CNTs with other materials.
7. Growth of quantum dots by thermal evaporation.
8. Prepare a disc of ceramic of a compound and study its XRD.
9. Fabricate a thin film of nanoparticles by spin coating (or chemical route) and study its XRD and UV-Visible spectra.
10. Prepare a thin film capacitor and measure capacitance as a function of temperature or frequency.
11. Fabricate a PN diode by diffusing Al over the surface of N-type Si/Ge and study its V-I characteristic.

Reference For Theory:

1. Solid State Physics, M. A. Wahab, 2011, Narosa Publications
2. Solid State Physics by J. R. Hall and H. E. Hall, 2nd edition (2014) Wiley
3. Quantum Mechanics by S. P. Singh, M. K. Bagde and K. Singh, S. Chand and Company Ltd.
4. Introduction to Nanoelectronics, V.V. Mitin, V.A. Kochelap and M.A. Stroscio, 2011, Cambridge University Press.
5. C.P. Poole, Jr. Frank J. Owens, Introduction to Nanotechnology 1st edition (2003) Wiley India Pvt. Ltd.
6. S.K. Kulkarni, Nanotechnology: Principles & Practices 2nd edition (2011) (Capital Publishing Company)

7. K.K. Chattopadhyay and A. N. Banerjee, Introduction to Nanoscience and Technology (2009) (PHI Learning Private Limited).
8. Electronic transport in mesoscopic systems by SupriyoDatta (1997) Cambridge University Press.
9. Electronic transport in mesoscopic systems by SupriyoDatta (1997) Cambridge University Press.
10. Fundamentals of molecular spectroscopy by C. N. Banwell and E. M. McCASH, 4th edition, McGraw Hill.

Reference for Practical:

1. C.P. Poole, Jr. Frank J. Owens, Introduction to Nanotechnology 1st edition (2003) Wiley India Pvt.Ltd.
2. S.K. Kulkarni, Nanotechnology: Principles & Practices 2nd edition (2011) (Capital Publishing Company).
3. K.K. Chattopadhyay and A. N. Banerjee, Introduction to Nanoscience and Technology (2009) (PHI Learning Private Limited).
4. Richard Booker, Earl Boysen, Nanotechnology for Dummies (2005) (Wiley Publishing Inc.).

Additional Resources:

1. Quantum Transport in semiconductor nanostructures by Carla Beenakker and HenK Van Houten (1991) (available at arXiv: cond-mat/0412664) open source
2. Sara cronewett Ph.D. thesis (2001).

GE: Thermal Physics and Statistical Mechanics (32225415)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

This course will introduce Thermodynamics, Kinetic theory of gases and Statistical Mechanics to the students. Th primary goal is to understand the fundamental laws of thermodynamics and it's applications to various thermo dynamical systems and processes. This coursework will also enable the students to understand the connection between the macroscopic observations of physical systems and microscopic behaviour of atoms and molecule through statistical mechanics.

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

- Learn 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, equipartition of energies, mean free path of molecular collisions, viscosity, thermal conductivity, diffusion and Brownian motion.
- Learn about the black body radiations, Stefan- Boltzmann's law, Rayleigh-Jean's law and Planck's law and their significances.
- Learn the 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 co-efficient of resistance, study variation of thermo emf across two junctions of a thermocouple with temperature etc

Unit 1

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

(22 lectures)

Unit 2

Thermodynamical Potentials: Enthalpy, Gibbs, Helmholtz and Internal Energy functions, Maxwell"s relations and applications - Joule-Thomson Effect, Clausius Clapeyron Equation, Expression for $(C_P - C_V)$, C_P/C_V, TdS equations.

(10 lectures)

Unit 3

Kinetic Theory of Gases: Derivation of Maxwell's law of distribution of velocities and its experimental verification, Mean free path (Zeroth Order), Transport Phenomena: Viscosity, Conduction and Diffusion (for vertical case), Law of equipartition of energy (no derivation) and its applications to specific heat of gases.

(10 lectures)

Unit 4

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

(6 lectures)

Unit 5

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.

(12 lectures)

Practical : 60 Hours
PRACTICALS- GE LAB: Thermal Physics and Statistical Mechanics Lab

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.

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.
6. To determine the temperature co-efficient of resistance by Platinum resistance thermometer.
7. To study the variation of thermo emf across two junctions of a thermocouple with temperature.

References for Theory:

1. Thermal Physics, S. Garg, R. Bansal and C. Ghosh, 1993, Tata McGraw-Hill.
2. A Treatise on Heat, Meghnad Saha, and B.N. Srivastava, 1969, Indian Press.
3. Heat and Thermodynamics, M.W.Zemasky and R. Dittman, 1981, McGraw Hill
4. Thermodynamics, Kinetic theory & Statistical thermodynamics, F.W.Sears and G.L.Salinger. 1988, Narosa.
5. Thermal Physics, A. Kumar and S.P. Taneja, 2014, R. Chand Publications.

References for Practicals:

1. Advanced Practical Physics for students, B.L.Flint & H.T.Worsnop, 1971, Asia Publishing House.
2. A Text Book of Practical Physics, Indu Prakash and Ramakrishna, 11thEdition, 2011, Kitab Mahal, New Delhi.
3. A Laboratory Manual of Physics for Undergraduate Classes, D.P. Khandelwal, 1985, Vani Publication.
4. An Advanced Course in Practical Physics, D. Chattopadhyay & P. C. Rakshit, 2013, New Book Agency (P) Ltd.
5. Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press
6. B.Sc. Practical Physics, H. Singh & P. S. Hemne, 2011, S Chand and Company Ltd
7. B.Sc. Practical Physics, C. L. Arora, 2011, S Chand and Company Ltd.

GE: Digital Signal Processing (32225416)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

- This paper describes the discrete-time signals and systems, Fourier Transform Representation of Aperiodic Discrete-Time Signals.
- This paper also highlights the concept of filters and realization of Digital Filters.
- At the end of the syllabus, students will develop the understanding of Discrete and fast Fourier Transform.

Course Learning Outcomes

In this course, students will be able to develop a thorough understanding of the central elements of discrete time signal processing theory and correlate this theory with the real-world signal processing applications. At the end of this course, students will be able to develop following learning outcomes:

- Students will learn basic discrete-time signal and system types, convolution sum, impulse and frequency response concepts for linear time-invariant (LTI) systems.
- The student will be in position to understand use of different transforms and analyze the discrete time signals and systems. They will learn to analyze a digital system using z-transforms and discrete time Fourier transforms, region of convergence concepts, their properties and perform simple transform calculations,.
- The student will realize the use of LTI filters for filtering different real world signals. The concept of transfer function and difference-Equation System will be introduced. Also, they will learn to solve Difference Equations.
- Students will develop an ability to analyze DSP systems like linear-phase, FIR, IIR, All-pass, averaging and notch Filter etc.
- Students will be able to understand the discrete Fourier transform (DFT) and realize its implementation using FFT techniques.
- Students will be able to learn the realization of digital filters, their structures, along with their advantages and disadvantages. They will be able to design and understand different types of digital filters such as finite & infinite impulse response filters for various applications.

Unit 1

Discrete-Time Signals and Systems: Classification of Signals, Transformations of the Independent Variable, Periodic and Aperiodic Signals, Energy and Power Signals, Even and Odd Signals, Discrete-Time Systems, System Properties. Impulse Response, Convolution Sum; Graphical Method; Analytical Method, Properties of Convolution; Commutative; Associative; Distributive; Shift; Sum Property System Response to Periodic Inputs, Relationship Between LTI System Properties and the Impulse Response; Causality; Stability; Invertibility, Unit Step Response.

Unit 2

Discrete-Time Fourier Transform: Fourier Transform Representation of Aperiodic Discrete-Time Signals, Periodicity of DTFT, Properties; Linearity; Time Shifting; Frequency Shifting; Differencing in Time Domain; Differentiation in Frequency Domain; Convolution Property.
The z-Transform: Bilateral (Two-Sided) z-Transform, Inverse z-Transform, Relationship Between z-Transform and Discrete-Time Fourier Transform, z-plane, Region-of-Convergence; Properties of ROC, Properties; Time Reversal; Differentiation in the z-Domain; Power Series Expansion Method (or Long Division Method); Analysis and Characterization of LTI Systems; Transfer Function and Difference-Equation System. Solving Difference Equations.

(15 Lectures)

Unit 3

Filter Concepts: Phase Delay and Group delay, Zero-Phase Filter, Linear-Phase Filter, Simple FIR Digital Filters, Simple IIR Digital Filters, All pass Filters, Averaging Filters, Notch Filters.

(5 Lectures)

Discrete Fourier Transform: Frequency Domain Sampling (Sampling of DTFT), The Discrete Fourier Transform (DFT) and its Inverse, DFT as a Linear transformation, Properties; Periodicity; Linearity; Circular Time Shifting; Circular Frequency Shifting; Circular Time Reversal; Multiplication Property; Parseval's Relation, Linear Convolution Using the DFT (Linear Convolution Using Circular Convolution), Circular Convolution as Linear Convolution with aliasing.

(10 Lectures)

Unit 4

Fast Fourier Transform: Direct Computation of the DFT, Symmetry and Periodicity Properties of the Twiddle factor (WN), Radix-2 FFT Algorithms; Decimation-In-Time (DIT) FFT Algorithm; Decimation-In-Frequency (DIF) FFT Algorithm, Inverse DFT Using FFT Algorithms.

(5 Lectures)

Unit 5

Realization of Digital Filters: Non Recursive and Recursive Structures, Canonic and Non Canonic Structures, Equivalent Structures (Transposed Structure), FIR Filter structures; Direct-Form; Cascade-Form; Basic structures for IIR systems; Direct-Form I.
Finite Impulse Response Digital Filter: Advantages and Disadvantages of Digital Filters, Types of Digital Filters: FIR and IIR Filters; Difference Between FIR and IIR Filters, Desirability of Linear-Phase Filters, Frequency Response of Linear-Phase FIR Filters, Impulse Responses of Ideal Filters, Windowing Method; Rectangular; Triangular; Kaiser Window, FIR Digital Differentiators.

Infinite Impulse Response Digital Filter: Design of IIR Filters from Analog Filters, IIR Filter Design by Approximation of Derivatives, Backward Difference Algorithm, Impulse Invariance Method.

(15 Lectures)

Practical : 60 Hours
PRACTICAL-GE LAB: Digital Signal Processing Lab

At least 06 experiments from the following using Scilab/Matlab. Introduction to Numerical computation software Scilab/Matlab be introduced in the lab.

1. Write a program to generate and plot the following sequences: (a) Unit sample sequence $\delta(n)$, (b) unit step sequence $u(n)$, (c) ramp sequence $r(n)$, (d) real valued exponential sequence $x(n) = (0.8)^n u(n)$ for $0 \leq n \leq 30$.
2. Write a program to compute the convolution sum of a rectangle signal (or gate function) with itself for N = 5

$$x(n) = rect\left(\frac{n}{2N}\right) = \Pi\left(\frac{n}{2N}\right) = \begin{cases} 1 & -N \leq n \leq N \\ 0 & otherwise \end{cases}$$

3. An LTI system is specified by the difference equation

$$y(n) = 0.8y(n-1) + x(n)$$

(a) Determine $H\left(e^{jw}\right)$

(b) Calculate and plot the steady state response $y_{ss}(n)$ to

$$x(n) = cos(0.5\pi n)u(n)$$

4. Given a casual system

$$y(n) = 0.9y(n-1) + x(n)$$

(a) Find $H(z)$ and sketch its pole-zero plot

(b) Plot the frequency response $\left|H\left(e^{jw}\right)\right|$ and $\angle H\left(e^{jw}\right)$

5. Design a digital filter to eliminate the lower frequency sinusoid of $x(t) = \sin 7t + \sin 200t$. The sampling frequency is $f_s = 500\,Hz$. Plot its pole zero diagram, magnitude response, input and output of the filter.

6. Let $x(n)$ be a 4-point sequence:

$$x(n) = \underset{\uparrow}{\{1,1,1,1\}} = \begin{cases} 1 & 0 \leq n \leq 3 \\ 0 & otherwise \end{cases}$$

Compute the DTFT $X\left(e^{jw}\right)$ and plot its magnitude
(a) Compute and plot the 4 point DFT of $x(n)$
(b) Compute and plot the 8 point DFT of $x(n)$ (by appending 4 zeros)
(c) Compute and plot the 16 point DFT of $x(n)$ (by appending 12 zeros)
7. Let $x(n)$ and $h(n)$ be the two 4-point sequences,

$$x(n) = \underset{\uparrow}{\{1,2,2,1\}}$$

$$h(n) = \underset{\uparrow}{\{1,-1,-1,1\}}$$

Write a program to compute their linear convolution using circular convolution.
8. Using a rectangular window, design a FIR low-pass filter with a pass-band gain of unity, cut off frequency of 1000 Hz and working at a sampling frequency of 5 KHz. Take the length of the impulse response as 17.
9. Design an FIR filter to meet the following specifications:

passband edge $F_p = 2\,KHz$
stopband edge $F_s = 5\,KHz$
Passband attenuation $A_p = 2\,dB$
Stopband attenuation $A_s = 42\,dB$
Sampling frequency $F_s = 20\,KHz$

10. The frequency response of a linear phase digital differentiator is given by

$$H_d\left(e^{jw}\right) = jw\,e^{-jrw}\,|w| \leq \pi$$

Using a Hamming window of length M = 21, design a digital FIR differentiator. Plot the amplitude response.

Reference Books:

1. Digital Signal Processing, Tarun Kumar Rawat, Oxford University Press, India.
2. A Guide to MATLAB, B.R. Hunt, R.L. Lipsman, J.M. Rosenberg, 2014, 3rd Edn., Cambridge University Press
3. Fundamentals of Digital Signal processing using MATLAB, R.J. Schilling and S.L. Harris, 2005, Cengage Learning.
4. Getting started with MATLAB, Rudra Pratap, 2010, Oxford University Press.
5. Digital Signal Processing, S. K. Mitra, McGraw Hill, India.
6. Fundamentals of signals and systems, P.D. Cha and J.I. Molinder, 2007, Cambridge University Press.

GE: Nuclear and Particle Physics (32225417)
Credit : 06 (Theory-05, Tutorial-01)
Theory : 75 Hours
Tutorial : 15 Hours

Course Objective

The objective of the course is to impart the understanding of the sub atomic particles and their properties. It will emphasize to gain knowledge about the different nuclear techniques and their applications in different branches Physics and societal application. The course will focus on the developments of problem based skills.

Course Learning Outcomes

- The acquire knowledge can be applied in the areas of nuclear, medical, archaeology, geology and other interdisciplinary fields of Physics and Chemistry. It will enhance the special skills required for these fields.
- Learn the ground state properties of a nucleus – the constituents and their properties, mass number and atomic number, relation between the mass number and the radius and the mass number, average density, range of force, saturation property, stability curve, the concepts of packing fraction and binding energy, binding energy per nucleon vs. mass number graph, explanation of fusion and fission from the nature of the binding energy graph.
- To be able to understand the basic properties of nuclei as well as knowledge of experimental assessments, the concept of binding energy and n-z curves and their significance
- Know about the nuclear models and their roles in explaining the ground state properties of the nucleus –(i) the liquid drop model, its justification so far as the nuclear properties are concerned, the semi-empirical mass formula, (ii) the shell model, evidence of shell structure, magic numbers, predictions of ground state spin and parity, theoretical deduction of the shell structure, consistency of the s hell structure with the Pauli exclusion principles.
- To appreciate the formulations and contrasts between different nuclear models such as Liquid drop and Shell Model and evidences in support.
- Radioactivity and decay laws. A detailed analysis, comparison and energy kinematics of alpha, beta and gamma decays. Outlines of Gamow's theory of alpha decay and Pauli's theory of beta decay with the neutrino hypothesis, the electron capture, the fine structure of alpha particle spectrum, the Geiger-Nuttall law, the radioactive series.
- Familiarization with different types of nuclear reactions, Q- values, compound and direct reactions.
- To know about energy losses due to ionizing radiations, energy losses of electrons, gamma ray interactions through matter and neutron interaction with matter.
- The students are expected to learn about the principles and basic constructions of particle accelerators such as the Van-de-Graff generator, cyclotron, betatron and synchrotron. They will acquire knowledge about Accelerator facilities in India along with a comparative study of a range of detectors and accelerators which are building blocks of modern day instruments.

- Learn about the detectors of nuclear radiations- the Geiger-Mueller counter, the scintillation counter, the photo-multiplier tube, the solid state and semiconductor detectors.
- It will acquaint students with the nature and magnitude of different forces, particle interactions, families of sub- atomic particles with the different conservation laws, concept of quark model.

Unit 1

General Properties of Nuclei: Constituents of nucleus and their Intrinsic properties, quantitative facts about mass, radii, charge density, matter density (experimental determination of each), binding energy, average binding energy and its variation with mass number, main features of binding energy versus mass number curve, N/Z plot, angular momentum, parity, magnetic moment, electric moments.

(10 Lectures)

Unit 2

Nuclear Models: Liquid drop model approach, semi empirical mass formula and significance of its various terms, condition of nuclear stability, nucleon separation energies (up to two nucleons), Fermi gas model (degenerate fermion gas, nuclear symmetry potential in Fermi gas), evidence for nuclear shell structure and the basic assumption of shell model.

(11 Lectures)

Unit 3

Radioactivity decay: Decay rate and equilibrium (Secular and Transient)(a) Alpha decay: basics of α-decay processes, theory of α-emission, 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 rays emission from the excited state of the nucleus & kinematics, internal conversion.

(10 Lectures)

Unit 4

Nuclear Reactions: Types of Reactions, units of related physical quantities, Conservation Laws, kinematics of reactions, Q-value, reaction rate, reaction cross section, Concept of compound and direct reaction, resonance reaction, Coulomb scattering (Rutherford scattering).

(8 Lectures)

Unit 5

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 (photoelectric effect, Compton scattering, pair production), neutron interaction with matter.

(9 Lectures)

Detector for Nuclear Radiations: Gas detectors: estimation of electric field, mobility of particle for ionization chamber and GM Counter. Basic principle of Scintillation Detectors

and construction of photo-multiplier tube (PMT). Semiconductor Detectors (Si and Ge) for charge particle and photon detection (concept of charge carrier and mobility), neutron detector.

(9 Lectures)

Particle Accelerators: Accelerator facility available in India: Van-de Graaff generator (Tandem accelerator), Linear accelerator, Cyclotron, Synchrotrons (Principal, construction, working, advantages and disadvantages).

(7 Lectures)

Unit 6

Particle physics: Particle interactions (concept of different types of forces), basic features, Cosmic Rays, types of particles and its families, Conservation Laws (energy and momentum, angular momentum, parity, baryon number, Lepton number, Isospin, Strangeness) concept of quark model, color quantum number and gluons.

(11 Lectures)

References

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. Concepts of Nuclear Physics by Bernard L Cohen, Tata McGraw Hill Publication, 1974.
4. Introductory Nuclear Physics by Kenneth S, Krane, Wiley-India Publication, 2008
5. Nuclear Physics : principles and applications by John Lilley, Wiley Publication, 2006.
6. Physics and Engineering of Radiation Detection by Syed Naeem Ahmed, Academic Press Elsevier, 2007.
7. Introduction to Modern Physics by Mani & Mehta, Affiliated East-West Press, 1990.
8. Introduction to elementary particles by David J Griffiths, Wiley, 2008.
9. Modern Physics by Serway, Moses and Moyer, CENGAGE LEARNING, 2012.

Additional Resources:

1. Radiation detection and measurement, G.F. Knoll, John Wiley & Sons, 2010.
2. Technique for Nuclear and Particle Physics experiments by William R Leo, Springer, 1994.
3. Concepts of Modern Physics by Arthur Beiser, McGraw Hill Education, 2009.
4. Nuclear Physics "Problem-based Approach" Including MATLAB by Hari M. Aggarwal, PHI Learning Pvt. Ltd. (2016)

Numerical Books :

1. Schaum's Outline of Modern Physics, McGraw-Hill Education, 1999.
2. Modern Physics by R. Murugaeshan. S.Chand Publication, 2010.

GE: Astronomy and Astrophysics (32225418)
Credit : 06 (Theory-05, Tutorial-01)
Theory : 75 Hours
Tutorial : 15 Hours

Course Objective

This General Elective course is meant to introduce undergraduate students of the University of Delhi 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 learn about diverse set of astronomical and astrophysical 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. The course presupposes school level understanding of mathematics and physics.

Course Learning Outcomes

Students completing this course gain

- An understanding of different types of telescopes, diurnal and yearly motion of astronomical objects, and 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
- The large scale structure of the Universe and its history
- Distribution of chemical compounds in the interstellar medium and astrophysical conditions necessary for the emergence and existence of life.

Unit 1
Introduction to Astronomy and Astronomical Scales: Wonders of the Universe, Overview of the Night Sky, Diurnal and Yearly motions of the Sun, Stars and Constellations. Size, Mass, Density and Temperature of Astronomical objects, Basic concepts of Positional Astronomy: Celestial Sphere, Astronomical Coordinate Systems, Horizon System, Equatorial System, Measurement of Time, Sidereal Time, Apparent Solar Time, Mean Solar Time, Equation of Time, Calendar, Astronomical Time Systems (LMT, UT, UTC)

(15 Lectures)

Unit 2

Basic Parameters of Stars: Determination of Distance by Parallax Method; Aberration, Proper Motion, Brightness, Radiant Flux and Luminosity, Apparent and Absolute Magnitude Scales, Distance Modulus; Determination of Temperature and Radius of a Star; Stellar Spectra, Atomic Spectra Revisited, Spectral Types and their Temperature

Dependence, Black Body Approximation, Luminosity Classification, H R Diagram and Relations Between Stellar Parameters

(15 Lectures)

Unit 3

Observational Tools and Physical Principles: 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 and Radio Telescopes, Current Indian Observatories. Virial Theorem for N Particle Systems and Applications, Mean Molecular Weight of Stellar Gas, Stellar Energy Sources.

(15 Lectures)

Unit 4

Sun and the Solar Family: Solar Parameters, Sun's Internal Structure, Solar Photosphere, Solar Atmosphere, Chromosphere. Corona, Solar Activity.
The Solar Family: Facts and Figures, Origin of the Solar System, The Nebular Model. Tidal Forces and Planetary Rings, Extra-Solar Planets.

(8 Lectures)

Unit 5

Milky Way: Basic Structure and Properties of the Milky Way, Nature of Rotation of the Milky Way (Differential Rotation of the Galaxy and Oort Constants, Rotation Curve of the Galaxy and the Dark Matter, Nature of the Spiral Arms), Properties of and around the Galactic Nucleus. Interstellar molecules.

(10 lectures)

Unit 6

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, Exoplanets

(12 Lectures)

References

1. Seven Wonders of the Cosmos, Jayant V Narlikar, Cambridge University Press
2. Fundamental of Astronomy (Fourth Edition), H. Karttunen et al. Springer
3. The Physical Universe: An Introduction to Astronomy, F H Shu, University Science Books
4. Astrophysics Stars and Galaxies K D Abhyankar, Universities Press
5. ModernAstrophysics, B.W. Carroll & D.A. Ostlie, Addison-Wesley Publishing Co.
6. Textbook of Astronomy and Astrophysics with elements of cosmology, V.B. Bhatia, Narosa Publication.
7. Baidyanath Basu, An introduction to Astrophysics, Second printing, Prentice - Hall of India Private limited, New Delhi,2001.
8. Introductory Astronomy and Astrophysics, M. Zeilik and S.A. Gregory, 4th

Edition, Saunders College Publishing.

9. Explorations: Introduction to Astronomy, Thomos Arny and Stephen Schneider, 2014, 7th edition, McGraw Hill
10. The Molecular Universe, A.G.G.M. Tielens, Reviews of Modern Physics, Vol 85, July September, 2013

GE: Atmospheric Physics (32225419)
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

This paper aims to describe the characteristics of earth's atmosphere and also its dynamics.

Course Learning Outcomes

- Good knowledge of Earth's atmosphere, its composition, effective temperature, Greenhouse effect. Hydrostatic equation and atmospheric thermodynamics. Local winds, clouds, fog, monsoon, cyclones, sea breeze and land breeze and thunderstorms etc.

- Essential knowledge of the instruments of meteorological observation, meteorological processes and systems.

- Understanding atmospheric dynamics, fundamental forces, conservation laws, rotating coordinate system and equations of motion. Circulation, vorticity, various types of circulations, atmospheric oscillations: biannual, annual and semi-annual oscillations.

- Understanding atmospheric waves. Surface water waves, accoustic waves, buoyancy waves, atmospheric gravity waves (AGW) and its propagation in non-homogeneous medium, Lamb and Rossy waves and their propagation in 3-dimension. Wave absorption and non linear effects.

- Skills to use atmospheric Radar and Lidar to study atmospheric phenomenon, basic knowledge of Radars and Lidars including Radar equation and signal processing. Develop numerical skills to do data analysis from Radar and Lidar.

- Knowledge of the classification and properties of aerosols, their concentrations and size distribution. Production and removal of aerosols. Radiative and health effects and observation techniques for aerosols.

- Understanding the absorption and scattering of solar radiation, Rayleigh scattering and Mie scattering, Boyer-Lambert law, optical phenomenon in atmosphere. Basics of radiometry.

- In the laboratory course through computer simulations students will learn Atmospheric wave using Dispersion relations, Kelvin waves, Rossby waves and Mountain waves.

(i) Offline and if possible online processing of RADAR data: VHF RADAR, X-band RADAR, UHF RADAR.
(ii) Offline and Online processing of LIDAR data
(iii)Study of Radiosonde data and its interpretation in terms of the atmospheric parameters
(iv)Interpretation of the satellite data using radio Occultation technique
(v) Time Series Analysis of Temperature using long term data and implications for climate change.

Unit 1

General features of Earth's atmosphere: Thermal structure of the Earth's Atmosphere, Composition of atmosphere, Hydrostatic equation, Potential temperature, Atmospheric Thermodynamics, Greenhouse effect, Local winds, monsoons, fogs, clouds, precipitation, Atmospheric boundary layer, Sea breeze and land breeze. Instruments for meteorological observations including RS/RW, meteorological processes and convective systems, fronts, Cyclones and anticyclones, thunderstorms.

(12 Lectures)

Unit 2

Atmospheric Dynamics: Scale analysis, Fundamental forces, Basic conservation laws, The Vectorial form of the momentum equation in rotating coordinate system, scale analysis of equation of motion, Applications of the basic equations, Circulations and vorticity, Atmospheric oscillations, Quasi biennial oscillation, annual and semi-annual oscillations, Mesoscale circulations, The general circulations, Tropical dynamics.

(12 Lectures)

Unit 3

Atmospheric Waves: Surface water waves, wave dispersion, acoustic waves, buoyancy waves, propagation of atmospheric gravity waves (AGWs) in a nonhomogeneous medium, Lamb wave, Rossby waves and its propagation in three dimensions and in sheared flow, wave absorption, non-linear consideration

(12 Lectures)

Unit 4

Atmospheric Radar and Lidar: Radar equation and return signal, Signal processing and detection, Various type of atmospheric radars, Applications of radars to study atmospheric phenomena, Lidar and its applications, Application of Lidar to study atmospheric phenomenon. Data analysis tools and techniques.

(12 Lectures)

Unit 5

Atmospheric Aerosols: Spectral distribution of the solar radiation, Classification and properties of aerosols, Production and removal mechanisms, Concentrations and size distribution, Radiative and health effects, Observational techniques for aerosols, Absorption and scattering of solar radiation, Rayleigh scattering and Mie scattering, Bouguert-Lambert law, Principles of radiometry, Optical phenomena in atmosphere, Aerosol studies using Lidars.

(12 Lectures)

Practical: 60 Hours
PRACTICALS- GE LAB: Atmospheric Physics Lab

Scilab/C ++ based simulations experiments based on Atmospheric Physics problems like (at least 05 experiments)

1. Numerical Simulation for atmospheric waves using dispersion relations
   (a) Atmospheric gravity waves (AGW) (b) Kelvin waves
   (c) Rossby waves and mountain waves
2. Offline and online processing of radar data
   (a) VHF radar,
   (b) X-band radar, and
   (c) UHF radar
3. Offline and online processing of LIDAR data 1374. Radiosonde data and its interpretation in terms of atmospheric parameters using vertical profiles in different regions of the globe.
4. Handling of satellite data and plotting of atmospheric parameters using different techniques such as radio occultation technique
5. Time series analysis of temperature using long term data over metropolitan cities in India – an approach to understand the climate change
6. PM 2.5 measurement using compact instruments
7. Field visits to National center for medium range weather forecasting, India meteorological departments, and ARIES Nainital to see onsite radiosonde balloon launch, simulation on computers and radar operations on real time basis.

References

1. Fundamental of Atmospheric Physics, M.L Salby; Academic Press, Vol 61, 1996
2. The Physics of Atmosphere – John T. Houghton; Cambridge University press; 3 rd edn. 2002.
3. An Introduction to dynamic meteorology – James R Holton; Academic Press, 2004
4. Radar for meteorological and atmospheric observations – S Fukao and K Hamazu, Springer Japan, 2014.

GE: Physics of Earth (32225420)
Credit : 06 (Theory-05, Tutorial-01)
Theory : 75 Hours
Tutorial : 15 Hours

Course Objective

This course familiarizes the students with the origin of universe and role of earth in the solar system.

Course 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
- In the tutorial section, through literature survey on the various aspects of health of Earth, project work / seminar presentation, the students will be able to appreciate need to 'save' Earth.

Unit 1

The Earth and the Universe: (a) Origin of universe, creation of elements and earth. A Holistic understanding of our dynamic planet through Astronomy, Geology, Meteorology and Oceanography . Introduction to various branches of Earth Sciences. (b) General characteristics and origin of the Universe. The Big Bang Theory. Age of the universe and Hubble constant. Formation of Galaxies. The Milky Way galaxy, Nebular Theory, solar system, Earth's orbit and spin, the Moon's orbit and spin. The terrestrial and Jovian planets. Titius-Bode law. Asteroid belt. Asteroids: origin types and examples. Meteorites & Asteroids. Earth in the Solar system, origin, size, shape, mass, density, rotational and revolution parameters and its age. (c) Energy and particle fluxes incident on the Earth. (d) The Cosmic Microwave Background.

(17 Lectures)

Unit 2

Structure: (a) The Solid Earth: Mass, dimensions, shape and topography, internal structure, magnetic field, geothermal energy. How do we learn about Earth's interior?
(b) The Hydrosphere: The oceans, their extent, depth, volume, chemical composition. River systems. (c) The Atmosphere: layers, variation of temperature with altitude, adiabatic lapse rate, variation of density and pressure with altitude, cloud formation (d) The Cryosphere: Polar caps and ice sheets. Mountain glaciers, permafrost.

(18 Lectures)

Unit 3

Dynamical Processes: (a) **The Solid Earth**: Origin of the magnetic field. Source of geothermal energy. Convection in Earth's core and production of its magnetic field. Mechanical layering of the Earth. Introduction to geophysical methods of earth investigations. Concept of plate tectonics; types of plate movements, hotspots; sea-floor spreading and continental drift. Geodynamic elements of Earth: Mid Oceanic Ridges, trenches, transform faults and island arcs. Origin of oceans, continents, mountains and rift valleys. Earthquake and earthquake belts. Seismic waves, Richter scale, geophones. Volcanoes: types products and distribution. (b) **The Hydrosphere**: Ocean circulations. Oceanic current system and effect of coriolis forces. Concepts of eustasy, tend – air-sea interaction; wave erosion and beach processes. Tides. Tsunamis. (c) **The Atmosphere**: Atmospheric circulation. Weather and climatic changes. Earth's heat budget. Cyclones and anti-cyclones. Climate: i. Earth's temperature and greenhouse effect. ii. Paleoclimate and recent climate changes. iii. The Indian monsoon system. (d) **Biospher**e: Water cycle, Carbon cycle. The role of cycles in maintaining a steady state.

(18 Lectures)

Unit 4

Evolution: Stratigraphy: Introduction and types, Standard stratigraphic time scale and introduction to the concept of time in geological studies. Time line of major geological and biological events. Introduction to geochronological methods and their application in geological studies. Radiometric dating: Advantages & disadvantages of various isotopes. History of development of concepts of uniformitarianism, catastrophism and neptunism. Various laws of stratigraphy. Introduction to the geology and geomorphology of Indian subcontinent. Origin of life on Earth, Role of the biosphere in shaping the environment. Future of evolution of the Earth and solar system: Death of the Earth (Probable causes).

(18 Lectures)

Unit 5

Disturbing the Earth – Contemporary dilemmas (a) Human population growth. (b) Atmosphere: Green house gas emissions, climate change, air pollution. (c) Hydrosphere: Fresh water depletion. (d) Geosphere: Chemical effluents, nuclear waste. (e) Biosphere: Biodiversity loss. Deforestation. Robustness and fragility of ecosystems.

(4 Lectures)

References

1. Planetary Surface Processes, H. Jay Melosh, 2011, Cambridge University Press.

2. Consider a Spherical Cow: A course in environmental problem solving, John Harte, University Science Books

3. Holme's Principles of Physical Geology, 1992, Chapman & Hall.

4. Planet Earth, Cosmology, Geology and the Evolution of Lifeand Environment, C. Emiliani, 1992, Cambridge University Press.

5. The Blue Planet:An Introduction to Earth System Science, Brian J. Skinner, Stephen C. Portere, 1994, John Wiley & Sons.

6. Physics of the Earth, Frank D. Stacey, Paul M. Davis, 2008, Cambridge University Press.

7. Fundamentals of Geophysics, William Lowrie, 1997, Cambridge University Press.

8. The Solid Earth: An Introduction to Global Geophysics, C. M. R. Fowler, 1990, Cambridge University Press.

9. The Earth: A Very Short Introduction, Martin Redfern, 2003, Oxford University Press.

10. Galaxies: A Very Short Introduction, John Gribbin, 2008, Oxford University Press.

11. Climate Change: A Very Short Introduction, Mark Maslin, 3 rd Edition, 2014, Oxford University Press.

12. The Atmosphere: A Very Short Introduction, Paul I. Palmer, 2017, Oxford University Press.

13. IGNOU Study material: PHE 15 Astronomy and Astrophysics Block 2

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LOCF (CBCS) Undergraduate Physics courses revision 2019
Department of Physics & Astrophysics, University of Delhi

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ANNEXURE 1B

Subject working groups
LOCF (CBCS) Undergraduate Physics courses revision 2019
Department of Physics & Astrophysics, University of Delhi

Group	Papers	Name of faculty	Role	College
I	• Waves and Optics (Hons. core /GE) • Electricity and magnetism (Hons. core/GE) • Electromagnetic theory (Hons. core) • Electricity and magnetism (Prog. core) • Waves and Optics (Prog. core) • Electrical circuits and Networks (SEC) • Applied Optics (SEC) • Introduction to Physical Computing (SEC)	Prof. Kirti Ranjan	Coordinator	Department of Physics & Astrophysics
		Dr. Sangeeta D. Gadre	Convenor	Kirori Mal College
		Dr. Pragati Ishdhir	Member	Hindu College
		Dr. K.C. Singh		Sri Venkateswara College
		Dr. Pushpa Bindal		Kalindi College
		Dr. Geetanjali Sethi		St. Stephen's College
		Dr. Pradeep Kumar		Hansraj College
		Dr. N. Chandrlika		Gargi College
II	• Elements of Modern Physics (Hons. core/GE) • Quantum Mechanics and applications (Hons. Core) • Elements of Modern Physics (Prog. DSE) • Quantum Mechanics (Prog. DSE/GE) • Advanced Quantum Mechanics (Hons. DSE) • Renewable energy and Energy harvesting (SEC)	Prof. P. Das Gupta	Coordinator	Department of Physics & Astrophysics
		Dr. P.K. Jha	Convenor	Deen Dyal Upadhyaya college
		Dr. N. Santakrus Singh		Hindu College
		Dr. Punita Verma		Kalindi College
		Dr. Siddharth Lahon		Kirorimal College
		Dr. Onkar Mangla		Daulat Ram College
		Dr. Sandhya		Miranda House
		Dr. Ajay Kumar		Sri Aurobindo College

III	• Thermal Physics (Hons. Core) • Statistical Mechanics (Hons. Core) • Thermal Physics and Statistical Mechanics (Program core/GE)	Prof. S. Annapoorni	Coordinator	Department of Physics & Astrophysics
		Dr. Anuradha Gupta	Convenor	SGTB Khalsa College
		Dr. Deepak Jain	Member	Deen Dyal Upadhyaya college
		Dr. Nimmi Singh		SGTB Khalsa College
		Dr. Ashok Kumar		Ramjas College
		Dr. Aditya Saxena		Deshbandhu College
		Dr. Maya Verma		Hansraj College
IV	• Solid State Physics (Hons. Core) • Solid State Physics (Prog. DSE/GE) • Nanomaterials and Applications (DSE-Hons.+ Prog.)/GE	Prof. S. Annapoorni	Coordinator	Department of Physics & Astrophysics
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		Dr. Mamta Bhatia	Member	AND College
		Dr. Rajveer Singh		ARSD College
		Dr. Shiva Upadhyaya		S.S.N. College
		Dr. Harish K. Yadav		St. Stephen's College
		Dr. Rashmi Menon		Kalindi College
		Dr. Yogesh Kumar		Deshbandhu College
V	• Mathematical Physics-I (Hons. Core) • Mathematical Physics-II (Hons. Core) • Mathematical Physics -III (Hons. Core) • Advanced Mathematical Physics (Hons. DSE) • Mathematical Physics (Program DSE/ Hons. GE) • Advanced Mathematical	Prof. T.R. Seshadri	Coordinator	Department of Physics & Astrophysics
		Dr. G.S. Chilana	Convenor	Ramjas College
		Dr. Abha Dev Habib	Member	Miranda House
		Dr. Agam Kumar Jha		Kirori Mal College
		Dr. Subhash Kumar		AND College

	Physics -II (Hons. DSE) • Computational Physics Skills (SEC) • Numerical Analysis (SEC) • Linear Algebra & Tensor Analysis (DSE)	Dr. Mamta		SGTB Khalsa College
		Dr. Neetu Aggarwal		Daulat Ram College
		Dr. Bhavna Vidhani		Hansraj College
		Dr. Ajay Mishra		Dyal Singh College
VI	• Mechanics (Hons. Core/GE) • Mechanics (Prog. Core) • Applied Dynamics (DSE/GE) • Classical Dynamics (DSE) • Physics Workshop Skills (SEC)	Prof. A. G. Vedeshwar	Coordinator	Department of Physics & Astrophysics
		Dr. Ashish Tyagi	Convenor	SSN College
		Dr. Shalini Lumb Talwar	Member	Maitreyi College
		Dr. Vandana Arora		Keshav Mahavidyalaya
		Dr. Arvind Kumar		Ramjas College
		Dr. Chitra Vaid		Bhagini Nivedita College
		Dr. Omwati Rana		Daulat Ram College
		Dr. Sunita Singh		Miranda House
		Dr. Pranav Kumar		Kirori Mal College
		Dr. Pooja Devi		Shyam lal College
VII	• Nuclear and particle Physics (Hons. DSE/GE) • Nuclear and particle physics (Prog. DSE) • Radiation Safety (SEC)	Prof. Samit Mandal	Coordinator	Department of Physics & Astrophysics
		Dr. Vandana Luthra	Convenor	Gargi College
		Dr. Namrata	Member	S.S.N. College
		Dr. Supriti Das		Gargi College
		Dr. Punit Tyagi		Ramjas College
VIII	• Astronomy and Astrophysics (DSE/GE) • Weather Forecasting (SEC)	Prof. Anjan Datta	Coordinator	Department of Physics & Astrophysics

		Medical Physics (DSE/GE)	Dr. Jacob Cherian	Convenor	St. Stephen's College
		• Medical Physics (DSE/GE) • Atmospheric Physics (DSE/GE) • Biological Physics (DSE/GE) • Physics of Earth (DSE/GE) • Technical Drawing (SEC) • Dissertation	Dr. S.K. Dhaka	Member	Rajdhani College
			Dr. Sanjay Kumar		St. Stephen's College
			Dr. Sushil Singh		SGTB Khalsa College
			Dr. Chetna Jain		Hansraj College
			Dr. Ayushi Paliwal		Deshbandhu College
			Dr. Rekha Gupta		St. Stephen's College
IX	• Digital Systems and Applications (Hons. Core) • Embedded Systems - Introduction to Microcontroller (DSE/GE) • Digital, Analog and Instrumentation (Prog. DSE/Hons. GE) • Verilog and FPA based System design (DSE/GE) • Digital Signal Processing (DSE/GE) • Linear and Digital Integrated Circuits –E • Microprocessors and Microcontrollers –E • Electronic Instrumentation - E(DSE) • Basic Instrumentation Skills (SEC) Dissertation-E	Prof. Vinay Gupta	Coordinator	Department of Physics & Astrophysics
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			Dr. Arijit Chowdhuri		AND College
			Dr. Anjali Sharma		ARSD College
			Dr. Kajal Jindal		Kirori Mal College
			Dr. Poonam Jain		Sri Aurobindo College
			Dr. Savita Sharma		Kalindi College
			Dr. Alka Garg		Gargi College
X	• Analog systems and Applications (Hons. Core) • Experimental techniques	Prof. Vinay Gupta	Coordinator	Department of Physics & Astrophysics

	(DSE) • Physics of Device and Communication (DSE) • Communication System (DSE/GE) • Network Analysis and Analog Electronics-E • Communication Electronics –E • Semiconductor Devices Fabrication - E(DSE) • Photonic Devices and Power Electronics -E (DSE) • Antenna theory and wireless network -E (DSE) • Electrical circuit network skills-Prog. SEC	Dr. Monika Tomar	Convenor	Miranda House
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XI	• Practicals of all Courses	Prof. Vinay Gupta	Coordinator	Department of Physics & Astrophysics
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LOCF (CBCS) Undergraduate Physics courses revision 2019
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