मणिपुर णिश्वणिद्यालय

MANIPUR UNIVERSITY

Bachelor of Science Physics

(Effective from Academic Year 2022-23)

Revised Syllabus as approved by

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Learning Outcomes-Based Curriculum Framework for Undergraduate Education in Physics

1. INTRODUCTION

The learning outcomes-based curriculum framework (LOCF) for a degree in B.Sc. 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 terms 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. 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 mathematics to find solutions, 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. PHYSICS

2.1 NATURE AND EXTENT OF THE PROGRAMME IN B.Sc. PHYSICS

The B.Sc. 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 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, 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 the gaps in the scientific knowledge and understanding of the 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. 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. 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. 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-fields 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 and beyond. 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 and a sense of responsibility towards human society and the planet. 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. PHYSICS

The qualification descriptor for B.Sc. 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.
- 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.
- Demonstrate Physics-related technological skills that are relevant to Physics-related trades and employment opportunities.
- Apply their knowledge, understanding and skills to new/unfamiliar contexts beyond Physics to identify and analyze problems and issues, and to solve complex problems.

5. PROGRAMME LEARNING OUTCOMES IN B.Sc. PHYSICS

Students graduating with the B.Sc. 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 methods, and the role of approximation and mathematical approaches to describing the physical world and beyond.
- 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;
  - (iv) appreciation of intellectual property, environmental and sustainability issues;
  - (v) 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 verification and confirmation 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. At the same time physics graduates also 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 procedure protocol for all the colleges is therefore essential. To be specific, it is desirable to have:

- Sufficient number of teachers in permanent positions 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 laboratories, libraries, and other equipment and to 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 these approaches for an efficient teaching-learning process:

i. Class room teaching with lectures using traditional as well as electronic boards. Demonstration of the required experiments in laboratory and sessions on necessary apparatuses, data analysis, error estimation and scientific report writing for effective and efficient learning of laboratory techniques.

ii. Imparting the 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.

iii. 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 modeling, in all courses.

iv. Teaching should be complimented with students' seminar to be organized very frequently.

v. Guest lectures and seminars should be arranged by inviting eminent teachers and scientists.

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

vii. Since actual undergraduate teaching is done in affiliated colleges which have differing levels of infrastructure and student requirements, the teachers should attend workshops organized by the University Department for college faculty on teaching methodology, reference materials, latest laboratory equipment and experiments, and computational physics software for achieving uniform standards. Common guidelines for individual courses need to be followed/evolved.

viii. 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.

ix. 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.

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

In the first year students are fresh from school. Given the diversity of their backgrounds, and the lack of adequate infrastructure and training in science learning in many schools, special care and teacher attention is essential in the first year. Mentorship with senior students and teachers can help them ease into rigors of university level undergraduate learning.

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.

All Core courses have a theory component. In addition, every core course has a physics laboratory component, or a computational physics component, which are integrated with their theoretical component. Even though the learning in theory and lab components proceeds in step, the teaching learning processes for the different components need specific and different emphases.

6.1.1 Teaching Learning Processes for Theory component of Core Courses

A significant part of the theoretical learning in core courses is done in the traditional lecture cum black-board method. Demonstrations with models, power-point projection, student project presentations, etc., are some other methods which should be judiciously used to enhance the learning experience. Problem solving should be integrated into theoretical learning 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 are 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 theoretical learning of these courses.

6.1.2 Teaching Learning Processes for Physics Laboratory component of Core Courses

Students learn essential physics laboratory skills mainly while preparing for experiments, performing them in the laboratory, and writing appropriate laboratory reports. Most of this learning takes place in the self-learningmode.However,teachers'roleiscrucialatcritical key points. Physics laboratory learning suffers seriously if students do not get appropriate guidance at these key points. Many students get their first proper exposure to physics laboratory work in their first year of undergraduate studies. Hence, laboratory teaching to first year students requires special care.

Demonstration on the working of required apparatuses should be given in few beginning laboratory sessions of all courses. Sessions on the essentials of experimental data analysis, error estimation, and scientific report writing are crucial in the first year physics laboratory teaching. Once the essentials have been learnt, sessions may be taken on applications of these for specific experiments in lab courses of later years. Students should be encouraged to explore experimental physics projects outside the curricula.

Many college laboratories lack latest laboratory equipment due to resource crunch. For example, very few laboratories have equipment for sensor and microprocessor based data acquisition, whose output can be directly fed into a computer for further analysis. Colleges need to make strategic planning, including student participation under teacher guided projects, to gradually get their laboratories equipped with latest equipment. The Department of the Physics and Astrophysics of the University can provide key guidance and help in this regard. It is recommended that the maximum size of group for all Physics Laboratory courses should be 12-15 students.

6.1.3 Teaching Learning Processes for Computational Physics Component of Core Courses

The CBCS has introduced computational physics as an integral component of undergraduate physics core courses. This is a crucial advance in the pedagogy of undergraduate physics learning. Computational physics is an essential tool to introduce physics concepts and principles into domains which cannot be accessed via analytical methods. Since computational work can easily be done outside the designated laboratory hours, it strengthens the self-learning ability among students.

Essential programming skills are the foremost requirement of computational physics learning. 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. The second requirement of computational physics learning is the ability to transform a physics problem into a computable problem for which a suitable program can be written. Appropriate problem based assignments are crucial in developing this ability. Every computational physics lab course should involve sessions on essential computational techniques, and the reduction of relevant physics problems to computational problems. Advanced level student project can be easily integrated into the learning of computational physics. Every student should be encouraged to undertake at least one project in a computational lab course. Since computational work can easily be done outside the scheduled laboratory hours, mentorship can be very useful in helping students become comfortable with computers. Colleges should ensure that students from weaker economic backgrounds have adequate access to computers.

It is recommended that the maximum size of group for all computational Physics Laboratory courses should be 12-15 students per group.

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.

Besides a theory component, every DSE paper has either an associated tutorial, or a physics laboratory, or a computational physics component. Teaching learning processes for theory, physics laboratory and computational physics components described above in sub-sections 6.1.1, 6.1.2 and 6.1.3 for core courses, should be applicable for DSE courses too.

6.2.1 Tutorials

It provides an opportunity for attending closely to learning issues with individual students, and hence an effective means to help create interest in the subject and assess their understanding. Pre-assigned weekly problem sets and assignments help structure tutorial sessions and should be used as often as possible. Students' performance in tutorials should be used for determining their internal assessment marks for the course.

It is recommended that the maximum size of group in a tutorial should be 8-10 students per group.

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-on' 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.

It is recommended that the maximum size of group in the Laboratory for SEC courses should be 12-15 students per group.

6.4 TEACHING LEARNING PROCESSES FOR GENERIC ELECTIVES

Physics GE papers are taken by students of other disciplines. 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.

Besides a theory component, every GE paper has either an associated physics laboratory, or a computational physics or a tutorial component. Teaching learning processes for theory, physics laboratory and computational physics components described above in sub-sections 6.1.1, 6.1.2 and 6.1.3 for core courses, and for tutorials described in sub-section 6.2.1 should be applicable for GE courses too.

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 creationof 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. 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 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. The internal assessment marks for theory component, and physics laboratory and computational physics laboratory components should be distributed in periodic assessments in different modes to serve the intended purpose.

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 these different kinds of courses.

7.1 ASSESSMENT METHODS FOR CORE COURSES

Core courses and associated physics laboratory and computational physics 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 the University Department among teachers teaching these courses in different colleges is 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.

7.1.1 Assessment Methods for the Theory component of Core courses

As per Clause 11 of the Manipur University Undergraduate Ordinance 2021, The evaluation scheme allots (25%) for internal assessment and semester end examination (75%) The internal assessment shall be distributed as (i) Test/Assignment/Field Work/Project Work/Case Study 20% and (ii) Attendance: 5%. Teachers should use a judicious combination of the above methods to assess students for these marks.

To help students prepare themselves for formative assessment during the semester, 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.

7.1.2 Assessment Methods for the Physics Laboratory component of Core courses

The internal assessment for the evaluation scheme for laboratory courses is best used in continuous evaluation of students' performance in the lab. This evaluation should include these components: i) Regular evaluation of experiments through (a) written report of each experiment and (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, and v) audio visual recording of the experiments being performed by students and its self-appraisal.

The end semester laboratory examination should ideally involve extensions of experiments done by students during the semester. Two or more experiments can be combined for this purpose. Open ended problems for which students can get the answer by designing their own experimental method should also be tried.

7.1.3 Assessment Methods for the Computational Physics component of Core courses

For awarding internal assessment marks in Computational Physics laboratory courses, students should be assessed for every computational assignment done during the semester. This should involve assessment of their program, report and a viva-voce. Periodic tests on unseen problems may form a part of the internal assessment.

It is essential that the end semester examination is based upon unseen computational physics problems.

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.

Besides a theory component, every DSE paper has either an associated tutorial, or a physics laboratory, or a computational physics component. Assessment methods for theory, Physics laboratory and computational physics components described above in sub-sections 7.1.1, 7.1.2 and 7.1.3 for core courses, should be applicable for DSE courses too.

Students should be assessed for their performance in **tutorials**, and this assessment should contribute to their internal assessment marks. Their work on pre-assigned problem sets/assignments, and participation in tutorial discussions should be taken into account while assessing their performance.

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.

Besides a theory component, every GE paper has either an associated tutorial, or a physics laboratory, or a computational physics component. Assessment methods for theory, Physics laboratory and computational physics components described above in sub-sections 7.1.1, 7.1.2 and 7.1.3 for core courses, should be applicable for GE courses too.

Students should be assessed for their performance in **tutorials**, and this assessment should contribute to their internal assessment marks. Their work on pre-assigned problem sets/assignments, and participation in tutorial discussions should be taken into account while assessing their performance.

8. STRUCTURE OF COURSES IN B.SC PHYSICS

8.1. Course Structure:

The course structure for the 4-year UG programme shall be as under:

(A) ***Bachelor's Certificate***

The Bachelor's Certificate in Physics is obtainable after 1 year (two semesters) of study. This Certificate may be awarded if a student studies 4 core papers in that discipline, 2 Ability Enhancement Compulsory Courses (AECC), 2 Skill Enhancement Courses (SEC) and minimum 3 Value Addition Courses (VAC), with the completion of courses equal to a minimum of 46 Credits.

(B) ***Bachelor's Diploma***

The Bachelor's Diploma in Physics is obtainable after 2 years (four semesters) of study. A Bachelor's Diploma in Physics may be awarded if a student studies 10 core papers in that discipline, 2 Ability Enhancement Compulsory Courses (AECC), 2 Skill Enhancement Courses (SEC), minimum 4 Value Addition Courses (VAC) and 2 Generic Elective courses (GEC), with the completion of courses equal to a minimum of 96 Credits.

(C) ***Bachelor's Degree***

The Bachelor's Degree in Physics is obtainable after 3 years (six semesters) of study. A Bachelor's degree (i.e., B.Sc.) in Physics degree may be awarded if a student studies 14 core papers in that discipline, 2 Ability Enhancement Compulsory Courses (AECC), 2 Skill Enhancement Courses (SEC), minimum 5 Value Addition Courses (VAC), 2 Discipline Specific Elective (DSE) courses and minimum 3 Generic Elective (GE) courses, with the completion of courses equal to a minimum of 140 Credits.

Table 8.1 Course Structure

(A) Bachelor's Certificate Physics(Level 5)

Semester	Discipline specific Core (DSC)	Discipline Specific Elective (DSE)	Generic Elective Course (GEC). (To be selected from GEC listings of other disciplines) (Credit)	Ability Enhancement Compulsory Courses (AECC)	Skill Enhancement Course (SEC) Select any one among A/B/C/D	Value Addition Courses (VAC) (To be selected from VAC listings of other disciplines). (Credit)	Semester Credit
Semester-I	PHC-101(6)			AECC-101(4) English/MIL	PHSEC-101A/B/C/D(4)	VAC-101(2)	24
	PHC-102(6)					VAC-102(2)	
Semester II	PHC-203(6)			AECC-202(4)	PHSEC-202A/B/C/D(4)	VAC-203(2)	24
	PHC-204(6)					VAC-204(2)	

Award of Certificate in Physics (after 1 Year: minimum 46 (four six) Credits)

(B) Bachelor's Diploma in Physics (Level 6)

Semester	Discipline specific Core (DSC)	Disciplin e Specific Elective (DSE)	Generic Elective Course (GEC). (To be selected from GEC listings of other disciplines) (Credit)	Ability Enhancement Compulsory Courses (AECC)	Skill Enhancement Course (SEC) Select any one among A/B/C/D	Value Addition Courses (VAC) (To be selected from VAC listings of other disciplines). (Credit)	Semester Credit
Semester III	PHC-305(6)		GEC-301(6)			VAC-305(2)	26
	PHC-306(6)						
	PHC-307(6)						
Semester IV	PHC-408(6)		GEC-402(6)			VAC-406(2)	26
	PHC-409(6)						
	PHC-410(6)						

Award of Diploma in Physics (after 2 Year: minimum 96 (nine six) Credits)

(C) Bachelor's Degree in Physics(Level 7)

Semester	Discipline specific Core (DSC))	Discipline Specific Elective (DSE)	Generic Elective Course (GEC). (To be selected from GEC listings of other disciplines) (Credit)	Ability Enhancement Compulsory Courses (AECC)	Skill Enhancement Course (SEC) Select any one among A/B/C/D	Value Addition Courses (VAC) (To be selected from VAC listings of other disciplines). (Credit)	Semester Credit
Semester-V	PHC-511(6)	PHE-501(6)	GEC-503(6)			VAC-507(2)	26
	PHC-512(6)						
Semester VI	PHC-613(6)	PHE-602(6)	GEC-604(6)			VAC-608(2)	26
	PHC-614(6)						

Award of B Sc degree in Physics (after 3 Year: minimum 140 (one four zero) Credits)

(D) Bachelor's (Hons) Degree (Level 8)

Semester	Discipline specific Core (DSC)	Discipline Specific Elective (DSE)	Generic Elective Course (GEC). (To be selected from GEC listings of other disciplines) (Credit)	Ability Enhancement Compulsory Courses (AECC)	Skill Enhancement Course (SEC) Select any one among A/B/C/D	Value Addition Courses (VAC) (To be selected from VAC listings of other disciplines). (Credit)	Semester Credit
Semester-VII	PHC-715(6)	PHE-703(6)	GEC-705(6)				24
	PHC-716(6)						
Semester VIII	PHC-817(6)	PHE-804(6)	GEC-806(6)				24
	PHC-818(6)						

Award of B Sc degree in Physics (after 4 Year: minimum 182 (one eight two) Credits

(D) Bachelor's Degree with Honours

The Bachelor's Degree with Honours in Physics is obtainable after 4 years (eight semesters) of study. A B Sc Physics (Honours) degree may be awarded if a student studies 18 core papers in that discipline, 2 Ability Enhancement Compulsory Courses (AECC), 2 Skill Enhancement Courses (SEC), minimum 5 Value Addition Courses (VAC), 4 Discipline Specific Elective (DSE) and minimum 4 Generic Elective courses (GEC), with the completion of courses equal to a minimum of 182 Credits.

The Course structure of 4-year B Sc Physics Programme is shown in Table 8.1given above.

8.2 Multiple Entry and Exit Options:

The entry and exit options for students, who enter the undergraduate programme, shall be as follows:

1ST YEAR

Entry 1: The entry requirement for Bachelor's certificate (Level 5) programme is Secondary School Leaving Certificate obtained after the successful completion of Grade 12. A programme of study leading to entry into the first year of the Bachelor's degree is open to those who have met the entrance requirements, including specified levels of attainment at the secondary level of education specified in the programme admission regulations. Admission to the Bachelor's degree programme of study is based on the evaluation of documentary evidence (including the academic record) of the applicant's ability to undertake and complete a Bachelor's degree programme.

Exit 1: Bachelor's certificate will be awarded when a student exits at the end of 1st year (Level 5). A Bachelor's certificate requires completion of courses equal to a minimum of 46 Credits at Level 5.

2ND YEAR

Entry 2. The entry requirement for Bachelor's diploma (Level 6) is a Bachelor's certificate obtained after completing the first year (two semesters) of the undergraduate programme. A programme of study leading to the second year of the Bachelor's degree is open to those who have met the entrance requirements, including specified levels of attainment, in the programme admission regulations. Admission to a programme of study is based on the evaluation of documentary evidence (including the academic record) of the applicant's ability to undertake and complete a Bachelor's degree programme.

Exit 2: At the end of the 2nd year (Level 6), if a student exits, a Bachelor's diploma shall be awarded. A Bachelor's Diploma requires completion of courses equal to a minimum of 96 Credits from Level 5 to Level 6.

3RD YEAR

Entry 3. The entry requirement for an undergraduate programme is a diploma obtained after completing two years (four semesters) of the undergraduate programme. A programme of study leading to the Bachelor's degree is open to those who have met the entrance requirements, including specified levels of attainment, in the programme admission regulations. Admission to a programme of study is based on the evaluation of documentary evidence (including the academic record) of the applicant's ability to undertake and complete a Bachelor's degree programme.

Exit 3: On successful completion of three years, the Bachelor's degree shall be awarded. A Bachelor's degree requires completion of courses equal to a minimum of 140 Credits from Level 5 to Level 7.

4TH YEAR

Entry 4. An individual seeking admission to a Bachelor's degree (Honours) (Level 8) in a discipline would normally have completed all requirements of the relevant three-year bachelor degree (Level 7) in that discipline. After completing the requirements of a three-year Bachelor's degree, candidates who meet a minimum CGPA of 7.5 shall be allowed to continue studies in the fourth year of the undergraduate programme to pursue and complete the Bachelor's degree with Honours in the discipline.

Exit 4: On the successful completion of the fourth year, a student shall be awarded a Bachelor's degree with Honours in the concerned discipline. A Bachelor's degree with Honours requires completion of courses equal to a minimum of 182 Credits from Level 5 to Level 8.

8.3 Qualification Levels and Credit Requirements:

Following the UGC's nomenclature, qualification titles such as certificate, diploma and degree for the undergraduate programmes are organized in a series of levels in ascending order as under:

Level 5: Bachelor's certificate; Level 6: Bachelor's diploma; Level 7: Bachelor's degree;
Level 8: Bachelor's degree with Honours.

The minimum credit requirements for these qualification types shall be as under:

(A) Bachelor's Certificate (**Level 5**)

Course (Credit)	**Number**	**Course Credits**	**Minimum Credits**
Core (6)	4	6 x 4=24	46
AECC (4)	2	4 x 2=8	
SEC (4)	2	4 x 2=8	
VAC (2)	3 (Minimum)	2 x 3=6 (Minimum)	

(B) Bachelor's Diploma (**Level 6**)

Course (Credit)	**Number**	**Course Credits**	**Minimum Credits**
Core (6)	10	6 x 10=60	96
GEC (6)	2	6 x 2=12	
AECC (4)	2	4 x 2=8	
SEC (4)	2	4 x 2=8	
VAC (2)	4 (Minimum)	2 x 4=8 (Minimum)	

(C) Bachelor's Degree (**Level 7**)

Course (Credit)	**Number**	**Course Credits**	**Minimum Credits**
Core (6)	14	6 x 14=84	140
DSE (6)	2	6 x 2=12	
GEC (6)	3 (Minimum)	6 x 3=18 (Minimum)	
AECC (4)	2	4 x 2=8	
SEC (4)	2	4 x 2=8	
VAC (2)	5 (Minimum)	2 x 5=10 (Minimum)	

(D) Bachelor's (Hons.) Degree (**Level 8**)

Course (Credit)	**Number**	**Course Credits**	**Minimum Credits**
Core (6)	18	6 x 18=108	182
DSE (6)	4	6 x 4=24	
GEC (6)	4 (Minimum)	6 x 4=24 (Minimum)	
AECC (4)	2	4 x 2=8	
SEC (4)	2	4 x 2=8	
VAC (2)	5 (Minimum)	2 x 5=10 (Minimum)	

8.4 Marks Distribution and Evaluation:

Total marks for each course shall be based on internal assessment (25%) and semester end examination (75%). The internal assessment of 25% shall be distributed as under:

(i) Test/Assignment/Seminar/Field Work/Project Work/Case Study: 20%;

(ii) Attendance: 5%.

Table 8.2: SEMESTER-WISE DISTRIBUTION OF COURSES

SEMESTER-WISE DISTRIBUTION OF COURSES

A. Discipline Specific Core Courses

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

Sl No	CC Paper Code	Semester	Course name
1.	PHC-101	I	Mathematical Physics – I (Theory + Lab)
2.	PHC-102	I	Mechanics (Theory + Lab)
3.	PHC-203	II	Electricity and Magnetism (Theory + Lab)
4.	PHC-204	II	Waves and Optics (Theory + Lab)
5.	PHC-305	III	Mathematical Physics – II (Theory + Lab)
6.	PHC-306	III	Thermal Physics (Theory + Lab)
7.	PHC-307	III	Digital Systems and Applications (Theory + Lab)
8.	PHC-408	IV	Mathematical Physics – III (Theory + Lab)
9.	PHC-409	IV	Elements of Modern Physics (Theory + Lab)
10.	PHC-410	IV	Analog Systems and Applications (Theory + Lab)
11.	PHC-511	V	Quantum Mechanics and Applications (Theory +Lab)
12.	PHC-512	V	Solid State Physics (Theory + Lab)
13.	PHC-613	VI	Electromagnetic Theory (Theory + Lab)
14.	PHC-614	VI	Statistical Mechanics (Theory + Lab)
15.	PHC-715	VII	Classical Mechanics (Theory+Lab)
16.	PHC-716	VII	Quantum Mechanics (Theory+Lab)
17.	PHC-817	VIII	Electrodynamics (Theory+Lab)
18.	PHC-818	VIII	Electronics (Theory +Lab)

B. Discipline Specific Electives

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.

Sl No	DSE Paper Code	Semester	DSE Name
1	PHE-501	V	A. Physics of Earth (Theory+Lab) B. Adv Math. Physics I(Theory+Lab) C. Embedded System: Introduction to Microcontrollers (Theory+Lab)
2	PHE-602	VI	A. Medical Physics (Theory+Lab) B. Biological Physics (Theoty+Tutorial) C. Physics of Devices and Instruments (Theory+Lab)
3	PHE-703	VII	A. Nuclear and Particle Physics (Theory+Tutorial) B. Adv Math Physics II (Theory+Lab) C. Astronomy and Astrophysics (Theory+Tutorial)
4	PHE-804	VIII	A. Nanomaterials and Applications (Theory+Lab) B. Communication Electronics (Theory+Lab) C. Atomic & Molecular Physics ((Theory+Tutorial_)

C. Skill Enhancement Courses

All courses have 4 credits with 2 credits of theory and 2 credits of Practical

/Tutorials/Projects and Field Work to be decided by the College.

S.No.	SEC Paper Code	Semester	SEC Name
1	PHSE-101A	I	Physics Workshop Skills
2	PHSE-101B	I	Computational Physics Skills
3	PHSE-101C	I	Electrical Circuit and Network Skills
4	PHSE-101D	I	Basic Instrumentation Skills
5	PHSE-202A	II	Renewable Energy and Energy Harvesting
6	PHSE-202B	II	Technical Drawing
7	PHSE-202C	II	Radiation Safety
8	PHSE-202D	II	Applied Optics

D. Ability Enhancement Compulsory Courses

All the courses have 4 credits including Theory/Practicals/Projects.

Sl. No.	AECC Paper Code	Semester	AECC Name
1	AECC-101	I	English/MIL
2	AECC-202	II	Environmental Science

E. Value Addition Courses

Sl. No.	VAC Paper Code	Semester	VAC Name
1	VAC-101	I	Yoga
2	VAC-102	I	Sports
3	VAC-203	II	Culture
4	VAC-204	II	Health Care
5	VAC-305	III	NCC
6	VAC-406	IV	Ethics
7	VAC-507	V	NSS
8	VAC-608	VI	History of Science

F. General Elective Courses

All the courses have 6 credits with 4 credits of theory and 2 credits of practicals. These courses are meant for students of other departments/disciplines**.**

00	GEC Paper Code	Semester	GEC Name
1	PHGE-301	III	Mechanics + Lab
2	PHGE-402	IV	Electricity and Magnetism + Lab
3	PHGE-503	V	Solid State Physics + Lab
4	PHGE-604	VI	Waves and Optics + Lab
5	PHGE-705	VII	Elements of Modern Physics +Lab
6	PHGE-806	VIII	Nuclear & Particle Physics + Tutorial

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

9.1. DISCIPLINE SPECIFIC CORE

PHC-101: Mathematical Physics-I
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 and critical skills required in solving problems of interest to physicists. The course will also expose students to fundamental computational physics skills enabling them to solve a wide range of physics problems. The skills developed during course will prepare them not only for doing fundamental and applied research but also for a wide variety of careers.

Course Learning Outcomes

After completing this course, student will be able to

- Draw and interpret graphs of various functions.
- Solve first and second order differential equations and apply these to physics problems.
- 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, the students will be able to design, code and test simple programs in C++ in the process of solving various 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 operator. Vector identities.

(8 Lectures)

Vector Integration: Ordinary Integrals of Vectors. Double and Triple integrals, 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, their verification (no rigorous proofs) and applications.

(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 events, 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.

- The course will consist of practical sessions and lectures on the related theoretical aspects of the Laboratory. The recommended group size is not more than 15 students.
- Evaluation to be done not only on the programming but also on the basis of formulating the problem.
- Aim at teaching students to construct the computational problem to be solved.
- Students can use any one operating system: Linux or Microsoft Windows.
- At least 12 programs must be attempted from the following covering the entire syllabus.
- The list of programs here is only suggestive. Students should be encouraged to do more practice. Emphasis should be giventoassessstudent'sabilitytoformulateaphysics problem as mathematical one and solve by computational methods.

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 size of 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
Maclaurin and Taylor's series	Approximate functions like sin(x), cos(x) by a finite number oftermsof Taylor'sseries.
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	Solution of linear and quadratic equation, solving $\alpha = \tan\alpha$; $I = I0\ [(\sin\alpha)/\alpha]^2$ 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:

Essential Readings:

1. Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India .
2. An introduction to ordinary differential equations, E. A. Coddington, 2009, PHI learning.
3. Vector Analysis: Schaum Outline Series, M. R Spiegel, McGraw Hill Education (2017).
4. Statistical data Analysis for The Physical Sciences by Adrian Bevan, Cambridge University Press (2013).
5. Advanced Mathematics for Engineers and Scientists: Schaum Outline Series, M. R Spiegel, McGraw Hill Education (2009).

Additional Readings:

1. Advanced Engineering Mathematics, D. G. Zill and W. S. Wright, 5 Ed., 2012, Jones and Bartlett Learning.
2. Mathematical Physics (1995), A.K. Ghatak, IC Goyal and S.J. Chua, Macmillan India, New Delhi.
3. Essential Mathematical Methods, K.F.Riley & M.P.Hobson, 2011, Cambridge Univ. Press.
4. Differential Equations, George F. Simmons, 2007, McGraw Hill.
5. Introduction to Vector Analysis, H.F. Davis and A. D. Snider, Wm. C. Brown Publishers; 6th edition (1991).
6. Statistics – A Guide to the Use of Statistical Methods n the Physical Sciences, R.J. Barlow, Wiley (1993).

References for Laboratory Work:

1. Schaum's Outline of Programming with C++', J. Hubbard, 2000, McGraw-Hill Education.
2. C++ How to Program', Paul J. Deitel and Harvey Deitel, Pearson (2016).
3. Introduction to Numerical Analysis, S.S. Sastry, 5th Edn., 2012, PHI Learning Pvt. Ltd.
4. Computational Physics, Darren Walker, 1st Edn., Scientific International Pvt. Ltd (2015).
5. Elementary Numerical Analysis, K.E. Atkinson, 3rd Edn., 2007, Wiley India Edition.

PHC-102: Mechanics
Credit: 06 (Theory-04, Practical-02)
Theory: 60 Hours
Practical: 60 Hours

Course Objective

This course reviews the concepts of mechanics learnt at school from a more advanced perspective and goes on to build new concepts. It begins with Newton's Laws of Motion and ends with the Fictitious Forces and Special Theory of Relativity. Students will also appreciate the Collisions in CM Frame, Gravitation, Rotational Motion and Oscillations. The students will be able to apply the concepts learnt to several real world problems.

Course Learning Outcomes

Upon completion of this course, students are expected to

- 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 translational and rotational dynamics of a system of particles.
- ApplyKepler's laws to describe the motion of planets and satellite in circular orbit.
- 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, 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: Essential Readings:

1. An Introduction to Mechanics (2/e), Daniel Kleppner & Robert Kolenkow, 2014, Cambridge University Press.
2. Mechanics Berkeley Physics Course, Vol. 1, 2/e: Charles Kittel, et. al., 2017, McGraw Hill Education.
3. Theory and Problems of Theoretical Mechanics, Murray R. Spiegel, 1977, McGraw Hill Education.
4. Intermediate Dynamics, Patrick Hamill, 2010, Jones and Bartlett Publishers.
5. Analytical Mechanics, G. R. Fowles and G. L. Cassiday, 2005, Cengage Learning.

Additional Readings:

1. Feynman Lectures, Vol. 1, R. P. Feynman, R. B. Leighton, M. Sands, 2008, Pearson Education.
2. University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole.
3. University Physics, H. D. Young, R. A. Freedman, 14/e, 2015, Pearson Education.
4. Fundamentals of Physics, Resnick, Halliday & Walker 10/e, 2013, Wiley.
5. Engineering Mechanics, Basudeb Bhattacharya, 2/e, 2015, Oxford University Press.
6. Physics for Scientists and Engineers, R. A. Serway, J. W. Jewett, Jr, 9/e, 2014, Cengage Learning.
7. Mechanics, D. S. Mathur, P. S. Hemne, 2012, S. Chand.

References for Laboratory Work:

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

PHC-203: Electricity and Magnetism
Credit: 06 (Theory-04, Practical-02)
Theory: 60 Hours
Practical: 60 Hours

Course Objective

This course reviews the concepts of electromagnetism learnt at school from a more advanced perspective and goes on to build new concepts. The course covers static and dynamic electric and magnetic fields, and the principles of electromagnetic induction. It also includes analysis of electrical circuits and introduction of network theorems. The students will be able to apply the concepts learnt to several real-world problems.

Course Learning Outcomes

At the end of this course the student will be able to

- 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.
- Apply Gauss's law of electrostatics to solve a variety of problems.
- 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.
- Understand the basics of electrical circuits and analyze circuits using Network Theorems.
- In the laboratory course the student will get an opportunity to verify network theorems and study different circuits such as RC circuit, LCR circuit. Also, different methods to measure low and high resistance, capacitance, self-inductance, mutual inductance, strength of a magnetic field and its variation in space will be learnt.

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: ElectrostaticPotential.Laplace'sandPoisson 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.

(5 Lectures)

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: Essential Readings:

1. Fundamentals of Electricity and Magnetism, Arthur F. Kip, 2nd Edn.1981, McGraw-Hill.
2. Electricity and Magnetism, Edward M. Purcell, 1986 McGraw-Hill Education
3. Introduction to Electrodynamics, D.J. Griffiths, 3rd Edn., 1998, Benjamin Cummings.
4. Electricity and Magnetism, J.H.Fewkes& J.Yarwood. Vol.I, 1991, Oxford Univ. Press.
5. Network, Lines and Fields, John D. Ryder, 2nd Edn., 2015, Pearson.

Additional Readings:

1. Feynman Lectures Vol.2, R.P.Feynman, R.B.Leighton, M.Sands, 2008, Pearson Education
2. Electricity, Magnetism & Electromagnetic Theory, S.Mahajanand Choudhury, 2012, Tata McGraw
3. Electricity and Magnetism, J.H.Fewkes & J.Yarwood. Vol.I, 1991, Oxford Univ. Press.
4. Problems and Solutions in Electromagnetics (2015), Ajoy Ghatak, K Thyagarajan & Ravi Varshney.
5. Schaum's Outline of Electric Circuits, J. Edminister & M. Nahvi, 3rd Edn., 1995, McGraw Hill.

References for Laboratory Work:

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

PHC-204: Waves and Optics
Credit: 06 (Theory-04, Practical-02)
Theory: 60 Hours
Practical: 60 Hours

Course Objective

This course reviews the concepts of waves and optics learnt at school from a more advanced perspective and goes on to build new concepts. It 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 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 Interference as superposition of waves from coherent sources derived from same parent source.
- Demonstrate basic concepts of Diffraction: Superposition of wavelets diffracted from aperture, understand Fraunhoffer and Fresnel Diffraction.
- 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 λ2–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: Essential Readings:

1. Vibrations and Waves, A.P. French, 1stEdn., 2003, CRC press.
2. Fundamentals of Optics, F.A. Jenkins and H.E. White, 1981, McGraw-Hill
3. The Physics of Vibrations and Waves, H. J. Pain, 2013, John Wiley and Sons.
4. The Physics of Waves and Oscillations, N.K. Bajaj, 1998, Tata McGraw Hill.
5. Optics, Eugene Hecht, 4thEdn., 2014, Pearson Education.

Additional Readings:

1. Waves: Berkeley Physics Course, vol. 3, Francis Crawford, 2007, Tata McGraw-Hill.
2. Principles of Optics, Max Born and Emil Wolf, 7th Edn., 1999, Pergamon Press.
3. Optics, (2017), 6th Edition, Ajoy Ghatak, McGraw-Hill Education, New Delhi
4. Fundamental of Optics, A. Kumar, H.R. Gulati and D.R. Khanna, 2011, R. Chand Publications

References for Laboratory Work:

1. Advanced Practical Physics for students, B.L.Flint and H.T.Worsnop, 1971, Asia Publishing House
2. A Text Book of Practical Physics, I.Prakash & 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. Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press

PHC-305: Mathematical Physics-II
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 and expose them to fundamental computational physics skills thus enabling them to solve a wide range of physics problems. This course will aim at introducing the concepts of Fourier series, special functions, 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.
- Obtain power series solution of differential equation of second order with variable coefficient using Frobenius method.
- Understand properties and applications of special functions like Legendre polynomials, Bessel functions and their differential equations and apply these to various physical problems such as in quantum mechanics.
- Learn about gamma and beta functions and their applications.
- Solve linear partial differential equations of second order with separation of variable method.
- In the laboratory course, the students will learn the basics of the Scilab software/Python interpreter and apply appropriate numerical method to solve selected physics problems both using user defined and inbuilt functions from Scilab/Python. They will also learn

to 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 ($J_0(x)$ 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 practical sessions and lectures on the related theoretical aspects. The recommended group size for the lab is not more than 15 students. Evaluation done not only on the basis of programming but also on the basis of formulating the problem. Minimum 12 programs must be attempted taking at least one from each programming section. The instructor may choose to use Python in place of Scilab covering all features as mentioned.

Topics	Description with Applications
Introduction to Numerical computation software using Scilab or Python	Introduction to Scilab, Advantages and disadvantages, Scilab environment, Command window, Figure window, Edit window, Variables and arrays, Initializing variables in Scilab, Multidimensional arrays, Sub-array, Special values, Displaying output data, data file, Scalar and array operations, Hierarchy of operations, Built in Scilab functions, Introduction to plotting, 2D and 3D plotting, 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 orBessel'sfunctionatN pointsandfinditsvalueatan 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'slawof cooling Classical equations of motion

System of First order Differential Equations	Attempt following problems using RK 4 order method: • Solve the coupled differential equations $\frac{dx}{dt} = y + x - \frac{x^3}{3}; \frac{dy}{dt} = -x$ 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 $0 \le t \le 15$ Application to linear electric networks
Second order differential equation (Euler and RK Methods)	Second Order Differential Equations: Harmonic oscillator (no friction) Damped Harmonic oscillator (Overdamped, Critically damped and Oscillatory behavior) Forced Harmonic oscillator (Transient and Steady state solution) Apply above to LCR circuits also The differential equation describing the motion of a pendulum is $\frac{d^2\theta}{dt^2} = -sin\theta$. 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 and1.0 and plot $\theta, \frac{d\theta}{dt}$ as a function of time in the range $0 \ll t \ll 8\pi$. Also plot the analytic solution valid for small $\theta (sin\theta \approx \theta)$. Solve $x^2 \frac{d^2y}{dx^2} - 4x(1+x)\frac{dy}{dx} + 2(1+x)y = x^3$ with initial condition at x=1 as $y(1) = \frac{1}{2}e^2, \frac{dy}{dx}(x=1) = -\frac{3}{2}e^2 - 0.5$ in the range 1<x<3. Plot y and $\frac{dy}{dx}$ 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:

Essential Readings :

1. Advanced Engineering Mathematics, Erwin Kreyszig, 2008, Wiley India .
2. Advanced Mathematics for Engineers and Scientists: Schaum Outline Series, M. R Spiegel, McGraw Hill Education (2009).
3. Dfferential Equations, George F. Simmons, 2006, Tata McGraw-Hill.
4. Mathematical Methods for Physicists, Arfken, Weber and Harris, Elsevier
5. Applied Mathematics for Engineers and Physicists, L.A. Pipes and L.R. Harvill, Dover Publications (2014).

Additional Readings:

1. Mathematical methods for Scientists & Engineers, D.A.Mc Quarrie, 2003, Viva Books
2. Mathematical Methods for Physics and Engineers, K.F Riley, M.P. Hobson and S. J. Bence, 3rd ed., 2006, Cambridge University Press
3. Mathematical Physics, A.K. Ghatak, I.C. Goyal and S.J. Chua, Laxmi Publications Private Limited (2017)
4. Partial Differential Equations for Scientists and Engineers, S.J. Farlow, Dover Publications (1993).
5. Fourier Analysis with Applications to Boundary Value Problems: Schaum Outline Series, M. R Spiegel, McGraw Hill Education (1974).

References for Laboratory Work:

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/ and the Python home page https://docs.python.org/3/
3. Computational Physics, Darren Walker, Scientific International Pvt. Ltd (2015).
4. Applied numerical analysis, Cutis F. Gerald and P.O. Wheatley, Pearson Education, India (2007).
5. An Introduction to Computational Physics, T. Pang, Cambridge University Press (2010).

PHC-306: Thermal Physics
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

This course deals with the relationship between the macroscopic properties of physical systems in equilibrium. It reviews the concepts of thermodynamics learnt at school from a more advanced perspective and develops them further. The primary goal is to understand the fundamental laws of thermodynamics and their applications to various systems and processes. In addition, it will also give exposure to students about the Kinetic theory of gases, transport phenomena 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, 2^{nd} 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 CO_2 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.

At least six experiments should be performed 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: Essential Readings:

1. Heat and Thermodynamics: M.W. Zemansky and R.Dittman, (Tata McGraw-Hill.)
2. A Treatise on Heat :M.N.Saha and B.N.Srivastava, 1958 (Indian Press.)
3. Thermal Physics: S. C.Garg, R. M. Bansal and C. K. Ghosh (Tata McGraw-Hill.)
4. Thermodynamics, Kinetic Theory & Statistical Thermodynamics :Sears and Salinger (Narosa).
5. Concepts in Thermal Physics: Blundell and Blundell (Oxford Univ. press)

Additional Readings:

1. An Introduction to Thermal Physics: D. Schroeder (Pearson)

2. Thermal Physics :C. Kittel and H. Kroemer (W. H. Freeman)

References for Laboratory work:

1. Advanced Practical Physics for students: B. L. Flint and H.T.Worsnop (Little Hampton Book)
2. A Text Book of Practical Physics : InduPrakash& Ramakrishna(KitabMahal)
3. Advanced level Practical Physics: Nelkon and Ogborn (Heinemann Educational Publ.)
4. An Advanced Course in Practical Physics: D. Chattopadhyay& P. C. Rakshit, (New Central Book Agency)
5. Practical Physics: G.L. Squires (Cambridge University Press)

PHC-307: Digital Systems and Applications

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 the concept of Integrated Chips (IC): its classification and uses.
- Differentiating 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.
- Sequential Circuits: Basic memory elements Flips-Flops, shift registers and 4-bits counters leading to the concept of RAM, ROM and memory organization.
- Timer circuits using IC 555 providing clock pulses to sequential circuits and develop multivibrators.
- 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 students will learn to construct both combinational and sequential circuits by employing NAND as building blocks and demonstrate Adders, Subtractors, Shift Registers, and multivibrators using 555 ICs. They are 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).

(2 Lectures)

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 for Theory: Essential Readings:

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, 4^{th} Edn, 2018, PHI Learning Pvt. Ltd. Digital Circuits and systems, Venugopal, 2011, Tata McGraw Hill
3. Microprocessor Architecture Programming & applications with 8085, 2002, R.S. Goankar, Prentice Hall.
4. Digital Computer Electronics, A.P. Malvino, J.A. Brown, 3rd Edition, 2018, Tata McGraw Hill Education.
5. Digital Design, Morris Mano, 5^{th} Ed. Pearson.

Additional Readings:

1. Digital Electronics G K Kharate ,2010, Oxford University Press
2. Logic circuit design, Shimon P. Vingron, 2012, Springer
3. Digital Electronics, Subrata Ghoshal, 2012, Cengage Learning. Digital Electronics, S.K. Mandal, 2010, 1st edition, McGraw Hill

References for Laboratory Work:

1. Modern Digital Electronics, R.P. Jain, 4^{th} Edition, 2010, Tata McGraw Hill
2. Basic Electronics: A text lab manual, P.B.Zbar, A.P.Malvino, M.A.Miller, 1994, Mc- Graw Hill.
3. Microprocessor 8085: Architecture, Programming and interfacing, A.Wadhwa, 2010, PHI Learning

PHC-408: Mathematical Physics III
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 will be examined on the basis of problems, seen and unseen. The course will develop understanding of the basic concepts underlying complex analysis and complex integration and enable student to use 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, find the derivative of a function and understand the properties of elementary complex functions.
- Work with multi-valued functions (logarithmic, complex power, inverse trigonometric

function) and determine branches of these functions

- Evaluate a contour integral using 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, find the residues and use the residue theory to evaluate a contour integral and real integral.
- Understand the properties of Fourier and Laplace transforms and use these to solve boundary value problems.
- In the laboratory course, the students will learn the basics of the Scilab software/Python interpreter and apply appropriate numerical method to solve selected physics problems both using user defined and inbuilt functions from Scilab/Python.

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 practical sessions and lectures on the related theoretical aspects of the Laboratory course. 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:

   A. Solution to Ordinary Differential equation (Boundary Value Problems using finite Difference and shooting methods):

      i. Solve $y''(x) + y(x) = 0$ with $y(0) = 1, y(\frac{\pi}{2}) = 1$ for $0 < x < \pi$.

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

   B. 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:

   i. Verification of Orthogonality of Legendre Polynomials.

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

   ii. Complex analysis: Integrate $\int_0^\infty \frac{1}{(x^2+2)}dx$ numerically using Gauss Lagurre method 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 $\frac{1}{\sqrt{2\pi\sigma^2}}\int exp\,(\frac{-(x-2)^2}{2\sigma^2})\,(x+3)dx$, for σ = 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:

   Evaluate the Fourier coefficients of a given periodic function (e.g. square wave, triangle wave, half wave and full wave rectifier etc.)

5. Weighted Least square fitting of given data $(x, y)$with known error/uncertainty-values using user defined function.

6. Integral transform:

   i. Discrete and Fast Fourier Transform of given function in tabulated or mathematical form e.g. function exp^{-x^2}

   ii. Perform circuit analysis of a general LCR circuit using Laplace's transform.

References for Theory: Essential Readings:

1. Mathematical Methods for Physics and Engineers, K.F Riley, M.P. Hobson and S. J. Bence, 3rd Edition., 2006, Cambridge University Press
2. Complex Variables and Applications, J.W. Brown& R.V. Churchill, 7th Edition. 2003, Tata McGraw-Hill.
3. Laplace Transform: Schaum's Outline, M.R> Speigel, McGraw Hill Education.

4. Complex Variables: Schaum's Outline, McGraw Hill Education.
5. Fourier Analysis and Its Applications (Wadsworth and Brooks/Cole Mathematics Series), Gerald B. Folland, Thomson Brooks/Cole (1992).

Additional Readings:

1. Mathematics for Physicists, P.Dennery and A.Krzywicki, 1967, Dover Publications.
2. Complex Variables, A.S.Fokas & M.J.Ablowitz, 8th Ed., 2011, Cambridge Univ. Press.
3. Mathematical Physics with Applications, Problems and Solutions, V. Balakrishnan, Ane Books (2017).
4. Fourier Analysis with Applications to Boundary Value Problems: Schaum Outline Series, M. R Spiegel, McGraw Hill Education (1974).
5. Fourier Transform and its Applications, 2nd Ed., Ronald New Bold Bracewell, McGraw Hill (1978).

References for Laboratory Work:

1. An introduction to computational Physics, T.Pang, 2nd Edn.,2006, Cambridge Univ. Press.
2. Applied numerical analysis, Cutis F. Gerald and P.O. Wheatley, Pearson Education, India (2007).
3. Friendly Introduction to Numerical Analysis, Brian Bradie, Pearson Education (2007).
4. Introduction to Numerical Analysis, S.S. Sastry, 5th Edn., PHI Learning Pvt. Ltd. (2012).
5. Partial Differential Equations for Scientists and Engineers, S.J. Farlow, Dover Publications (1993).

PHC-409: Elements of Modern Physics
Credit: 06 (Theory-04, Practical-02)
Theory: 60 Hours
Practical: 60 Hours

Course Objective

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

Course Learning Outcomes

After getting exposure to this course, the following topics would be learnt:

- Main aspects of the inadequacies of classical mechanics as well as understanding of the historical development of quantum mechanics.
- Formulation of Schrodinger equation and the idea of probability interpretation associated with wave-functions.

- The spontaneous and stimulated emission of radiation, optical pumping and population inversion. Three level and four level lasers. Ruby laser and He-Ne laser in details. Basic lasing
- 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: Nuclear processes to produce nuclear energy in nuclear reactor and stellar energy in stars.
- In the laboratory course, the students will get opportunity to measure Planck's constant, verify photoelectric effect, determine e/m of electron, Ionization potential of atoms, study emission and absorption line spectra. They will also find wavelength of Laser sources by single and Double slit experiment, wavelength and angular spread of He-Ne

  Laser using plane diffraction grating.

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. 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

Reference for Theory: Essential Readings

1. Concepts of Modern Physics, Arthur Beiser, 2002, McGraw-Hill.
2. Modern Physics by R A Serway, C J Moses and C A Moyer, 3rd edition, Thomson Brooks Cole, 2012.
3. Modern Physics for Scientists and Engineers by S T Thornton and A Rex, 4th edition, Cengage Learning, 2013.
4. Concepts of Nuclear Physics by B L Cohen, Tata McGraw Hill Publication, 1974.
5. Quantum Mechanics, Robert Eisberg and Robert Resnick, 2ndEdn., 2002, Wiley.

Additional Readings:

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

Reference for Laboratory

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

PHC-410: Analog Systems and Applications
Credit: 06 (Theory-04, Practical-02)
Theory: 60 Hours
Practical: 60 Hours

Course Objective

This course introduces the concept of semiconductor devices and their applications. It also emphasizes on understanding of amplifiers, oscillators, operational amplifier and their applications.

Course Learning Outcomes

At the end of this course, the following concepts will be learnt

- Characteristics and working of pn junction.
- Two terminal devices: Rectifier diodes, Zener diode, photodiode etc.
- NPN and PNP transistors: Characteristics of different configurations, biasing, stabilization and their applications.
- CE and two stage RC coupled transistor amplifier using h-parameter model of the transistor.

- Designing of different types of oscillators and their stabilities.
- Ideal and practical op-amps: Characteristics and applications.
- In the laboratory course, the students will be able to study characteristics of various diodes and BJT. They will be able to design amplifiers, oscillators and DACs. Also different applications using Op-Amp will be designed.

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) and 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 for Theory: Essential Readings:

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. Linear Integrated Circuit, R. A. Gayakwad, 4th edition, 2000, Prentice Hall
3. 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
4. Electronic Principles, A. Malvino, D.J. Bates, 7th Edition, 2018, Tata Mc-Graw Hill

Education.

5. Electronic Devices & circuit Theory, R.L. Boylestad & L.D. Nashelsky, 2009, Pearson

Additional Readings:

1. Solid State Electronic Devices, B.G.Streetman & S.K.Banerjee, 6th Edn.,2009, PHI
2. Learning Electronic Devices & circuits, S.Salivahanan & N.S.Kumar, 3rd Ed., 2012, Tata Mc-Graw Hill OP-Amps
3. Microelectronic Circuits, M.H. Rashid, 2nd Edition, Cengage Learning
4. Microelectronic Devices & Circuits, David A.Bell, 5th Edn.,2015, Oxford University Press
5. Basic Electronics: Principles and Applications, C.Saha, A.Halder, D.Ganguli, 1st Edition, 2018, Cambridge University Press.

References for Laboratory Work:

1. Basic Electronics: A text lab manual, P.B.Zbar, A.P.Malvino, M.A.Miller, 1994, Mc-Graw Hill. OP-Amps.

PHC-511: Quantum Mechanics &Applications
Credit: 06 (Theory-04, Practical-02)
Theory: 60 Hours
Practical: 60 Hours

Course Objective

After learning the elements of modern physics, in this course students would be exposed to more advanced concepts in quantum physics and their applications to problems of the sub atomic world.

Course Learning Outcomes

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

- Methods to solve time-dependent and time-independent Schrodinger equation.
- Quantum mechanics of simple harmonic oscillator.
- Non-relativistic hydrogen atom: spectrum and eigenfunctions.
- 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:

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

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, $\hbar c$ = 1973 (eVÅ) and m = 0.511x10^6 eV/c^2.

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

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

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

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

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 $\hbar c$ = 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:

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

For a harmonic oscillator potential

$$\mathrm{V}(r) = \frac{1}{2}\mathrm{k}r^2 + \frac{1}{3}\mathrm{b}r^3$$

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

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

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

where m is the reduced mass of the two-atom system for the Morse potential

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

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

Take $m = 940 \times 10^6\ eV/\ c^2, D = 0.755501\ eV, \alpha = 1.44, r_0 = 0.131349A$

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

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 Essential Readings

1. Quantum Mechanics, B. H. Bransden and C. J. Joachain; 2nd Ed., Prentice Hall, 2000.
2. A Text book of Quantum Mechanics, P.M. Mathews and K. Venkatesan, 2^{nd} Ed.,2010, McGraw Hill.
3. Quantum Mechanics for Scientists & Engineers, D.A.B. Miller, 2008, Cambridge University Press.
4. Quantum Mechanics: Theory and Applications, (2019), (Extensively revised 6^{th} Edition), Ajoy Ghatak and S. Lokanathan, Laxmi Publications, New Delhi.
5. Introduction to Quantum Mechanics, D.J. Griffith, 2^{nd} Ed. 2005, Pearson Education.

Additional Readings

1. Introduction to Quantum Mechanics, R. H. Dicke and J. P. Wittke, Addison-Wesley Publications, 1966.
2. Quantum Mechanics, Leonard I. Schiff, 3^{rd} Edn. 2010, Tata McGraw Hill.
3. Quantum Mechanics, Robert Eisberg and Robert Resnick, 2ndEdn., 2002, Wiley.
4. Quantum Mechanics, Bruce Cameron Reed, 2008, Jones and Bartlett Learning.
5. Quantum Mechanics, Walter Greiner, 4^{th} Edn., 2001, Springer.
6. Introductory Quantum Mechanics, R. L. Liboff; 4th Ed., Addison Wesley, 2003.
7. Quantum Mechanics: Concepts and Applications, 2nd Edition, Nouredine Zettili, A John Wiley and Sons, Ltd., Publication

References for Laboratory Work:

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.

PHC-512: Solid State Physics
Credit: 06 (Theory-04, Practical-02)
Theory: 60 Hours
Practical: 60 Hours

Course Objective

This course introduces the basic concepts and principles required to understand the various properties exhibited by condensed matter, especially solids. It enables the students to appreciate how the interesting and wonderful properties exhibited by matter depend upon its atomic and molecular constituents. The gained knowledge helps to solve problems in solid state physics using relevant mathematical tools. It also communicates the importance of solid-state physics in modern society.

Course Learning Outcomes

On successful completion of the module students should be able to

- Elucidate the concept of lattice, crystals and symmetry operations.
- Understand the elementary lattice dynamics and its influence on the properties of materials.
- Describe the main features of the physics of electrons in solids: origin of energy bands, and their 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.
- In the laboratory students will carry out experiments based on the theory that they have learned to measure the magnetic susceptibility, dielectric constant, trace hysteresis loop. They will also employ to four probe methods to measure electrical conductivity

  and the hall set up to determine the hall coefficient of a semiconductor.

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. Edward's 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 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: Essential Readings:
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. Solid-state Physics, H. Ibach and H. Luth, 2009, Springer.

Additional Readings
1. Elementary Solid State Physics, M.Ali Omar, 2006, Pearson
2. Solid State Physics, Rita John, 2014, McGraw Hill
3. 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. Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press
5. Advanced level Physics Practicals, Michael Nelson and Jon M. Ogborn, 4th Edition, reprinted 1985, Heinemann Educational Publishers.

PHC-613: Electromagnetic Theory
Credit: 06 (Theory-04, Practical-02)
Theory: 60 Hours
Practical: 60 Hours

Course Objective
This core course develops further the concepts learnt in the electricity and magnetism course to understand the properties of electromagnetic waves in vacuum and different media.

Course Learning Outcomes
At the end of this course the student will be able to:
- Apply Maxwell's equations to deduce wave equation, electromagnetic field energy, momentum and angular momentum density.
- Understand electromagnetic wave propagation in unbounded media: Vacuum, dielectric medium, conducting medium, plasma.
- Understand electromagnetic wave propagation in bounded media: reflection and

transmission coefficients at plane interface in bounded media.

- Understand polarization of Electromagnetic Waves: Linear, Circular and Elliptical Polarization. Production as well as detection of waves in laboratory.
- Learn the features of planar optical wave guide.
- Understand the fundamentals of propagation of electromagnetic waves through optical fibres.
- In the laboratory course, the students get an opportunity to perform experiments with Polarimeter, Babinet Compensator, Ultrasonic grating, simple dipole antenna. Also, to study phenomena of interference, refraction, diffraction and polarization.

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 Brewster’s angle.

References for Theory: Essential Readings:

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. Classical Electrodynamics, J.D. Jackson, 3rd Edn., 2010, Wiley
4. Principle of Optics, M. Born and E. Wolf, 6th Edn., 1980, Pergamon Press
5. Optics, (2017), 6th Edition, Ajoy Ghatak, McGraw-Hill Education, New Delhi

Additional Readings:

1. Elements of Electromagnetics, M.N.O. Sadiku, 2001, Oxford University Press.
2. Fundamentals of Electromagnetics, M.A.W. Miah, 1982, Tata McGraw Hill
3. Problems and solution in Electromagnetics (2015), Ajoy Ghatak, K Thyagarajan & Ravi Varshney.
4. Electromagnetic field Theory, R.S. Kshetrimayun, 2012, Cengage Learning
5. Engineering Electromagnetic, Willian H. Hayt, 8th Edition, 2012, McGraw Hill.
6. Electromagnetics, J.A. Edminster, Schaum Series, 2006, Tata McGraw Hill.

References for Laboratory Work:

1. Advanced Practical Physics for students, B.L. Flint and H.T. Worsnop, 1971, Asia Publishing House.
2. Electromagnetic Field Theory for Engineers & Physicists, G. Lehner, 2010, Springer
3. Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Pres.
4. Engineering Practical Physics, S. Panigrahi & B.Mallick, 2015, Cengage Learning India Pvt. Ltd.

PHC-614: Statistical Mechanics
Credit: 06 (Theory-04, Practical-02)
Theory: 60 Hours
Practical: 60 Hours

Course Objective

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, phase space, thermodynamic probability and partition function.
- Understand the use of Thermodynamic probability and Partition function forcalculation of thermodynamic variables for physical system (Ideal gas, finite level system). Difference between the classical and quantumstatistics.
- Understand the properties and Laws associated with thermal radiation.
- Apply the Fermi- Dirac distribution to model problems such as electrons in solids and white dwarf stars
- Apply the Bose-Einstein distribution to model problems such as blackbody radiation and Helium gas.
- In the laboratory course, with the exposure in computer programming and computational techniques, the student will be in a position to perform numerical simulations for solving the problems based on Statistical Mechanics.

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-Jean's 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 Blackbody radiation w.r.t. wavelength/frequency at different temperatures. Compare it with Rayleigh-Jean's Law and Wien's distribution law for a given temperature.

References for Theory: Essential Readings:

1. Statistical Mechanics: R.K. Pathria and P. D. Beale (Academic Press)
2. Introductory Statistical Mechanics: R. Bowley and M. Sanchez (Oxford Univ. Press)
3. Statistical Physics: F. Mandl (Wiley)
4. A treatise on Heat: M.N. Saha and B.N. Srivastava (Indian Press)
5. Problems and Solutions on Thermodynamics andStatistical Mechanics: Lim Yung-Kou (Sarat Book House)

Additional Readings:

1. Statistical Physics: Berkeley Physics Course, F. Reif, (McGraw-Hill)
2. An Introduction to Statistical Physics: W.G.V. Rosser (Wiley)
3. An Introduction to Thermal Physics: D. Schroeder (Pearson)
4. Concepts in Thermal Physics: Blundell and Blundell (Oxford Univ. press)
5. Statistical and Thermal Physics: Loknathan and Gambhir (PHI)

References for Laboratory work:

1. Elementary Numerical Analysis: K.E. Atkinson (Wiley)
2. Introduction to Modern Statistical Mechanics: D. Chandler (Oxford University Press)
3. Thermodynamics, Kinetic Theory and Statistical Thermodynamics: F. W. Sears and G. L. Salinger (Narosa)

4. Modern Thermodynamics with Statistical Mechanics: Carl S. Helrich (Springer)
5. Statistical and Thermal Physics with Computer Applications: H. Gould and J.Tobochnik (Princeton University Press)

PHC-715: Classical Mechanics
Credit: 06 (Theory-04, Practical-02)
Theory: 60 Hours
Practical: 60 Hours

Course Objective

The primary objective is to teach the students Classical Mechanics at a level more advanced than what they have learnt in B.Sc. This is a course which forms the basis of Physics of many areas of Physics.

Contents

Unit 1

Lagrangian Formulation of Mechanics (1 Credit)

The variational principles and least action principles, Lagrangian equations of motion, constraints, Principle of virtual work and D'Alembert's principle, generalized coordinates, conjugate variables and phase space, symmetries and conservation laws.

Unit 2

Hamiltonian Formulation of Mechanics (1 Credit)

Hamilton's equations, canonical transformations, Symplectic approach to canonical transformations, Poisson brackets, Liouville's theorem, Hamilton-Jacobi equation, action-angle variables,

Unit 3

Selected Classical Mechanics Topics (2 Credits)

Rigid body motion (inertia tensors, Euler angles, rotation matrices)

Small oscillations (normal modes, ordinary resonance, parametric resonances)

Central force problems (the Kepler problem and scattering).

Course Learning Outcomes

Students will be equipped for advanced and specialized courses. The student learn to deal with particle mechanics at an advanced level and to learn the foundations of the classical theory of fields

References:

1. Goldstein, H., Classical Mechanics, Addison Wesley

2. Landau, L.D. And Lifshitz, E.M., A Course of Theoretical Physics, Vol I, Mechanics, Pergamon, NY.

PHC-716: Quantum Mechanics
Credit: 06 (Theory-04, Practical-02)
Theory: 60 Hours
Practical: 60 Hours

Course Objective

The primary objective is to teach the students the physical and mathematical basis of quantum mechanics for non-relativistic and relativistic systems

Contents

Basic Postulates of Quantum Mechanics. Interpretation of the eigenvalues eigenfunctions, expansion coefficients, expectation values, orthonormality, completeness, closure. Dirac bra and ket notation. Position and momentum representation of states and dynamical variables. Dirac δ function.

Commuting operators, compatibility and the Heisenberg Uncertainty Principle. Unitary transformation. Matrix representation of operators. Time evolution and Schrodinger equation. The Schrodinger and Heisenberg pictures.

Creation and annihilation operators. Operator algebra method of finding energy eigenvalues and eigenstates of the linear harmonic oscillator. System of identical particles. Symmetric and antisymmetric wave functions. Pauli's exclusion principle. Slater determinant.

Angular momentum in Quantum Mechanics: Commutation relations of angular momentum operators. Eigenvalues and Eigen functions. Rotation and angular momentum. Matrix representation of angular momentum operators. Pauli spin matrices and their properties. Addition of angular momenta and the Clebsch Gordan coefficients.

Relativistic quantum Mechanics: Klien- Gordon and Dirac equation. Properties of Dirac matrices. Free particle solution of Dirac equation.

Course Learning Outcomes

Students will learn the mathematical formalism of Hilbert space, hermitian operators, eigen values, eigen states and unitary operators, which form the fundamental basis of quantum theory. Application to simple harmonic oscillators, hydrogen-like atoms and angular momentum operators will teach the students how to obtain eigen values and eigen states for such systems elegantly. The topic of density matrices that plays significant roles in quantum information theory and statistical mechanics will also help the students considerably.

Suggested Books:

1. B H Bransden & C J Joachain, Quantum Mechanics, Pearson Education, 2000.
2. R H Shankar, Principles of Quantum Mechanics, Springer 2008.
3. J J Sakurai, Modern Quantum Mechanics, Addition- Wessley, 1993.
4. B Craseman and J Powell, Quantum Mechanics, Addition- Wessley.
5. S Gasiorowicz, Quantum Physics, Wiley.
6. Ajoy Ghatak and S. Lokanathan, Quantum Mechanics: Theory and Applications, Springer Science.

PHC-817: Electrodynamics
Credit: 06 (Theory-04, Practical-02)
Theory: 60 Hours
Practical: 60 Hours

Course Objective

This course aims to introduce the student to topics in Electromagnetic Theory, Relativity and the Relativistic formulation of electromagnetism. The course reviews and builds on the students' knowledge of Relativity and introduces the formulation of relativity in 4-vector notation. It also builds up a covariant formulation of electrodynamics and includes a study of motion of charges in fields as well as radiation from moving charges as well as antennae

Contents

Maxwell's equations in free space and linear isotropic media; boundary conditions on fields at interfaces; Scalar and vector potentials; Gauge invariance; Electromagnetic waves in free space, dielectrics, and conductors.

Reflection and refraction, polarization, Fresnel's Law, interference, coherence, and diffraction; Dispersion relations in plasma; Transmission lines and wave guides.

Lorentz transformation as 4-vector transformations; Electromagnetic field tensor; transformation of electro-magnetic fields; Covariance of Maxwell's equations; Dynamics of charged particles in static and uniform electromagnetic fields.

Retarded potential and Lienard-Wiechert potentials, Dipole radiation; Centre-fed linear antenna, Radiation from moving point charges, Power radiated by a point charge: Larmor's formula; Angular distribution of radiated power.

Course Learning Outcomes

A student having taken this course is expected to have a fair degree of familiarity with tensors and tensorial formulation of relativity and electrodynamics. In addition, he/she is expected to be able to solve problems of motion of charged particles in various field formations as well as find the radiation patterns from different time varying charge and current densities.

Suggested Books:

1 David Griffiths: Introduction to Electrodynamics (Benjamin Cummings, 1999)

2 David K. Cheng: Field and Waves Electromagnetics (Addison-Wesley, 1999)

3 J.D. Jackson: Classical Electrodynamics (John Wiley & Sons, 1999)

4 Bhag Guru & H. Hiziroglu: Electromagnetic Field Theory Fundamentals (Cambridge University Press, 2004)

5 M.N.O. Sadiku: Elements of Electromagnetics (Oxford University Press, 1995)

6 K.Y.Singh: An Introduction to Electromagnetics (Mohit Publications: Delhi, 2009)

PHC-818: Electronics
Credit: 06 (Theory-04, Practical-02)
Theory: 60 Hours
Practical: 60 Hours

Course Objective

To buildup on the basic knowledge of electronics with the introduction of advanced topics like circuit analysis and applications of semiconductor devices in analog and digital circuits.

Course Learning Outcomes:

A student of this course is expected to be able to understand the design and functional performance of electronic circuits using various semiconductor devices. In addition, the student will understand the functional properties and characteristics of semiconductor devices in analog & digital circuits using analog and digital signals.

Contents

Unit I: Circuit Analysis:

Admittance, impedance, scattering and hybrid matrices for two and three-port networks and their cascade and parallel combinations. Review of Laplace Transforms. Response functions, location of poles and zeros of response functions of active and passive systems (Nodal and Modified Nodal Analysis).

(10 Lectures)

Unit II: Physics of Semiconductor Devices:

p-n junction, BJT, JFET, equivalent circuits and high frequency effects, UJT, 4 layer pnpn device (SCR). MOS diode, accumulation, depletion and inversion, MOSFET: I-V, C-V characteristics. Enhancement and depletion mode MOSFET. Metal-semiconductor junctions; Ohmic and rectifying contacts, Schottky diode, I-V, C-V relations.

(20 Lectures)

Unit III: Analog circuits

Active filters and equalizers with feedback, Phase shift and delay.

(10 Lectures)

Unit IV: Digital Circuits

Introduction to digital IC parameters (switching time, propagation delay, fan out, fan in etc.). TTL, MOS and CMOS gates, Emitter-coupled logic, MOSFET as transmission gate. A/D and D/A converters. Basics of micro-processor and micro-controller.

(10 Lectures)

Unit V: Communication Systems

Amplitude, Angle and Pulse-analog modulation: Generation and detection. Model of communication system, classification of signals, representation of signals.

(10 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. To design and study of a Regulated Power Supply using diodes.
2. To design CLAMPERS and CLIPPERS using semiconductor diodes.
3. To study the merits and demerits of different biasing techniques.
4. To study the frequency response of (i) low pass filter, (ii) bandpass filter and highpass filter
5. To study the characteristics and applications of Silicon Controlled Rectifier:
   - (i). To plot the SCR characteristics under different gate current conditions and to obtain the values of the following parameters, (a) Forward break over voltage (V_{BRF}) for specified gate current, (b) Forward ON voltage (V_F)
   - (ii). To measure holding current (I_H)
   - (iii). To study the effect of varying dc gate current on the firing point of the SCR connected as an *ac* rectifier.
6. Push-Pull Amplifier**,**
   - (i). To study the output waveforms of push-pull amplifier in different classes of operation and to measure the efficiencies in each case, and
   - (ii). To plot the frequency response of the amplifier operated at the class *AB*.
7. To design Modulation and Demodulation circuits and
   - (i). To sketch the modulated waveform for at least two modulating signal frequencies and different indices of modulation.
   - (ii). To sketch the demodulated signal for a particular modulating signal and modulation index for three values of the *RC* time constant.
8. To determine the energy band gap in p-n junction diode.
9. Experiment on FET and MOSFET characterization and application as an amplifier.
   - a. To measure V_p.
   - b. To plot the output characteristics of the CS configuration.
   - c. To plot the transfer characteristics and hence to obtain trans-conductance
   - d. To measure V_p
   - e. To plot the output characteristics of the CS configuration.
   - f. To plot the transfer characteristics and hence to obtain trans conductance (g_m)
   - g. To plot the frequency response of the CS FET amplifier with and without feedback.
10. Experiment on Uni-Junction Transistor and its application.
    - (i). To plot the input characteristics of UJT and to obtain the values *of* η, I_P, V_V, I_v, $V_{e(sat)}$
    - (ii). To plot the output characteristics of UJT and to obtain the value of R_{BB}
    - (iii). To study the working of a UJT saw tooth generator
11. To design a circuit that can be used for addition and subtraction of two given four bit binary numbers using transistors/diodes. Explain its working and verify the result.
12. To design analog to digital converter (ADC) of given specifications.
13. To design digital to analog converter (DAC) using ladder network.
14. Electronic voltmeter
    - (i). To determine, the percentage error for, the ordinary voltmeter and electronic voltmeter and to determine their internal resistances,
    - (ii). To plot the frequency response of the same.
15. To examine the properties of the MOS amplifier configurations, and to investigate their small signal performance.

16. To design a multi-stage CMOS amplifier of a given specifications

References for theory:

1. Network Analysis and Synthesis by F.F. Kuo
2. Network Analysis with Applications by W.D. Stanley
3. Electronic Devices and Circuits by J. Millman and C.C. Halkias
4. Semiconductor Devices: Physics and technology by S M Szee
5. Communication Systems by Simon Haykins
6. Digital Signal Processing by J. G. Proakis and D. G. Manolakis
7. Solid State Electronic Devices by B.G. Streetman
8. Digital Design by M. Mano
9. Digital principles and Applications by A.P. Malvino and D.P.Leac

References for laboratory works:

1. Basic Electronics: A text lab manual by Paul Zbar, Albert Malvino, Michael Miller

9.2. DISCIPLINE SPECIFIC ELECTIVE (DSE)

PHE – 501 A: Physics of Earth
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, 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,geothermalenergy.HowdowelearnaboutEarth'sinterior?

(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 : Essential Readings :

1. Planetary Surface Processes, H. Jay Melosh, 2011, Cambridge University Press.
2. Holme'sPrinciplesofPhysicalGeology,1992,Chapman&Hall.
3. Planet Earth, Cosmology, Geology and the Evolution of Life and Environment, C. Emiliani, 1992, Cambridge University Press.
4. Physics of the Earth, Frank D. Stacey, Paul M. Davis, 2008, Cambridge University Press.

Additional Readings:

1. The Blue Planet: An Introduction to Earth System Science, Brian J. Skinner, Stephen C. Portere, 1994, John Wiley & Sons.
2. Consider a Spherical Cow: A course in environmental problem solving, John Harte, University Science Books.
3. Fundamentals of Geophysics, William Lowrie, 1997, Cambridge University Press.
4. The Solid Earth: An Introduction to Global Geophysics, C. M. R. Fowler, 1990, Cambridge University Press.
5. Climate Change: A Very Short Introduction, Mark Maslin, 3 rd Edition, 2014, Oxford University Press.
6. The Atmosphere: A Very Short Introduction, Paul I. Palmer, 2017, Oxford University Press.
7. IGNOU Study material: PHE 15 Astronomy and Astrophysics Block 2

PHE – 501 B: Advanced Mathematical Physics - I
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

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

- Understand algebraic structures in n-dimension and basic properties of the linear vector spaces.
- Represent Linear Transformations as matrices and understand basic properties of matrices.
- Apply vector spaces and matrices in the quantum world.
- Learn basic properties of Cartesian and general tensors with physical examples 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.
- In the laboratory course, the students are expected to solve the problems using the Scilab/C++/Python computer language: Eigenvalues and Eigenvectors of given matrix, determination of wave functions for stationary states as eigenfunctions, eigen energy values of Hermitian differential operators, Lagrangian formulation in classical dynamics 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'sLaw.

(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: 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 to 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: Essential Readings:

1 Mathematical Tools for Physics, James Nearing, 2010, Dover Publications

2 Theory and Problems of Linear Algebra, Seymour Lipschutz, 1987, McGraco-Hill Inc.

3 Theory and Problems of Vector Analysis and an introduction to Tensor Analysis, Murray R. Spiegel, 1974, McGraw Hill, Inc.

4 Introduction to Matrices & Linear Transformations, D.T.Finkbeiner,1978, Dover Pub.

5 Matrices and tensors in Physics: A.W. Joshi, New Age International Pvt. Ltd (2017).

Additional Readings:

1. Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber and F.E.Harris,1970, Elsevier.
2. Elementary Linear Algebra, Applications Version, Howard Anton and Chris Rorres, Wiley Student edition.
3. Mathematics for Physicists, Susan M. Lea, 2004, Thomson Brooks/Cole
4. Introduction to Vectors and Tensors, Ray M Bowen, C -C Wang, Dover Publications (2009)
5. An Introduction to Linear Algebra and Tensors, M A Akivis, V V Goldberg, Richard and Silverman, Dover Publications (2012)
6. Vector Analysis and Cartesian Tensors, D.E. Bourne and P.C. Kendall, CRC Press (1992).
7. Cartesian Tensors, Harold Jeffreys, Cambridge University Press (1931).

References for Laboratory Work:

1. Scilab by example: M. Affouf, 2012, ISBN: 978-1479203444
2. Learning Scientific Programming with Python, Christian Hill, Cambridge University Press (2016)
3. Computational Problems for Physics: With Guided Solutions Using Python, Rubin H. Landau, Manuel José Páez, CRC Press (2018).
4. Numerical Recipes in C^{++}: The Art of Scientific Computing, W.H. Press et.al., 2^{nd}Edn.,

Cambridge University Press (2013).
5. Elementary Numerical Analysis, K.E. Atkinson, 3rd Edn., 2007, Wiley India Edition.

PHE – 501 C: Embedded systems - Introduction to Microcontroller
Credit: 06 (Theory-04, Practical-02)
Theory: 60 Hours
Practical: 60 Hours

Course Objective

This course familiarizes students to the designing and development of embedded systems. This corse gives a review of microprocessor and introduces microcontroller 8051.

Course Learning Outcomes

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

- Know the major components that constitute an embedded system.
- Understand what is a microcontroller, microcomputer embedded system.
- Describe 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.
- Interface 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
- Learn to use the Arduino Uno (an open source microcontroller board) in simple applications.
- In the laboratory, students will program 8051 microcontroller and Arduino to perform various experiments.

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)

8051microcontroller: 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 microcontrollers, 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

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'inthesevensegmentLEDdisplay.
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 for Theory : Essential Readings :

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. Introduction to embedded system, K.V. Shibu, 1st edition, 2009, McGraw Hill
4. Microprocessors and Microcontrollers, Krishna Kant, 2nd Edition, 2016. PHI learning Pvt. Ltd.

Additional Readings :

1. Embedded Systems & Robots, Subrata Ghoshal, 2009, Cengage Learning
2. Embedded System, B.K. Rao, 2011, PHI Learning Pvt. Ltd.

References for Laboratory Work :

1. Microcontrollers in practice, I.Susnea and M.Mitescu, 2005, Springer.

Embedded Microcomputer systems: Real time interfacing, J.W.Valvano 2011, Cengage Learnin

PHE – 602 A: Medical Physics
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.
- Gain 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.

(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. 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, ImageGuided 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

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 for Theory: Essential Readings:

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)

Additional Readings:

1. The essential physics of Medical Imaging: Bushberg, Seibert, Leidholdt and Boone Lippincot Williams and Wilkins, Second Edition (2002)
2. Handbook of Physics in Diagnostic Imaging: R.S.Livingstone: B.I. Publication Pvt Ltd.
3. The Physics of Radiology-H E Johns and Cunningham.

Physics of Radiation Therapy : F M Khan - Williams and Wilkins, 3rd edition (2003)

PHE – 602 B: Biological Physics
Credit : 06 (Theory-05, Tutorial-01)
Theory : 75 Hours
Tutorial : 15 Hours

Course Objective

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

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 for Theory: Essential Readings:

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)

Evolution; M. Ridley (Blackwell Publishers, 2009, 3rd edition).

PHE – 602 C: Physics of Devices and Instruments

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 the basic knowledge of semiconductor device physics and electronic circuits along with the practical technological considerations and applications.
- Understand the operation of devices such as UJT, JFET, MOS, various bias circuits of MOSFET, Charge coupled Devices and Tunnel Diode.
- Learn to analyze MOSFET circuits and develop an understanding of MOSFET I-V characteristics and the allowed frequency limits.
- Learn the IC fabrication technology involving the process of diffusion, implantation, oxidation and etching with an emphasis on photolithography and electron-lithography.
- Apply concepts for the regulation of power supply by developing an understanding of various kinds of RC filters classified on the basis of allowed range of frequencies.
- Learn basic principles of phase locked loop (PLL) and understand its operation.

- Gain understanding of Digital Data serial and parallel Communication Standards. Knowledge of USB standards and GPIB.
- 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.

(15 lectures)

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 for Theory: Essential Readings:

1. Physics of Semiconductor Devices, S.M.Sze and K.K.Ng, 3rd Edition 2008, John Wiley & Sons
2. Electronic Devices and Circuits, A. Mottershead, 1998, PHI Learning Pvt. Ltd.
3. Electronic Communication systems, G. Kennedy, 1999, Tata McGraw Hill.
4. Integrated Electronics, J. Millman and C.C. Halkias, 1991, Tata Mc-Graw Hill.
5. Electronics: Fundamentals and Applications, J.D. Ryder, 2004, Prentice Hall.

Additional Readings:

1. Op-Amps & Linear Integrated Circuits, R.A.Gayakwad, 4 Ed. 2000, PHI Learning Pvt. Ltd

   Introduction to Measurements & Instrumentation, A.K.Ghosh, 4th Edition, 2017, PHI Learning

   Semiconductor Physics and Devices, D.A. Neamen, 2011, 4th Edition, McGraw Hill

References for Laboratory Work:

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

of India
2. Basic Electronics: A text lab manual, P.B.Zbar, A.P.Malvino, M.A.Miller,1994, Mc-Graw Hill
3. Introduction to PSPICE using ORCAD for circuits& Electronics, M.H.Rashid,2003, PHI Learning.

PHE – 703 A: Nuclear and Particle Physics
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

- 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 for Theory:

Essential Readings:

1. Basic ideas and concepts in Nuclear Physics: An introductory approach by K Heyde, third edition, IOP Publication, 1999.

2. Nuclear Physics by S N Ghoshal, First edition, S. Chand Publication, 2010.
3. Introductory Nuclear Physics by K S Krane, Wiley-India Publication, 2008.
4. Nuclear Physics: principles and applications by J Lilley, Wiley Publication, 2006.
5. Radiation detection and measurement, G F Knoll, John Wiley & Sons, 2010.
6. Introduction to elementary particles by D J Griffiths, Wiley, 2008.

Additional Readings:

1. Concepts of Nuclear Physics by B L Cohen, Tata McGraw Hill Publication, 1974.
2. Physics and Engineering of Radiation Detection by S N Ahmed, Academic Press Elsevier, 2007.
3. Techniques for Nuclear and Particle Physics experiments by WR Leo, Springer, 1994.
4. Modern Physics by R A Serway, C J Moses and C A Moyer, 3rd edition, Thomson Brooks Cole, 2012.
5. Modern Physics for Scientists and Engineers by S T Thornton and A Rex, 4th edition, Cengage Learning, 2013.
6. Modern Physics by R A Serway, C J Moses and C A Moyer, 3rd edition, Thomson Brooks Cole, 2012.
7. Concepts of Modern Physics by Arthur Beiser, McGraw Hill Education, 2009.

References for Tutorial:

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

PHE – 703 B: Advanced Mathematical Physics-II
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 its applications: Geodesics in two and three dimensions, Euler Lagrange Equation and simple problems in one and two dimensions.
- Acquire basic concept of Hamiltonian, Hamilton'sprincipleand Hamiltonianequationof motion, Poisson and Lagrange brackets.
- Learn elementary group theory: 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.

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 for Theory:

Essential Readings:

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 Probability, J. V. Uspensky, 1937, Mc Graw-Hill.

Additional Readings:

Introduction to Mathematical Physics: Methods & Concepts: Chun Wa Wong, 2012, Oxford University Press

PHE – 703 C: Astronomy and Astrophysics
Credit : 06 (Theory-05, Tutorial-01)
Theory : 75 Hours
Tutorial : 15 Hours

Course Objective

This course is designed to provide students with the basic knowledge about the theory and techniques of observational astronomy and physics of the astrophysical phenomenon. It applies theoretical concepts and mathematical techniques students have learnt in their earlier courses to astronomical and astrophysical phenomenon.

Course Learning Outcomes

Students completing this course will 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: 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 for Theory: Essential Readings:

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. BaidyanathBasu, An introduction to Astrophysics, Second printing, Prentice - Hall of India Private limited, New Delhi,2001.
5. Introductory Astronomy and Astrophysics, M. Zeilik and S.A. Gregory, 4th Edition, Saunders College Publishing.

Additional Readings:

1. Explorations: Introduction to Astronomy, ThomosArny and Stephen Schneider, 2014, 7th edition, McGraw Hill
2. Principles of Stellar Dynamics, S Chandrasekhar, Dover Books
3. The Physical Universe: An Introduction to Astronomy, F H Shu, University Science Books
4. Textbook of Astronomy and Astrophysics with elements of cosmology, V.B. Bhatia, Narosa Publication.

PHE – 804 A: Nano Materials and Applications
Credit : 06 (Theory-04, Practical-02)
Theory : 60 Hours
Practical : 60 Hours

Course Objective

The syllabus introduces the basic concepts and principles to 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. 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 the role of confinement on the density of state function and so on the various properties exhibited by nanomaterials compared to bulk materials.
- Explain various methods for the synthesis/growth of nanomaterials including top down and bottom up approaches.
- 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 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 various applications of nano particles, quantum dots, nano wires etc
- Explain why nanomaterials exhibit properties which are sometimes very opposite, like magnetic, to their bulk counterparts.
- In the Lab course students will synthesize nanoparticles by different chemical routes and characterize them in the laboratory using the different techniques, learnt in the theory. They will also carry out thin film preparation and prepare capacitors and evaluate its performance. They will 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 LaserDeposition (PLD), electric arc deposition for CNT, C grapheme, Chemical vapor 60 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).

PHE – 804 B: Communication Electronics
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 and communication techniques based on Analog Modulation, Analog and digital Pulse Modulation. Communication and Navigation systems such as GPS and mobile telephony system are also introduced. This paper will essentially connect the text book knowledge with the most popular communication technology in real world.

Course Learning Outcomes

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

- Understand of fundamentals of electronic communication system and electromagnetic communication spectrum with an idea of frequency allocation for radio communication system in India.
- Gain an insight on the use of different modulation and demodulation techniques used in analog communication
- Learn the generation and detection of a signal through pulse and digital modulation techniques and multiplexing.
- Gain an in-depth understanding of different concepts used in a satellite communication system.
- Study the concept of Mobile radio propagation, cellular system design and understand mobile technologies like GSM and CDMA.
- Understand evolution of mobile communication generations 2G, 3G, and 4G with their characteristics and limitations.
- In the laboratory course, students will apply the theoretical concepts 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

PHYSICS LAB-DSE LAB: Communication System 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 for Theory : Essential Readings :

1. Electronic Communications, D. Roddy and J. Coolen, Pearson Education India.
2. Advanced Electronics Communication Systems- Tomasi, 6th Edn. Prentice Hall.
3. Electronic Communication systems, G. Kennedy, 3rd Edn., 1999, Tata McGraw Hill.
4. Principles of Electronic communication systems – Frenzel, 3rd edition, McGraw Hill

Additional Readings :

1. Modern Digital and Analog Communication Systems, B.P. Lathi, 4th Edition, 2011, Oxford University Press.
2. Communication Systems, S. Haykin, 2006, Wiley India
3. Wireless communications, Andrea Goldsmith, 2015, Cambridge University Press

References for Laboratory Work:

1. Electronic Communication system, Blake, Cengage, 5th edition.
2. Introduction to Communication systems, U. Madhow, 1st Edition, 2018, Cambridge University Press

PHE 804C: Atomic and Molecular Physics
Credit:06 (Theory-04, Practical-02)
Theory: 60 Hours
Practical: 60Hours

Course Objectives

The main objective is to teach the students the basic atomic and molecular (diatomic) structures with quantum mechanical approach leading to their fundamental spectroscopies. The fundamentals and properties of a coherent light source as Laser and its types will also be taught.

Course learning outcomes:

Students will learn the details of atomic and diatomic molecular (diatomic) structures in terms of quantum mechanical treatment elaborately beyond the basic models. It will give the descriptions of fine structure of atoms and rotational, vibrational and electronic energies of molecules manifesting in their respective spectroscopies. The details of these spectroscopies would serve as the fundamentals for various concerned experimental results. The basic principles of light coherence as laser with their types and variants will also be covered exposing the students to the important modern spectroscopic tool

Unit1

Atomic Physics: Quantum states of one electron atoms-Atomic orbitals-Hydrogen spectrum-Pauli's principle - Spectra of alkali elements-Spin orbit interaction, Two electron systems-interaction energy in *LS* and *JJ* Coupling, Normal and anomalous Zeeman effect-Paschen Back effect - Stark effect

(15 lectures)

Unit2

Molecular Physics: Introduction to molecular structure, The Born-Oppenheimer separation for diatomic molecules, Heitler-London and molecular orbital theories of H2, bonding and anti-bonding MOs, Rotation and vibration of diatomic molecules, Electronic states, Electronic spectra of diatomic molecules, Franck-Condon principle

(15 lectures)

Unit3

Molecular Spectra: Microwave, Infrared, Raman and UV-VIS spectra of diatomic and polyatomic molecules, Quantum theory of Raman effect, rotational, vibrational and rotation-vibration Raman spectra of diatomic and polyatomic molecules

(14 lectures)

Unit4

Lasers: Photons, spontaneous and stimulated emission, Einstein A and B coefficients and relation to the Planck distribution, rate equations for absorption and emission, two level and three level systems, population inversion and light amplification, optical resonators and the basic working principle of a laser, Ruby laser, He-Ne laser, Ar-ion laser, Semiconductor laser.

(16 lectures)

Practical: 60Hours

1. Verification of Bohr's atomic orbital theory through Frank-Hertz experiment.
2. To determine the wavelength of laser light using single slit diffraction pattern.
3. To prove the Zeeman effect experiment and find the Lande-g factors of the electronic energy levels involved in transitions.
4. Determination of Rydberg constant by studying Hydrogen/ Helium spectrum.
5. Determination of wave length of LASER light by Michelson interferometer.
6. Determination of wave length of light by Fabry Perot interferometer.
7. Determination of refractive index of glass plate using Michelson interferometer.
8. To determine the line spacing of grating element by using laser.

References : Essential Readings:

1 Bransden and Joamchain, Physics of Atoms and Molecules.
2 Dahl, The quantum world of atoms and molecules.
3 H.E.White(T), Introduction to Atomic spectra
4 C.B.Banwell (T), Fundamentals of molecular spectroscopy.
5 Walker & Straughen, Spectroscopy Vol I, II & III.
6 G.M.Barrow, Introduction to Molecular spectroscopy.
7 Molecular Physics, W. Demtroder (Wiley-VCH, 2005)

9.3. SKILL-ENHANCEMENT COURSES (SEC)

PHSEC – 101 A: Physics Workshop Skills
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.

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

Teacher may give long duration project based on this paper.
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].HSEC – 101 B: Computational Physics Skills

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 and data visualization using GNU plot. Further they will also learn to prepare long formatted document using latex.

Course Learning Outcomes

Students will be able to

- Use computers for solving problems in Physics.
- Prepare algorithms and flowcharts for solving a problem.
- Use Linux commands on terminal
- Use an unformatted editor to write sources codes.
- Learn "Scientific Word Processing", in particular, using LaTeX for preparing articles, papers etc. which include mathematical equations, picture and tables.
- Learn the basic commands of Gnuplot.

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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

(9 Lectures)

Practicals/Hands on exercises:

PRACTICALS-SEC LAB: Computational Physics Skills Lab

Teacher may give long duration project based on this paper.

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.

References

1. Computer Programming in Fortran 77".V.Rajaraman(Publisher:PHI).
2. LaTeX–A Document Preparation System", Leslie Lamport (Second Edition, Addison-Wesley, 1994).
3. Gnuplot in action: understanding data with graphs, Philip K Janert, (Manning 2010).
4. Schaum's Outline of Theory and Problems of Programming with Fortran, S Lipsdutz and A Poe, 1986Mc-Graw Hill Book Co.
5. Elementary Numerical Analysis, K.E.Atkinson,3rd Edn., 2007, Wiley India Edition.

PHSEC – 101 C: Electrical circuits and Network Skills
Credit:04 (Theory-02, Practical-02)
Theory: 30 Hours
Practical : 60 Hours

Course Objectives

To develop an understanding of basic principles of electricity and its household applications. To impart basic knowledge of solid state devices and their applications, understanding of electrical wiring and installation.

Course Leaning Outcomes

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

- Demonstrate good comprehension of basic principles of electricity including ideas about voltage, current and resistance.
- Develop the capacity to analyze and evaluate schematics of power efficient electrical circuits while demonstrating insight into tracking of interconnections within elements while identifying current flow and voltage drop.
- Gain knowledge about generators, transformers and electric motors. The knowledge would include interfacing aspects and consumer defined control of speed and power.
- Acquire capacity to work theoretically and practically with solid-state devices. Delve into practical aspects related to electrical wiring like various types of conductors and cables, wiring-Star and delta connections, voltage drop and losses.
- Measure current, voltage, power in DC and AC circuits, acquire proficiency in fabrication of regulated power supply.
- Develop capacity to identify and suggest types and sizes of solid and 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 Essential Readings:

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. Performance and design of AC machines - M G Say ELBS Edn.
4. Electronic Devices and Circuits, A. Mottershead,1998, PHI Learning Pvt. Ltd.
5. Network, Lines and Fields, John D. Ryder, Pearson Ed. II, 2015.

Additional Readings:

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

PHSEC – 101 D: Basic Instrumentation Skills
Credit:04 (Theory-02, Practical-02)
Theory : 30 Hours
Practical : 60 Hours

Course Objective

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

Course Learning Outcomes

At the end of this course the students will learn the following:

- The student is expected to have the necessary working knowledge on accuracy, precision, resolution, range and errors/uncertainty in measurements.
- Course learning begins with the basic understanding of the measurement and errors in measurement. It then familiarizes about each and every specification of a multimeter, 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 ability to use analog and digital instruments like 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

Practical:

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 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 Essential Readings:

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

Additional Readings:

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

PHSEC – 202 A: Renewable Energy and Energy harvesting
Credit:04 (Theory-02, Practical-02)
Theory : 30 Hours
Practical : 60 Hours

Course Objective

To impart knowledge and hands on learning about various alternate energy sources to teach the ways of harvesting energy using wind, solar, mechanical, ocean, geothermal energy etc. To review the working of various energy harvesting systems which are installed worldwide.

Course Learning Outcomes

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

- Knowledge of various sources of energy for harvesting
- Understand the need of energy conversion and the various methods of energy Storage.
- A good understanding of various renewable energy systems, and its components.
- Knowledge about renewable energy technologies, different storage technologies, distribution grid, smart grid including sensors, regulation and their control.
- Design the model for sending the wind energy or solar energy plant.
- The students will gain hand on experience of:
  - (i) different kinds of alternative energy sources,
  - (ii) conversion of vibration into voltage using piezoelectric materials,
  - (iii) 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.**

(3 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.

(6 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.

(3 Lectures)

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

Teacher may give long duration project based on this paper.

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).

PHSEC – 202 B: Technical Drawing
Credit:04 (Theory-02, Practical-02)
Theory: 30 Hours
Practical : 60 Hours

Course Objective

To introduce the students to modern visualization techniques and their applications in diverse areas including computer aided design. To offer hands-on experience of engineering drawing based on knowledge gained using computer aided designing software.

Course Learning Outcomes

This course 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 section.
- 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.
- Using Computer Aided Design (CAD) software and AutoCAD techniques.

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)

Practical: 60 Hours

PRACTICALS-SEC LAB: Engineering Design and Prototyping/Technical Lab

Teacher may give long duration project based on this paper. Five experiments based on the above theory.

Teacher may design at least five experiments based on the above syllabus.

References

1. Engineering Graphic, K. Venugopal and V. Raja Prabhu, New Age International
2. Engineering Drawing, Dhananjay A Jolhe, McGraw-Hill.
3. Don S. Lemons, Drawing Physics, MIT Press, M A Boston, 2018, ISBN:9780262535199.
4. AutoCAD 2010 Tutor for Engineering Graphics, Alan J KalaMeja, Delmar Cengage Learning.
5. James A. Leach, AutoCAD 2017 Instructor, SDC publication, Mission, KS 2016. ISBN:978163057029.

PHSEC – 202 C: Radiation Safety
Credit: 04 (Theory-02, Practical-02)
Theory: 30 Hours
Practical: 60 Hours

Course Objective

This course focusses 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.

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.

- 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 detectors, Determination of gamma ray linear and mass absorption coefficient of a given material for radiation shielding application.

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

Teacher may give long duration project based on this paper.

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_4 etc.). Investigation of possible radiation in different routine materials by operating GM counter at operating voltage.
11. Study of absorption of beta particles in Aluminum using GM counter.
12. 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 for Theory: Essential reading:

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

Additional reading:

1. Radiation detection and measurement by G F Knoll, 4th Edition, Wiley Publications, 2010.
2. Techniques for Nuclear and Particle Physics experiments by W R Leo, Springer, 1994.
3. Thermoluminescence dosimetry by A F Mcknlay, Bristol, Adam Hilger (Medical Physics Hand book 5.
4. Medical Radiation Physics by W R Hendee, Year book Medical Publishers, Inc., London, 1981.
5. Physics and Engineering of Radiation Detection by S N Ahmed, Academic Press Elsevier, 2007.
6. Nuclear and Particle Physics by W E Burcham and M Jobes, Harlow Longman Group, 1995.
7. IAEA Publications: (a) General safety requirements Part 1, No. GSR Part 1 (2010), Part 3 No. GSR Part 3 (Interium) (2010); (b) Safety Standards Series No. RS-G-1.5 (2002), Rs-G-1.9 (2005), Safety Series No. 120 (1996); (c) Safety Guide GS-G-2.1 (2007).

References for Laboratory Work:

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

PHSEC – 202 D: Applied Optics
Credit:04 (Theory-02, Practical-02)
Theory: 30 Hours
Practical: 60 Hours

Course Objective

This paper provides the conceptual understanding of various branches of modern optics to the students. This course introduces basic principles of LASER, Holography and signal transmission via optical fiber.

Course Learning Outcomes

Students will be able to:

- Understand basic lasing mechanism qualitatively, types of lasers, characteristics of laser light and its application in developing LED, Holography.
- Gain concepts of Fourier optics and Fourier transform spectroscopy.
- Understand basic principle and theory of Holography.
- Grasp the idea of total internal reflection and learn the characteristics of optical fibers.

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

Teacher may give long duration project based on this paper

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. Introduction to Fourier Optics, Joseph W. Goodman, The McGraw- Hill, 1996.
2. Introduction to Fiber Optics, A. Ghatak & K. Thyagarajan, Cambridge University Press.
3. Fibre optics through experiments, M.R.Shenoy, S.K.Khijwania, et.al. 2009, Viva Books
4. Optical Electronics, Ajoy Ghatak and K. Thyagarajan, 2011, Cambridge University Press.
5. Optics, Karl Dieter Moller, Learning by computing with model examples, 2007, Springer.

9.4. GENERIC ELECTIVE (GE)

PHGE - 301: Mechanics
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.

Course Learning Outcomes

Upon completion of this course, students are expected to

- 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 translational and rotational dynamics of a system of particles.
- ApplyKepler'slaws to describe the motion of planets and satellite in circular orbit.

- 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, 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

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: Essential Readings:

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. University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole

Additional Readings:

1. Engineering Mechanics, Basudeb Bhattacharya, 2nd ed., 2015, Oxford University Press.

References for Laboratory Work:

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

PHGE - 402: Electricity and Magnetism
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

- Gain the concepts of vector analysis.
- 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.
- Calculate the magnetic forces that act on moving charges and the magnetic fields due to currents (Biot- Savart and Ampere laws).
- Gain 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.
- In the laboratory course the student will get an opportunity to verify network theorems and study different circuits such as RC circuit, LCR circuit. Also, different methods to measure low and high resistance, capacitance etc.

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

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 the Self Induction of a Coil by Rayleigh’s Method.
2. To compare the capacitance 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: Essential Readings:

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. University Physics, Ronald Lane Reese, 2003, Thomson Brooks/Cole.
5. D.J. Griffiths, Introduction to Electrodynamics, 3rd Edn., 1998, Benjamin Cummings.

References for Laboratory Work:

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. Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press

PHGE - 503: Solid State Physics
Credit: 06 (Theory-04, Practical-02)
Theory: 60 Hours
Practical: 60 Hours

Course Objective

This course introduces the basic concepts and principles required to understand the various properties exhibited by condensed matter, especially solids. It enables the students to appreciate how the interesting and wonderful properties exhibited by matter depend upon its atomic and molecular constituents. The gained knowledge helps to solve problems in solid state physics using relevant mathematical tools. It also communicates the importance of solid state physics in modern society.

Course Learning Outcomes

On successful completion of the module students should be able to

- Elucidate the concept of lattice, crystals and symmetry operations.
- Understand the elementary lattice dynamics and its influence on the properties of materials.
- Describe the main features of the physics of electrons in solids: origin of energy bands, and their 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.
- Learn the properties of superconductivity in solid.
- In the laboratory students will carry out experiments based on the theory that they have learned to measure the magnetic susceptibility, dielectric constant, trace hysteresis loop.

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 Lecture)

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 susceptibiity 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, 8^{th} Ed.,2004, Wiley India Pvt. Ltd.
2. Elements of Solid State Physics, J.P. Srivastava, 2^{nd} 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. Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press

PHGE - 604: Waves and Optics

Credit : 06 (Theory-04, Practical-02)

Theory : 60 Hours

Practical : 60 Hours

Course Objective

This course reviews the concepts of waves and optics learnt at school from a more advanced perspective and goes on to build new concepts. It 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 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 Interference as superposition of waves from coherent sources derived from same parent source.
- Demonstrate basic concepts of Diffraction: Superposition of wavelets diffracted from aperture, understand Fraunhoffer and Fresnel Diffraction.
- 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 wavefron. Youngs'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 λ2 – 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: Essential Readings :

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

Additional Readings:

1. Fundamentals of Optics, A. Kumar, H.R. Gulati and D.R. Khanna, 2011, R. Chand Publications
2. University Physics. F.W. Sears, M.W. Zemansky and H.D. Young. 13/e, 1986. Addison-Wesley.

References for Laboratory Work:

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

PHGE - 705: Elements of Modern Physics
Credit: 06 (Theory-04, Practical-02)
Theory: 60 Hours
Practical: 60 Hours

Course Objective

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

Course Learning Outcomes

After getting exposure to this course, the following topics would be learnt:

- Main aspects of the inadequacies of classical mechanics as well as understanding of the historical development of quantum mechanics.
- Formulation of Schrodinger equation and the idea of probability interpretation associated with wave-functions.
- The spontaneous and stimulated emission of radiation, optical pumping and population inversion. Three level and four level lasers. Ruby laser and He-Ne laser in details. Basic lasing.
- 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: Nuclear processes to produce nuclear energy in nuclear reactor and stellar energy in stars.
- In the laboratory course, the students will get opportunity to measure Planck's constant, verify photoelectric effect, determine e/m of electron, Ionization potential of atoms, study emission and absorption line spectra. They will also find wavelength of Laser sources by single and Double slit experiment, wavelength and angular spread of He-Ne

Laser using plane diffraction grating.

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, 2^{nd} Edition, 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} Edition, 2011, Kitab Mahal.
4. Practical Physics, G.L. Squires, 2015, 4th Edition, Cambridge University Press

Additional Resources:

2. Six Ideas that Shaped Physics: Particle Behave like Waves, T.A.Moore, 2003, McGraw Hill
3. Thirty years that shook physics: the story of quantum theory, George Gamow, Garden

City, NY: Doubleday, 1966

4. Lectures on Quantum Mechanics: Fundamentals and Applications, eds. A. Pathak and Ajoy Ghatak, Viva Books Pvt. Ltd., 2019
5. Quantum Theory, David Bohm, Dover Publications, 1979
6. Introduction to Quantum Mechanics, David J. Griffith, 2005, Pearson Education.

PHGE - 806: Nuclear and Particle Physics
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

- 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 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 for Theory: Essential Readings:

1. Basic ideas and concepts in Nuclear Physics: An introductory approach by K Heyde, third edition, IOP Publication, 1999.
2. Nuclear Physics by S N Ghoshal, First edition, S. Chand Publication, 2010.
3. Introductory Nuclear Physics by K S Krane, Wiley-India Publication, 2008.

4. Nuclear Physics: principles and applications by J Lilley, Wiley Publication, 2006.
5. Radiation detection and measurement, G F Knoll, John Wiley & Sons, 2010.
6. Introduction to elementary particles by D J Griffiths, Wiley, 2008.

Additional Readings:

1. Concepts of Nuclear Physics by B L Cohen, Tata McGraw Hill Publication, 1974.
2. Physics and Engineering of Radiation Detection by S N Ahmed, Academic Press Elsevier, 2007.
3. Techniques for Nuclear and Particle Physics experiments by WR Leo, Springer, 1994.
4. Modern Physics by R A Serway, C J Moses and C A Moyer, 3rd edition, Thomson Brooks Cole, 2012.
5. Modern Physics for Scientists and Engineers by S T Thornton and A Rex, 4th edition, Cengage Learning, 2013.
6. Modern Physics by R A Serway, C J Moses and C A Moyer, 3rd edition, Thomson Brooks Cole, 2012.
7. Concepts of Modern Physics by Arthur Beiser, McGraw Hill Education, 2009.

References for Tutorial:

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