Undergraduate
Course Handbook

Curriculum and Syllabus

for the B.Sc. (Honors) Degree in Physics

(For students admitted in session: 2018-19 to 2021-22)

Department of Physics, Jahangirnagar University, Savar, Dhaka -1342, Bangladesh.

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Guideline to use this handbook

Students in their first year should read the two sections 'Introduction' and 'First Year' in detail and skim the remainder for an overview of the courses. Students in later years should read the sections on Final Honors examination structure, the details for the relevant year. The handbook gives telephone numbers and e-mail addresses for contacting members of the academic staff, a comprehensive book list for the whole course.

Members of faculty will be happy to answer any questions you might have that are not answered in our printed documentation, but for particular information about teaching, students should contact their course teachers. Further information about the courses can be obtained from the Department of Physics web site http://juniv.edu/department/phy and from the Physics Teaching Faculty in the faculty offices.

For full and up-to date information on lecture timetables, contact respective course teachers or the office at the Physics Department.

Introduction

What is Physics?

Physics is a fundamental subject that serves as a foundation for most areas of science and engineering. Physics is a fundamental science, which seeks to investigate and understand the physical world, from the outermost reaches of the universe, to the innermost parts of the atom. It reaches from the quark to the largest of galaxies, through the material world we perceive directly with our senses, and encompassing all matter and timescales within these extremes. Physics is the subject that constantly asks "how and why?" of the material world, questioning why matter and energy exist and act as they do, and discovering the underlying rules which govern their behavior. Such a profound understanding of nature comes from the interplay of careful observation and critical reflection. Observations of the physical world lead physicists to formulate hypotheses which can be tested by experiments whose results allow even more refined theories to be advanced. Physicists now believe that all phenomena observed in the universe can be explained in terms of a handful of forces: gravity, electricity, magnetism, weak nuclear, and strong nuclear interactions. This combination of theory and experiment has progressed over the last four hundred years and is directly responsible for the technological advances that are central to our everyday lives. Wireless communications, radio, television and mobile phones are all made possible through an understanding of the theory of electromagnetism. X-rays, radioactivity and particle beams have led to advances in medicine. The invention of lasers and solid-state transistors by physicists paved the way for computers, DVD players and iPods. Understanding physical principles and discovering new laws that explain our universe at an even deeper level are the challenges that confront physicists and advance the subject in the 21st century. Physics graduates are equipped with the skills to understand these phenomena and prepared for a range of career pathways.

What will I study as part of my degree?

A physics graduate is someone who has demonstrated an ability to work through a demanding course of study and gained a wide variety of transferable technical skills. The physics degree provides a strong foundation in the core of the subject with opportunities to specialize in areas of particular interest. Among the physics subjects that can be studied at Jahangirnagar University (JU) are: Newtonian Dynamics; Quantum Mechanics; Special Relativity; Electromagnetism; Optics; Thermodynamics and Statistical Mechanics; Atomic, Nuclear and Particle Physics; Condensed Matter Physics; Astrophysics; Biophysics; Nanophysics; Atmospheric Physics; Medical Physics. The course achieves a balance between theoretical aspects, delivered by lectures, tutorials or small group projects, and practical work where students perform experiments to test the theory. Tackling problems in physics, describing the physical world using mathematics, carrying out experiments and comparing results critically with predictions from theory are all part of the training of a physics student. Due to their training, physicists are adaptable and proficient at mathematics and problem solving.

The department of Physics at JU aims to guide Physics graduates through these territory and to equip them with a range of thinking and practical skills which they will need for a subsequent career in Physics. The Four-year B.Sc. (Honors) in Physics degree programme at JU allows student to develop:

- Knowledge and understanding of the physical world and the underlying appropriate mathematical or experimental methodologies used to describe it;
- The attitude of mind conducive to critical questioning and creative thinking and the capacity to formulate ideas mathematically and explore them algebraically, graphically, and numerically;

- An understanding of laboratory experimentation and the ability to analyze experimental data and assess what can be inferred from it in the light of theoretical expectations and experimental uncertainties;
- The skills to formulate a coherent written and oral presentation based on material gathered and organized independently, use initiative, organize your time to meet deadlines and interact constructively with other people on a given physics topic;
- Knowledge of frontier activities capitalizing on the strengths of a thriving and diverse research environment;
- The skills required for employment in science-based industry, education and the wide spectrum of professions calling for numerate problem-solvers;
- General transferable skills related to IT & computing, problem-solving and communication.

What are the opportunities for graduates in Physics?

The spectacular expansion of our comprehension of the physical world forms an impressive part of the intellectual and cultural heritage of our times. The opportunity to add to this heritage is an important source of motivation for young physicists. The application of discoveries in physics to the solution of complex modern technological problems offers a vast field in which physicists make decisive contributions. The interplay of pure and applied physics has always been fruitful and today ensures many rewarding career opportunities for physics students. A physics graduate will have a sound knowledge of the fundamental theories of physics and how to apply them to practical problem solving, and will be well-prepared for a career in research, as a professional physicist, or for other high-flying positions in a wide range of areas. The physics degree trains students to think independently and critically, and to understand and analyze scientific and technological information. Many employers, across a wide variety of sectors, express a preference for hiring physics graduate because of their problem-solving abilities and their excellent mathematical and scientific literacy. The key transferable skills that graduate employers look for, includes:

- excellent communication skills
- work independently or as part of a team
- the ability to analyze problems
- time management

More than 30% of recent Physics graduates from JU go on to study for a higher degree, leading to careers in universities, in research and development in industrial and national laboratories like BCSIR, Atomic Energy Commission etc., nuclear power plant, medical imaging, radiological protection, the government institutions, meteorology, telecommunications, secondary and tertiary level teaching, computing and software design. Many others enter professions unrelated to Physics, such as finance and business, where the analytical and problem-solving skills they have developed are highly sought after. Many graduates pursue research degrees to MSc or PhD level and some continue their research careers both in Bangladesh and abroad at world renowned institutions.

The Physics Department

The Department of Physics at Jahangirnagar University (JU) is one of the leading Physics department in Bangladesh, with an average annual intake of about 70 undergraduates and it has 37 faculty positions in the department. The Department of Physics was established in 1973 and from then it successfully engaged in teaching and research activities. From those pioneering days and throughout the illustrious history of the department, the students and faculty members have aspired to contribute significantly to JU’s reputation as one of the premier institutions for higher study in the country by conducting many researches and developing the careers of the next generation of physicists.

Teaching and Research Activities

The Physics department offers the four-year B.Sc. (Honors) degree programme where students are taught courses in Physics and other basic sciences (Chemistry, Statistics), computer programming as well as English Language course. The department also runs a 1.5-year M.S. in Physics degree programme as well as an active Ph.D. programme with specialization in many major and frontline areas of Physics. Sharing a strong tie with Bangladesh Atomic Energy Commission (BAEC), Bangladesh Council of Scientific and Industrial Research (BCSIR) and other major research institutions of the country, research students work to develop experimental techniques and theoretical methods to investigate nature. The department conducts research on condensed matter physics, material science, plasma physics, computational physics, nuclear physics, radiation and health physics, bio- and medical physics, atmospheric physics and electronics. These represent the main areas of research carried out in the department. Students and faculties of the department have authored numerous articles published in international peer-reviewed journals and preceded on international conferences and seminars. They have regularly worked in many academic institutions and research facilities abroad as well.

Resources and Locations

The Department is located in the Physics buildings on the north side of the newly established Wazed Miah Science Research Centre (WSRC) and south side of the central Shaheed Minar, a monument established in memory of those who were killed during the 1952 Bengali Language Movement demonstrations. The main entrance to the Physics building is directly opposite to the Chemistry building. The Physics building is surrounded by a well tendered beautiful garden. There are 5 lecture rooms in the building, the lecture gallery is on the ground floor left to the main entrance. All the undergraduate practical laboratories are in the Physics building. The seminar library at the Physics building is well stocked with the recommended physics textbooks. The central library at JU also has a comprehensive collection of physics books and journals and physics student may use this library with their library card. There are numerous computer workstations in the computer laboratories on third floor of the Physics building. Students can use the computers at any time during office hours as well as use the computers to save and analyze data taken during practicals.

Student Support and Guidance

Student support and welfare are primarily University responsibilities: tutors, proctors, and other advisers make up a sympathetic and effective network of support for students. The Proctors’ and Assistant’s provides general information on welfare, health and recreation, as well as on student conduct and on the running of University examinations. In particular, complaints, appeals and advice on illness during examinations is provided. In addition, the University has a Counselling Service available to help student for personal development planning and also a Careers Service which provides careers advice for both undergraduates and graduates, both based in the Teacher and Student Center (TSC) Office, and the Physics department has dedicated faculty member for working actively to promote student support and welfare. Students are encouraged to make an appointment to responsible faculty member for further information and to ask any of the academic staff for help regarding Physics courses and practicals. Information on research opportunities is also available from the faculty members. Faculty members may also be contacted by telephone or by e-mail. A list of telephone numbers, e-mail addresses and research affiliations is given in this booklet.

Student Engagement and Interaction

To enhance student engagement and interaction, the department of Physics hold a wide range of events associated with the undergraduate/postgraduate student journey including, Welcome Week, Study Tour, Physics events and Graduation celebration events. Physics students are encouraged to participate in Physics conferences and professional events to build up their knowledge of the science community and enhance their professional development. Students can also take part in:

- the department's Physical Sciences Colloquia, a popular series of talks given by internal and external experts on relevant and current topics
- the student-run Physics Societies, which organize talks with renowned physicist, practical demonstrations and social events

To ensure the student voice is heard and appropriate feedback obtained, department hold informal meetings with the Undergraduate and Postgraduate representatives who are elected across all years. Student reps facilitates communications between faculty members and students. Student feedback is also provided via student surveys and we encourage students to take part in these when they are invited to do so.

Structure of Undergraduate (Physics) Curriculum

Four-year B.Sc. Program in Physics

Jahangirnagar University's four-year BSc program is intended to provide a broad-based education at undergraduate level to facilitate an early induction to global research scenario. The undergraduate curriculum in physics has been carefully designed to encompass theoretical, experimental and computational aspects of physics education, to provide a firm knowledge of the basic principles of physics, an appreciation of a wide range of physical problems of current interest, and the capacity to formulate and solve new problems. In addition to classwork and problem solving, the curriculum includes studying physical phenomena in the laboratory. Sufficient exposure is to be provided on mathematics, chemical and engineering sciences; moreover, elements of computer programming, statistical science and communication skills are added for an all-round intellectual development. The exposure to physics and interdisciplinary research is to be provided through a plethora of departmental and non-departmental optional courses pitched at the appropriate level and also by involving students to **undergraduate research programs** through departmental projects. Physics students are strongly encouraged to go beyond the formal theoretical and experimental course work and become involved in research projects under the guidance of individual faculty members. These opportunities render the present program unique and attractive for the students motivated to make important contribution to research at the cutting edge not only in Physics but also in related science and engineering science disciplines.

The Physics Courses – Aims and Objectives

The BSc Physics degree forms the core of department's teaching programme. Across the four years students will learn the fundamentals of modern physics, together with the mathematical, practical and computational skills that will need to fully appreciate the subject. The four-year undergraduate degree allows students to cover physics in more breadth and depth. Building on the core physics programme, students will study a range of specialized allied courses delivered by esteemed faculty members. On completion of BSc courses, students should have developed a thorough understanding and broad knowledge of the general theoretical and experimental scientific principles of physics, so that they have the resources to apply their knowledge to a wide range of physical phenomena. They should have learned the techniques required in a modern mathematically-based physics course, gained an understanding of the conceptual structure associated with the major physical theories, understood how to set up simple models of physical problems and learned a wide range of problem-solving skills, both analytical and computational, and how to apply them in contexts that may not be familiar. Students will also have learned the experimental techniques required by working physicists involving sound and safe procedures, how to record and analyze data and how to write accounts of laboratory work which can be clearly understood by other scientists, and will have investigated experimentally some of the most important physical phenomena. On completion of their course, BSc students will have gained some experience of working on an open-ended assignment and all students will have had the opportunity either to acquire some expertise in a more specialized area of physics of their choice. MS students, in addition, will have acquired in-depth knowledge in chosen specialization within physics, and – from their thesis/project work – they will have learned how to plan and execute an open-ended piece of work, and will have gained experience of a research environment.

Year One and Two

First years courses offer extensive student support to assist the transition into higher education and develop independent learning skills. Physics students will build up their knowledge of the subject through courses in the core elements of physics. In their freshman and sophomore year, physics students get to grips with the broad knowledge base on which physical science is built, including electricity and optics, mathematics, mechanics, thermodynamics and matter. They will also develop the mathematical skills needed to speak the language of advanced physics, and carry out laboratory work to provide the background they need in experimentation and computation. Students also develop their experimental, statistical and analytical skills.

Year Three (Junior Year)

The first and second-year courses lead into more advanced areas of the subject such as statistical physics and quantum mechanics. They will build on the core skills developed in the freshman and sophomore year to study aspects of physics including solid-state physics, nuclear physics and electrodynamics. Similarly, students will have the opportunity to develop the core practical skills learned in the freshman and sophomore year to undertake more advanced laboratory work, making frequent use of computer control in their experiments.

Year Four (Senior Year)

In the fourth year of the BSc, student will finish off the core physics syllabus. In addition to the coursework carried out during the senior year, the student is required to write a senior project based on their own research which will be supervised by a dedicated research faculty member. The topic might be chosen from one of the active experimental or theoretical research fields of the Physics Department, or might be suggested by a faculty member with some subsidiary interest. A student could also choose a topic relating physics and another field in an area that interests them, such as biophysics, geophysics, or engineering physics. The purpose of the project is to give students exposure to how physics research is actually performed by immersing them in journal, as opposed to textbook, literature and apply the theoretical, computational and experimental techniques they have learned to a problem at the cutting-edge of physics. During the project, BSc students will receive additional support to help them prepare for independent learning by continuously assessed activities such as the preparation of scientific reports and student presentations in their final year. Each project will be written in close consultation with a faculty adviser, who is typically performing research in the subject area of the paper. The combination of specialist courses and an attachment to one of department's research teams opens avenues for even deeper exploration: for example, in electronics, medical physics, space physics, fiber optics, the atomic-scale structure of a new engineering material, or neutron scattering work.

The B. Sc. (Hons.) in Physics consists of the following theoretical and laboratory courses spread over four academic years: Part-I, Part-II, Part-III, Part-IV and carries a total of **140 credits** and **3500 Marks.** These courses develop transferable skills related to communication, computing, and problem solving. Their aim is to ensure that, on graduation, all students will be in a position to choose from many different careers, and have the skills, knowledge and understanding to make a rapid contribution to their chosen employment or research area, and that those with the aptitude are prepared for postgraduate study in physics, and thus contribute to the vitality of Bangladesh research.

The following pages outline the compulsory and optional elements for BSc Honors degree programme for each year of study. This structure may be modified in future academic years as a part of a process of curriculum review and development.

Freshman Year (First Year): Courses of studies for Part-I Examination

Course No.	Course Title	Course Nature	Credit	Unit	Marks
PHY-101	Mechanics	Theory	4.0	1.0	**100**
PHY-102	Properties of Matter and Waves	Theory	4.0	1.0	**100**
PHY-103	Electricity and Magnetism	Theory	4.0	1.0	**100**
PHY-104**	Mathematical Methods for Physics	Theory	4.0	1.0	**100**
PHY-105**	Chemistry-I	Theory	2.0	0.5	**50**
PHY-106**	Principle of Statistics	Theory	2.0	0.5	**50**
PHY-107**	Functional English	Theory	2.0	0.5	**50**
PHY-108	Physics Lab.-I	Practical	4.0	1.0	**100**
	Viva Voce	Oral	2.0	0.5	**50**
Total			**28**	**7.0**	**700**

Sophomore Year (Second Year): Courses of studies for Part-II Examination

Course No.	Course Title	Course Nature	Credit	Unit	Marks
PHY-201	Thermal Physics	Theory	4.0	1.0	**100**
PHY-202	Optics	Theory	4.0	1.0	**100**
PHY-203	Mathematical Physics	Theory	4.0	1.0	**100**
PHY-204	Classical Mechanics	Theory	4.0	1.0	**100**
PHY-205	Basic Electronics	Theory	4.0	1.0	**100**
PHY-206**	Computer Programming & Numerical Methods	Theory	4.0	1.0	**100**
PHY-207**	Chemistry-II	Theory	2.0	0.5	**50**
PHY-208	Physics Lab.-II	Practical	4.0	1.0	**100**
PHY-209	Computer Programming Lab.	Practical	2.0	0.5	**50**
PHY-210	Chemistry- Laboratory for Physics	Practical	2.0	0.5	**50**
	Viva voce	Oral	2.0	0.5	**50**
Total			**36**	**9.0**	**900**

Junior Year (Third Year): Courses of studies for Part-III Examination

Course No.	Course Title	Course Nature	Credit	Unit	Marks
PHY-301	Quantum Mechanics-I	Theory	4.0	1.0	**100**
PHY-302	Electrodynamics	Theory	4.0	1.0	**100**
PHY-303	Atomic and Molecular Physics	Theory	4.0	1.0	**100**
PHY-304	Statistical Mechanics	Theory	4.0	1.0	**100**
PHY-305	Solid State Physics-I	Theory	4.0	1.0	**100**
PHY-306	Nuclear Physics-I	Theory	4.0	1.0	**100**
PHY-307	Digital Electronics	Theory	4.0	1.0	**100**
PHY-308	Computational Physics	Theory	4.0	1.0	**100**
PHY-309	Physics Lab.-III	Practical	4.0	1.0	**100**
	Viva voce	Oral	2.0	0.5	**50**
Total			**38**	**9.5**	**950**

Senior Year (Fourth Year): Courses of studies for Part-IV Examination

Course No.	Course Title	Course Nature	Credit	Unit	Marks
PHY-401	Quantum Mechanics-II	Theory	4.0	1.0	**100**
PHY-402	Astrophysics	Theory	2.0	0.5	**50**
PHY-403	Plasma Physics	Theory	4.0	1.0	**100**
PHY-404	Solid State Physics-II	Theory	4.0	1.0	**100**
PHY-405	Nuclear Physics-II	Theory	4.0	1.0	**100**
PHY-406	Reactor Physics	Theory	4.0	1.0	**100**
PHY-407	Geophysics	Theory	2.0	0.5	**50**
PHY-408	Renewable Energy	Theory	2.0	0.5	**50**
PHY-409	Biomedical Physics	Theory	4.0	1.0	**100**
PHY-410	Senior Honors Project	Practical	2.0	0.5	**50**
PHY-411	Physics Lab.-IV	Practical	4.0	1.0	**100**
	Viva voce	Oral	2.0	0.5	**50**
Total			**38**	**9.5**	**950**

Grand Total **Credits: 140** **Units: 35** **Marks: 3500**

** Indicates Allied courses

Teaching and learning methods and strategies

Physics students will learn through a mixture of scheduled teaching and independent study. The teaching of the courses is carried out through lectures, practical sessions in the laboratories and tutorials. The bulk of the teaching programme is conducted through lectures. This teaching is supported through study resources generally delivered during the class lectures or through WWW. These resources vary in extent and character; they invariably include a detailed syllabus, reading list and problem-set; in some instances they incorporate substantial multimedia material including animations and illustrative simulations. Additional directed study and reading will also be recommended. There are comprehensive and challenging lecture courses, in which faculties are allowed flexibility in their approach, which may frequently lead to the inclusion of material reflecting developments in the field not contained in standard textbooks. If there is something you do not understand, you are always welcome to discuss it with a faculty member.

Students need to learn how to take good lecture notes, and supplement them with their own private study, using textbooks and other sources recommended by the faculties. Students are encouraged to take their own notes or to amend handouts as they find appropriate. Teaching material, including lecture notes or handouts must not be made available on the web without permission.

Physics depends on experimental observations, and learning how to perform and design experiments effectively is an essential part of physics education. Practical work is recorded in logbooks, and practicals have to be written up. The practical modules involve working between three and six hours per week in laboratories, where, in addition to traditional experimental techniques, we emphasize the importance of computer control and simulation throughout the course. Students will learn a modern programming language so that they can solve equations and model physical situations. Computing courses are conducted through supervised sessions in dedicated teaching laboratories in groups of 20-30.

Vacations

At JU, the teaching terms are quite short – they add up to about 30 weeks in one year. Therefore it is essential that you set aside significant amounts of time each vacation for academic work. The course assumes that you will do this in preparation for final examination that are held at the end of each academic year. You should go over your notes, revising the material and supplementing it by information gained from tutorials and from your own reading. In addition to consolidating the previous term's work, there may be preparatory reading for the next term's courses. Your faculties may also set you some specific vacation work.

Coursework and Assessment

The course structure ensures there are formative assessments throughout the year to help students to guide their studies and gain regular feedback on how they're getting on. To ensure they make steady progress and achieve the required grades, their learning will be assessed through coursework and examinations. Physics students have an average of twenty one-hour lectures and one or two days of practical each week.

Examinations

Course units are normally assessed formally at the end of the year via written examinations and by continuous assessment of practical classes and other written assignments. Laboratory or computer based course units also employ assignments and other methods of continuous assessment such as class tests, projects, group work or presentations. Experimental and other practical work is continually assessed through laboratory notebooks and formal reports. The Final Year exams (**Part-I/ Part-II/ Part-III/ Part-IV**) consist of compulsory and allied papers, and satisfactory completion of practical work. Assessment of a student in a particular course will be based on marks obtained in (i) the particular course-end examinations (written examination in the case of a theoretical course and practical examination in the case of a practical field-work course). (ii) Class work in the form of tutorial tests, assignments, presentations and class attendance. The distribution of marks for a course will be as follows:

(a) Part-end examinations: 70%

(b) In-course work which will include

- **(i) Tutorial (written)/ Practical tests 20%**
- **(ii) Class attendance 10%**

The compulsory papers are individually classified as Pass and Fail, with a Pass mark of 40%. A failed compulsory or allied paper can be re-taken in the final exam of the following year. The University requires that these papers must be passed at no more than two sittings: see the *Examination Regulations* (please contact exam controller office) for full details. The Examiners are chosen by an exam committee set up each year by the Department's Academic Committee. The Finals Examiners include external examiners from other Bangladesh Universities to set and mark some individual papers, projects, etc. In general, papers are set and marked by the internal and external examiners; indeed the identity of the examiners for any paper is confidential. The identity of the candidates is hidden from the examiners; no communication with the candidate is allowed. The questions are required to be set in conformity with the syllabus, whose interpretation is guided by previous papers except where there has been an explicit change of syllabus. The current syllabuses for the final examinations in physics are printed in this booklet.

Past Exam Papers

Past examination papers and other information regarding past exam papers are available on the Physics Seminar Library. Also visit http://juniv.edu/department/phy for more details.

Assessment of Class

Each course has its own assessment criteria appropriate to the specified Learning Objects of the course as detailed in the course specification. All courses are assessed using the University Common Marking Scheme. The typical assessment methods for a student on this programme are outlined below, however the balance between written exams, practical exams and coursework will vary depending on what courses you choose to study. These might include written or practical exams or coursework such as class tests, projects, group work or presentations.

There will be a minimum number of class tests spread over the entire academic year, each of at least one-hour duration in each course as prescribed below:

(a) For a 4 credit theoretical/practical/field work course: 3 written/practical tests

(b) For a 2 credit theoretical/practical/field work course: 2 written/practical tests

These are marked throughout the year and returned with feedback comments typically within weeks of submission. Group presentation typically involve teams of about 3-5 students working largely autonomously; written feedback is given on all aspects. All lecture based courses offered examination feedback where student can view their marked scripts and receive personal feedback from the course faculties. Class performance and common error feedback on class tests are supplied during classes. How the examiners work is their responsibility, subject to guidance from the Physics Academic Committee, and regulations laid down by the central bodies of the University. However, the following gives some indication of recent marking practice.

A mark of 90% and above: the candidate shows excellent problem-solving skills and excellent knowledge of the material, and is able to use that knowledge in unfamiliar contexts;

A mark of 80% to less than 90%: the candidate shows good problem-solving skills and good knowledge of the material;

A mark of 70% to less than 80%: the candidate shows basic problem-solving skills and adequate knowledge of most of the material;

A mark of 60% to less than 70%: the candidate shows some problem-solving skills and adequate knowledge of at least part of the material;

A mark of 40% to less than 60%: the candidate has made a meaningful attempt of at least some questions.

Class Attendance

A student with class attendance of less than 60% in any course will be debarred from appearing at the course-end examination of that particular course. Credits in the form of marks will be given to students attending classes over the minimum 60% mandatory requirement. Basis for awarding marks for class attendance will be as follows:

Class attendance	Marks allocated for 4 credit courses	Marks allocated for 2 credit course
90 % and above	10	5.0
85 % to less than 90 %	09	4.5
80 % to less than 85 %	08	4.0
75 % to less than 80 %	07	3.5
70 % to less than 75 %	06	3.0
65 % to less than 70 %	05	2.5
60 % to less than 65 %	04	2.0
Less than 60%	00	00

Regulations of Classes

As the program is running with yearly system,

(i) Usually class duration should be one (01) hour and there will be minimum three (03) classes in a week for a full unit course and two 1-hour class for half unit course. A full unit course should be conducted with 60-80 Lectures and 30-40 Lectures for a half unit course in one academic year.

(iii) Students are not allowed to carry mobile phone in the class room.

Assessment of Practical Work

Practical and computing classes are assigned by continuous assessment either via written submitted reports, laboratory notebooks or, for computing classes, specified checkpoints assessed by during the assigned classes. All submitted reports and notebooks are returned with written feedback, and students receive verbal feedback and advice on computer checkpoints from the assessors. The *Examination Regulations* read: "Failure to complete practical work without good reason will be deemed by the Exam Moderators as failure in the examination and the candidate will be required to complete the outstanding practicals by completing them alongside next year study, before entry to the upper year examination will be permitted."

The practical mark consists of marks for the experiments, the oral or written skills exercise and an assessed practical. The total marks are made up as follows:

	Marks (%)
(i) Experiments (Final Exam)	**50**
(ii) Oral Skills (Final Exam)	**10**
(iii) Written Skills (Class Tests)	**20**
(iv) Assessed Practical	**10**
(v) Attendance	**10**
Total	100

For an overview of the marking Scheme for Oral and Written Skills

- **A mark of 100%**: Students can attract the top mark for exceptional performance for their oral presentation (talk) or for their written skills report.
- **A mark of 80%**: Students will attract this mark if the oral presentation or written skills report is regarded as very good.
- **A mark of 70%**: Students will be awarded this mark if the presentation or written skills report was acceptable and average in quality.
- **A mark of 60% or below**: Students will be awarded this mark if the presentation or written skills report is deemed to be below standard.

An average student with an average presentation or written skills report should achieve 60% marks. Students who put in little or no effort can score very low marks. The marks which will be awarded by faculty, will be based on **both** the quality of the **entire logbook** and the understanding of the **assessed practical** demonstrated by the student. An average student with an average logbook should expect to achieve ~ 60% marks. It is important that students **consult their faculties early** in the event of difficulty with practical work.

Senior Honors Project

The project work provides the opportunity to study a topic in depth that has been chosen or which has been suggested by a faculty member. Project work as Senior Honors is assessed via written report and oral presentation; written feedback is given on all aspects.

Guidelines for doing project

1. Project work should be done as an extension of topics in the syllabus.
2. Project can be experimental / theoretical or done in collaboration (association) with a recognized lab. or organization.
3. Project work may be done individually or as group of maximum of six students.
4. A supervisor has to guide a group of maximum 12 students. For an additional group another supervisor has to be appointed. However the existing work load should be maintained.

The student's first carryout a literature survey which will provide the background information necessary for the investigations during the research phase of the project. The various steps in project works are the following:-

1. Wide review of a topic.
2. Investigation on an area of Physics in systematic way using appropriate techniques.
3. Systematic recording of the work.
4. Reporting the results with interpretation in written and oral forms.

The assessment will be done on the basis of the following.

1. Performance during the Project [Initiative, motivation, log book keeping and overall work]
2. Written report [contents and understanding]
3. Presentation and viva-voce

The components of Evaluation.

There should be a both internal and external evaluation.

Component Weightage

1. Written report		**30**
2. Presentation & Performance	**(10+10)**	**20**
Total		**50**

Only internal evaluation shall apply for item 2 and both internal & external evaluation for item 1

Prizes

A number of prizes are awarded annually for excellence in various aspects of the BSc and MS final examinations:

- Talent Pool Prizes for overall best performances (separately for BSc and MS)
- A Gold Medal for excellence in the BSc and MS examination in the whole faculty
- The S Nahar Prize for Outstanding Performance in each year's final examinations
- A complementary prize for the top 50% student in each final examinations
- Various prizes are available in the Physics Department's Poster, Physics Quiz, Project Competition etc.

Eligibility for Bachelor (Honors) Degree

A student who has

a) secured at least GPA of 2.00 for theoretical and practical courses as well as viva voce in Part-I, Part-II and Part-III examinations,

b) secured at the end of Part-IV a CGPA of 2.25 will be deemed to have qualified for the Bachelor (Honors) Degree in the subject offered.

Award of Bachelor (Honors) Degree

a) A successful candidate who has secured a minimum of 2.25 at the end of part-IV will be awarded a Degree of Bachelor of Science with Honors [cited as B. Sc. (Honors)] in the Faculties of Mathematical and Physical Sciences.

b) Students attaining a CGPA of 3.75 or above will be awarded a Bachelor (Honors) Degree with distinction and citation to be made in the transcript and certificate.

Award of Bachelor (Pass) Degree

Bachelor Degree (Pass) will be given to students under the following circumstances:

a) A student with poor results defined by the situation where he fails to secure a minimum CGPA of 2.25 after the regular Part-IV final examination (that is, without taking any improvement examination) but succeeds in securing a CGPA between 2.00 and 2.25 after availing all chances of improvement will be eligible for Bachelor Degree (Pass).

b) After completing three years of study and attaining a CGPA of 2.00 or higher a student may decide to discontinue the course and can apply in written for a Bachelor (Pass) Degree.

Grading Scheme

Based on the total marks obtained in the class attendance, tutorial and final examinations grading scheme will be as follows:

Marks (%)	Letter Grade	Grade Point
80 % and above	A^+	4.00
75 % to less than 80 %	A	3.75
70 % to less than 75 %	A^-	3.50
65 % to less than 70 %	B^+	3.25
60 % to less than 65 %	B	3.00
55 % to less than 60 %	B^-	2.75
50 % to less than 55 %	C^+	2.50
45 % to less than 50 %	C	2.25
40 % to less than 45 %	D	2.00
Less than 40 %	F(Fail)	0
Incomplete	I	0

All the necessary examinations are conducted as per provisions of the relevant examinations rules of this university and the ordinance for the Bachelor (Honors) Degree.

Syllabuses for Freshman Year (First Year) Courses of Studies

PHY-101: Mechanics	**Theory: 60 Lectures**	**Credit: 4**
Physics Core Course	**Contact Hours: 60 hours**	**Full Marks: 100**
Pre-requisites: Intermediate Level Physics and Mathematics	**Lectures: 3 (1 hour) sessions/week**	

Course Description

Fundamentals of Mechanics is a first year course for students who intend to major in Physics. It's a basic Physics course which study mechanics phenomena. It is an introduction to the phenomena, concepts, and theories of classical physics, including: Newtonian mechanics, kinematics, dynamics, momentum, energy, rotational motion and vector.

Aims and objectives

To introduce the fundamental concepts of Newtonian mechanics. To develop the knowledge and skills required to solve a variety of mechanical and dynamical problems using Euclidean space.

The objective of this course are as follows:

1. To explain the basic laws of nature and relation with science and engineering.
2. To understand how physics approach and solve problems in mechanics.
3. Solve one- and two-dimensional motion problems (including projectile motion) using kinematic relationships involving an object's position, velocity, and acceleration.
4. Explain Newton's Laws and apply them to the analysis of objects and systems in motion or in equilibrium while under the influence of forces, including forces and friction.
5. Apply the concepts of work, energy, and momentum and the conservation laws for energy and momentum to the solution of motion and collision problems.
6. To understand the relation between linear and circular motion and solve circular motion problems.
7. Solve rotational motion problems using torque, rotational inertia, kinetic energy, momentum and rotational conservation laws.
8. To make understanding about all scalar and vector quantities and there different operations, explain scalar and vector fields.

Learning outcomes

On completion successful students will be able to demonstrate an understanding of:

1. the concept of a frame of reference and its associated coordinate systems.
2. Newton's laws and know how to apply them in calculations of the motion of simple systems.
3. the concepts of energy, work, power, momentum, force, impulse, angular velocity, angular acceleration and torque.
4. the concepts of conservation of energy, momentum, and angular momentum and be able to perform calculations using them.
5. the concepts of simple rotation of rigid bodies and be able to perform calculations using them.
6. the concepts of simple motion in a gravitational field and be able to perform calculations using them.

Course Contents		**No. of lectures**
	PART-A	
1.	**Vector Algebra:** Vector and scalar quantities; Vector addition and subtractions; Vector differentiation and integration; Gradient of scalar quantities; Divergence and curl of vector quantities; Scalar and vector products and their significance.	**10**
2.	**Vector Integral Theorems & Coordinates:** Line, surface and volume elements; Gauss's divergence theorem, Stokes' theorem and Green's theorem; Polar, spherical and cylindrical coordinates; Del and Laplacian operators in polar, cylindrical and spherical coordinates.	**10**
	PART-B	
3.	**Kinematics and Particle Dynamics:** Concept of motion and frames of reference; Equations of motion; Tangential and normal components of acceleration in a plane; Projectile motion; Uniform circular motion; Newton's laws of motion; Concept of mass and force; Frictional forces.	**08**
4.	**Work, Energy and Power:** Work done by constant and variable forces; Kinetic and potential energies; Work-energy theorem; Conservative and non-conservative forces; One dimensional forces depending on position only; Two and three dimensional conservative systems; Principle of conservation of energy.	**08**
5.	**Conservation of Linear Momentum:** Centre of mass; Motion of a system of particles and its linear momentum; Conservation of linear momentum for a system of particles; Application of the linear momentum in the case of rocket propulsion; Collision phenomena.	**09**
6.	**Rotational Kinematics & Dynamics:** Rotational motion; Rotational quantities as vectors; Rotation with constant angular acceleration; Relation between linear and angular kinematics of a particle in circular motion. Torque and angular momentum and their relation; Kinetic energy of rotation and moment of inertia; Rotational dynamics of a rigid body; Parallel and perpendicular axis theorems for moment of inertia, Calculation of moment of inertia; Conservation of angular momentum.	**15**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. Spiegel, M.; Vector Analysis; McGraw Hill Book Company.
2. Tinker, M. & Lambourne, R. Further Mathematics for the Physical Sciences (Wiley)
3. Resnick, R. and Halliday, D. and Walker, J.; Fundamentals of Physics; John Wiley and Sons.
4. Resnick, R., Halliday, D. & K. Krane; Physics; John Wiley & Sons.
5. Sears, F.W. Zemansky, M.W. and Young, H.D.; University Physics; Addison Wesley Publishing Company.
6. Symon, K.R.; Mechanics; Addison Wesley Publishing Company.
7. Tipler, P.A., Physics for Scientists and Engineers (W.H. Freeman and company)

PHY-102: Properties of Matter and Waves	**Theory: 60 Lectures** **Contact Hours: 60**	**Credit: 4** **Full Marks: 100**
Physics Core Course	**Lectures: 3 (1 hour) sessions/week**	

Pre-requisites: Intermediate Level Physics and Mathematics, PHY 104

Aims and objectives

1. To show how the properties of macroscopic bodies can be derived from the knowledge that matter is made up from atoms.
2. To explore the detailed behavior of vibrating systems and wave motion in many different physical systems.

Learning outcomes

On completion successful students will be able to demonstrate an understanding of:

1. techniques for finding appropriate averages to predict macroscopic behavior.
2. how these techniques are applied to the calculation of the properties of matter.
3. demonstrate understanding of the behavior of oscillating systems and wave motion.
4. use the mathematical formalism that describes them.
5. recognize examples across many areas of physics.

	Course Contents	**No. of lectures**
	PART-A	
1.	**Gravitation :** Kepler's laws; Newton's law of gravitation; Gravitational attraction; Determination of gravitational constant; Mass and density of the earth; Inertial and gravitational mass; Gravitational field; Gravitational potential energy; Escape velocity; Energy and orbits; The acceleration due to gravity; Variations in 'g'; Measurement of the acceleration due to gravity.	**08**
2.	**Elasticity:** Stress; Plane stress; Examples of plane stress; Hydrostatic pressure; Strain; Hooke's law; Stress-strain diagram; Elastic hysteresis; Elastic moduli; Internal elastic potential energy; Relations between elastic constants; Torsion; Coil spring; Determination of the elastic constants; The bending of beams; Cantilever.	**07**
3.	**Hydrostatics and Surface Tension:** Hydrostatic pressure; Change of pressure with elevation; Pascal's law; Hydrostatic paradox; Thrust on an immersed plane; Center of pressure; Equilibrium of floating bodies; Pressure gauges: Force against a dam. Surface tension; Surface energy; Pressure difference across a surface film; Minimal surfaces; angle of contact and capillarity; Measurement of the angle of contact; Experimental determination of surface tension; Factors affecting surface tension.	**08**
4.	**Hydrodynamics and Viscosity:** Lines and tubes of flow; Equation of continuity; Bernoulli's equation and its applications; Flow in a curved duct; Viscosity; Coefficient of viscosity: Poiseuille's law; Stokes' law; Determination of coefficient of viscosity of liquids and gases; Variation of viscosity with temperature.	**08**

PART-B

5.	**Oscillations:** Harmonic motion; Simple harmonic motion (SHM); Energy consideration in SHM; Applications of SHM; Relation between SHM and uniform circular motion; Combination of harmonic motions; Damped harmonic motion; Forced oscillations and resonance,	**08**
6.	**Traveling Waves:** Equation of traveling waves; Speed of propagation of waves in a stretched string; Longitudinal waves in a bar; Plane waves in fluid; Transmission of energy by traveling waves; The superposition principle; Waves in a canal; Ripples; Fourier series; Group speed and phase speed.	**07**
7.	**Stationary Waves:** Reflection and transmission at a junction; Reflection at a fixed end of a stretched string; Boundary conditions for no reflection; Normal modes and proper frequencies of a stretched string.	**07**
8.	**Sound Waves:** Intensity and intensity levels; Loudness and pitch; Waves in three dimensions; Interference of spherical (sound) waves; Diffraction of sound waves; Radiation efficiency of a sound source; Beats; Combination of tones; Doppler effect and its applications.	**07**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. Sears F.W.; Mechanics, Wave Motion and Heat; Addison Wesley Publishing Company.
2. King G.C., Vibrations and Waves (Manchester Physics Series, Wiley, 2009)
3. Halliday, D. and Zemansky, M.W & Young, H.D; University Physics; Addison Wesley Publishing Company.
4. Mathur, D. S.; Elements of Properties of Matter; Shyamlal Charitable Trust.
5. Neuman & Searle; Properties of Matter.
6. Flowers, B.H., Mendoza, E. Properties of Matter (Wiley)

PHY-103: Electricity and Magnetism	**Theory: 60 Lectures** **Contact Hours: 60**	**Credit: 4** **Full Marks: 100**
Physics Core Course	**Lectures: 3 (1 hour) sessions/week**	
Pre-requisites: Intermediate Level Physics, PHY 104		

Aims and objectives

To develop a basic understanding of electric and magnetic fields in free space using the integral forms of Maxwell's laws. To ensure that students can competently use an electric device and to foster an understanding of the way electrical signals are shaped by passive circuit elements.

Learning outcomes

On completion successful students will be able to:

1. describe the electric field and potential, and related concepts, for stationary charges.
2. calculate electrostatic properties of simple charge distributions using Coulomb's law, Gauss's law and electric potential.
3. describe the magnetic field for steady currents and moving charges.
4. calculate magnetic properties of simple current distributions using Biot-Savart and Ampere's laws.
5. describe electromagnetic induction and related concepts, and make calculations using Faraday and Lenz's laws.
6. understand the behavior of capacitors and inductors.
7. describe the basic physical content of Maxwell's laws in integral form.

	Course Contents	**No. of lectures**
	PART-A	
1.	**Electric Field:** Electric charge; Coulomb's law; Electric field; Point charge in an electric field; Dipole in an electric field; Electric flux; Gauss's law and some of its applications.	**08**
2.	**Electric Potential:** Potential and field strength; Potential due to a point charge, A group of point charges and a dipole; Electric potential energy; Calculation of field strength from potential; Insulated conductor; Electrostatic generator.	**08**
3.	**Capacitors and Dielectrics:** Capacitor and capacitance –its calculations for different geometry; Dielectric and Gauss's law; Parallel plate capacitor with and without dielectric; Three Electric vectors; Energy stored in an electric field.	**07**
4.	**Current and Resistance:** Current and current density; Drift speed of charge carrier; Resistance, resistivity and conductivity; Ohm's law; Resistivity: Atomic view; Energy transfer in an electric circuit, Electromotive force and potential difference; Kirchhoff's laws: Single loop and multi loop circuits; Potentiometer, ammeter, voltmeter and galvanometer; RC circuits. Thermoelectricity: Peltier effect; Seeback effect; Thermocouple.	**08**

PART-B

5.	**Magnetic Field:** Magnetic induction and magnetic effects of currents; Magnetizing force; Magnetic force on a charge and on a current; Torque on a current loop; Moving coil galvanometer; The Hall effect; Ampere's law and its applications; Magnetic effects of currents; Biot-Savart law and its applications.	**07**
6.	**Electromagnetic Induction and Inductance:** Faradays' law of electromagnetic induction; Lenz's law; Self and mutual inductance and their applications; LR circuit; Energy stored in a magnetic field.	**07**
7.	**Alternating Current:** The simple AC generator; Alternating voltage and current and their graphical representation; R.M.S. Value of an AC voltage applied to resistors, capacitors and inductors; AC current and voltage in series RL and RC circuits; LCR circuits; Power dissipation in an AC circuit; Transformer.	**08**
8.	**Circuit Analysis & Network Theorems:** Thevenin's theorem; Superposition theorem; Maximum power transfer theorem; Norton's theorem; Transient currents.	**07**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. Edward M. Purcell, David J. Morin; Electricity and Magnetism 3rd Edition
2. Halliday, D.; & Resnick, R; Physics; New Age International Publishers
3. Sears, F.W. & Zemansky, M.W; University Physics
4. Serway, Raymond A., and John W. Jewett, Jr. Physics for Scientists and Engineers.
5. Grant, I. S. & Phillips, W. R. Elements of Physics (OUP)
6. Dakworth, H. E.; Electricity and Magnetism.
7. Halliday, Resnick, Walker, Fundamentals of Physics (Wiley)
8. Young, H. D. & Freedman, R. A. University Physics (Addison-Wesley)
9. Dobbs, E. R. Basic Electromagnetism (Chapman-Hall)
10. Duffin, W. J. Electricity and Magnetism (McGraw-Hill)
11. Kip, A. F. Fundamentals of Electricity and Magnetism (McGraw Hill)
12. Feynman, Lectures in Physics Volume 1
13. Grant, I. S. & Phillips, W. R. Electromagnetism (Wiley)
14. Griffiths, D. J. Introduction to Electrodynamics (Wiley)

PHY-104: Mathematical Method for Physics	**Theory: 60 Lectures**	**Credit: 4**
	Contact Hours: 60	**Full Marks: 100**
Physics Allied Course	**Lectures: 3 (1 hour) sessions/week**	
Pre-requisites: Intermediate Level Mathematics		

Aims and objectives

To allow students to develop their mathematical competence with functions, calculus, complex numbers, power series, linear algebra and differential equations to a level where they can cope with the demands of the first year of the physics course and beyond.

Learning outcomes

On completion successful students will be able to:

1. understand the properties of different types of functions and be able to sketch them in both 2D cartesian and polar coordinates.
2. integrate and differentiate functions of one variable using a range of techniques and be able to apply integration and differentiation to a range of physical problems.
3. show how smooth functions can be expressed in terms of power series.
4. demonstrate an understanding of the properties of complex numbers and be familiar with some basic complex functions.
5. solve first and second order ordinary differential equations using a range of techniques.

	Course Contents	**No. of lectures**
	PART-A	
1.	**Set Theory:** Algebra of sets; Union, Intersection and Cartesian product; Relations and functions; Elements of logic.	**10**
2.	**Complex Numbers and Their Properties:** Complex numbers; De Moivere's theorem and its applications; Hyperbolic functions and their relations to trigonometric functions.	**09**
3.	**Analytic Geometry of Two and Three Dimensions:** General equations of second degree for two and three dimensions and reductions to standard form; General properties of conic sections.	**09**
	PART-B	
4.	**Introduction of Elementary Calculus:** Limits; Continuity and related theories; Derivatives of elementary functions; Chain rule; Higher derivatives; Taylor series; Partial differentiation; Euler's rule for partial differentiation of homogeneous functions; Maxima; Minima; L' Hospitals rule; Asymptotic and tangent normal of curves, Arc length and radius of curvature of curves.	**10**
5.	**Integral Calculus:** Definite integral as the limit of a sum; Indefinite integrals and different techniques of integration; Fundamental theorem of integral calculus; Determination of length and area of plane curves and volume obtained by revolution of plane curves.	**11**

6. **Ordinary Differential Equations:** Introduction of Linear, non-linear and homogeneous differential equations; Solutions of linear first order differential equations; Solutions of second order differential equations with constant and variable coefficients; Solutions by the method of variation of parameters and undetermined coefficients. Solutions of the differential equations by the method of variable separation. Applications of ordinary differential equations in physics problems. **11**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. Tinker, M. & Lambourne, R. Further Mathematics for the Physical Sciences (Wiley)
2. Lambourne, R. & Tinker, M. Basic Mathematics for the Physics Sciences (Wiley)
3. Barnard and Child; Higher Algebra; S. G. Wasani for Macmillan India Ltd.
4. Jordan, D. & Smith, P. Mathematical Techniques (OUP)
5. Schaum's Series, Complex Variable.
6. Askwith, H., Analytic Geometry of Conic Sections.
7. Bacon, H.M., Differential and Integral Calculus.
8. Ayers, F. (Schaum Series), Calculus.
9. Ayers, F. (Schaum Series), Set Theory.

PHY-105: Chemistry-I	**Theory: ~ 30 Lectures**	**Credit: 2**
Physics Allied Course	**Contact Hours: ~ 30**	**Full Marks: 50**
Pre-requisites: Intermediate Level Chemistry and Physics	**Lectures: 2 (1 hour) sessions/week**	

Aims and objectives

The physics explains the world around us by building various models. The models such as kinetic theory of gases, collision theory of reactions etc. are purely classical-based. In contrast, for subatomic world, one needs to go beyond classical world and invoke the laws of quantum mechanics to describe small particles like electron. In classical and quantum worlds alike, the physics needs the support of mathematics to construct its models. The general goal of learning physical chemistry is to obtain an in-depth understanding of why and how chemical reactions occur, which in turn may enable us to accurately design reactions leading to novel molecules of the future.

This course will introduce concepts of physical chemistry while developing the tools to solve quantitative problems in the physical sciences, an emphasis will be placed on developing a deeper conceptual understanding of the physics that forms the foundation of chemistry.

Learning outcomes

After completion of the course the successful students should be able to:

1. discuss fundamental theoretical principles and models and solve conceptual problems in chemical reaction dynamics, electron- and energy transfer.
2. describe the basic principles of thermochemistry and electrochemistry .
3. solve numerical problems related to the course content.
4. perform advanced laboratory experiments related to the course content, analyze and report the results and discuss them in context.

	<u>Course Contents</u>	**No. of lectures**
	PART-A	
1.	**Thermochemistry:** Heats of reaction; Exothermic and endothermic reactions; Energy units; Sign convention; Heats of formation; Thermochemical laws; heats of combustion; Heats of solution; Problems relating to thermochemistry.	**05**
2.	**Surface Chemistry and Colloids:** Adsorption; Langmuir Adsorption Isotherm; Determination of Surface Area; Colloids- Classification, Preparation, Purification, Properties and Importance; Elementary Ideas about Emulsion and Gels.	**04**
3.	**Solution:** Various types of standard solution; Preparation of standard solution; Titrimetry; Nernst distribution law; Deviations from distribution laws; Solvent extraction; Properties of non-volatile, non-electrolytic dilute solutions; Raoult's law of vapour pressure lowering; Elevation of boiling point and depression of freezing point; Vant Hoff's law of osmotic pressure; Determination of molecular weight of substances using Raoult's law; Application of Vant Hoffs law for measuring	**06**

molecular weight of monomers and polymers; Determination of molecular weight of gases and volatile liquids using ideal gas equation.

PART-B

4. **Chemical Equilibrium:** Equilibrium states; Law of mass action; Equilibrum constants; variation of units for different types of reaction; examples; Le Chatelier principle and variables affecting equilibrium concentration; Specific example of each case; Calculation of equilibrium constants; Dissociative and associative reactions; Homogeneous and heterogeneous equilibria; Examples. **05**

5. **Electrochemistry:** Electrolytic conduction; Generation of electricity involving chemical reaction; Examples; Faraday's law of electrolysis; Faraday cell; Constant equivalent conductance; Specific conductance; Transport numbers; Mobility of hydrogen and hydroxyl ions; Electrochemical cell; Reversible and irreversible cell; reactions and e.m.f. of standard cells. **05**

6. **Oxidation Reduction Reactions:** Oxidation number; the modern concept of acids and bases according to Arrhenius, Browsted-Lowry, and Lewis; Frankline and Lux-flood Concepts; Neutralization Reactions; Strength of acids and bases, measurements of pH of a buffer solution; Hydrolysis of salts and pH of salts solutions. **05**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. Atkins, P. W.; De Paula, Julio. Physical Chemistry. 10 ed. Oxford University Press, 2014
2. Karplus, M., and R. Porter. Atoms and Molecules: An Introduction for Students of Physical Chemistry.
3. Hoque, M.M. and (Nawab, M. A) Molla Y.A,; Brothers's Publication
4. Silbey, R., R. Alberty, and M. Bawendi. Physical Chemistry. 4th ed., John Wiley & Sons, 2004.

PHY-106: Principle of Statistics	**Theory: 30 Lectures**	**Credit: 2**
Physics Allied Course	**Contact Hours: ~ 30**	**Full Marks: 50**
Pre-requisites: Intermediate Level Mathematics and Statistics	**Lectures: 2 (1 hour) sessions/week**	

Aims and objectives

- To introduce basics of statistical methods and modern day advanced data analysis techniques, as required in all fields working with data.
- To deepen the understanding of how data analysis works for small and large data samples.
- To obtain a comprehensive set of tools to analyze data.

Learning outcomes

On completion successful students will be able to:

1. Demonstrate an understanding of the basics of the statistical analysis of data.
2. Explain methods of data analysis and their idea.
3. Apply a set of analysis techniques as required for basic and advanced datasets.
4. Critically assess new results derived from datasets.
5. Use the knowledge of statistical data analysis to understand more advanced and new techniques.

	Course Contents	**No. of lectures**
	PART-A	
1.	**Elements of Statistics :-**	
(a)	**Statistics:** Its nature and scope; Nature of statistical data; Attributes and variables; Discrete and continuous variable; Method of data collection; Tabulation; Graphs and diagrams.	**04**
(b)	**Measures of Location:** Arithmetic mean; Geometric mean; Harmonic mean; Median; Mode; Quartiles; Deciles; Percentiles.	**03**
(c)	**Measures of Dispersion :** Characteristics of an ideal measure of dispersion; Absolute measure; Relative measure; Range; Standard Deviation; Mean deviation; Quartile deviation; Coefficient of dispersion; Coefficient of variation; Skewness and kurtosis.	**04**
(d)	**Regression and Correlation:** Relationship between variables; Fitting of simple linear regression; Simple correlation; Multiple correlation and multiple regression.	**03**
	PART-B	
2.	**Elements of Probability:** Meaning and definition of probability; Apriori and a posteriori probability; Experiment; Sample space and event; Theorems of total, compound and conditional probability; Random variables; Probability functions; Expectation of sum and products; Concepts of Binomial, Poisson's and Normal distribution.	**05**
3.	**Sampling Technique:** Simple random sampling; Stratified random sampling and systematic sampling.	**04**

4.	**Tests of Significance:** Type -1, Type -11 level of significance, size of the test, power of the test; Tests of means; Variance; Correlation coefficient and regression coefficient; Contingency table analysis.	**05**
5.	**Theory of Errors:** Error; Causes of variation of measurements; Measurement of error; Distribution of error; Methods of estimation of error; Minimizing error, examples related to physics problems.	**04**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. Barlow, R., Statistics – A Guide to the Use of Statistical Methods in the Physical Sciences, Wiley
2. Behnke, O., et al, Data Analysis in High Energy Physics: A Practical Guide to Statistical Methods, Wiley
3. Devor, T. L.; Probability and Statistics for Engineering and Sciences.
4. Hines, W.W. and Montgomery, D. C.; Probability and Statistics in Engineering and Management Science; John Wiley and Sons.
5. Chung, K. L.; Elementary Probability Theory with Stochastic Processes.
6. Cowan, G., Statistical Data Analysis, Oxford
7. Millor, I.R., Freund, J.E. and Johnson, R.; Probability and statistics for Engineering.
8. Helstrom, C.W.; Probability and Stochastic process for Engineers.
9. Woonacolt, R. J. and Woonacolt, T. H.; Introduction to Statistics.

PHY-107: Functional English	**Theory: 30 Lectures**	**Credit: 2**
Physics Allied Course	**Contact Hours: 30**	**Full Marks: 50**
Pre-requisites: Intermediate Level English	**Lectures: 2 (1 hour) sessions/week**	

Course Description

The basic idea behind offering English as a subject at the undergraduate level is to acquaint students with a language held by common consent to be the most popular language and predictably the most used in countries across the globe. The lessons included as part of syllabus, aim to take the nuances of English to students as it reveals its strengths and complexity when used to perform a variety of functions.

Aims and objectives

At the end of the course, students will have enough confidence to face competitive examinations (IELTS/ TOEFL/GRE etc.) to pursue MS/PhD degree. They will also acquire language skills required to write their Reviews/Projects/Reports. They will be able to organize their thoughts in English and hence face job interviews more confidently. The Curriculum designed is student-centered and it is guidance for their career.

The objective of this course are as follows:

1. To introduce different social situations to learners for developing their communication skills and enhance English language proficiency in social and work situations.
2. To make learners aware of the special features of the format and style of informal communication through various modes.
   To make learners familiar with the sub-skills of writing, the use of specific formats of the written discourse and enhance learners' writing skills.
3. To familiarize the learners with English sounds through listening.
4. To enable the learners to achieve an optimum level of intelligibility and fluency in speech and achieve accuracy in oral production by encouraging the use of a pronunciation dictionary (Oxford Advanced Learners' Dictionary).
5. To introduce corrective measures to eliminate grammatical errors in speaking and writing. Theoretical and conceptual understanding of the elements of grammar.

Learning outcomes

On completion successful students will be able to:

1. Demonstrate listening and reading skills in speaking and writing technical contents.
2. Explain in one's own words the steps for performing a complex tasks: group discussion and interview.
3. Analyze information in science and technological context.
4. Evaluate approaches, methods and solutions related to learning LSRW Skills.
5. Design a strategy to perform a specific task.
6. Equip themselves with critical reading and get information from the context with the help of root words and contextual clues.

Course Contents		No. of lectures
	PART-A	
1.	**Grammar:** Review: Parts of speech; Articles; Verb patterns; Tenses; Voice; Narration; Prepositions; Sentences and its classifications; Transformations of sentences; Analysis of sentences; Synthesis of sentences; Group verbs; Common idioms and phrases; Glossaries. Common errors, Transformation of Sentences,	**08**
2.	**Technical & Scientific Writing:** Spelling: Rules of spelling; Word formation; difficult spellings; Punctuation; Common confusable; Writing definition of scientific terms; Writing physical phenomena, designing posters; Features of Technical Writing, Writing Scientific Projects, Technical Report writing, Writing Project Proposals, Writing Research papers, Writing Manuals, Writing paragraphs on instruments and devices;. Word building (English words /phrases derived from other languages), Technical Jargons, Synonyms/Antonyms, Analogies.	**06**
	PART-B	
3.	**Reading:** Skimming; Scanning; Extracting main ideas; Summarizing.	**06**
4.	**Listening:** Strategies for listening; Barriers to effective listening.	**04**
5.	**Speaking:** Pronunciation: General points of pronunciation; Difficult pronunciation; How to invite, ask questions, make request and give instructions; How to respond to queries, invitations and statements; How to thank, introduce, express gratitude, regret or appreciation; How to express different concepts: ability, possibility, futurity, necessity, obligation, assumption, regularity, continuity, arrangement, comparison, etc.; Conversation with classmates; teachers, neighbors, and people in bus, train, plane etc.	**06**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. Hornby, A S. Oxford Advanced Learner’s Dictionary. 8th Edition. Oxford: Oxford University Press, 2010.
2. Leech, Geoffrey, and Jan Svartvik. A Communicative Grammar of English. 2nd Edition. London and New York: Longman, 1996.
3. Brown et al. Houghton Mifflin English Grammar and Composition: First Course. Boston. Houghton Mifflin Company, 1984.
4. Swan, Michael. Practical English Usage. 2nd Edition. Oxford University Press, 1995.
5. Murphy, Raymond. Intermediate English Grammar. 2nd Edition. Cambridge: Cambridge University Press. 2003.
6. Jonathon Law; Oxford English Language References; Oxford University Press; Oxford, 2001.
7. Thompson and Martinet; Practical English Grammar. Oxford; Fourth Edition
8. The Craft of Scientific Presentations: Critical Steps to Succeed and Critical Errors to Avoid 2nd ed. 2013 Edition by Michael Alley,Springer
9. How to Write and Publish a Scientific Paper, 8th Edition by Barbara Gastel and Robert A. Day, Greenwood
10. Writing Science: How to Write Papers That Get Cited and Proposals That Get Funded 1st Edition by Joshua Schimel, Oxford University Press
11. Technical Writing- Process and Product by Sharon J. Gerson & Steven M. Gerson, 3rd edition, Pearson Education Asia, 2000
12. Hargie, Owen.Ed. The Handbook of Communication Skills. New York: Routledge, 2006.
13. Baker, Joanna and Heather Westrup. Essential Speaking Skills. London: VSO Books, 2003.
14. Bygate, Martin. Speaking. New York: OUP, 2003.
15. Francois Grellar Developing Reading Skills. Cambridge University Press.

PHY-108: Physics Lab-I	**Lab: ~ 25 Sessions**	**Credit: 4**
Physics Core Practicals	**Contact Hours: ~ 200**	**Full Marks: 100**
Pre-requisites: PHY-101, 102, 103	**Practical: 1 sessions/week, 6-8 hour/session**	

Aims and objectives

To teach basic laboratory skills and illustrate physics topics such as basic principles of electric circuit analysis, damping and resonance in electric circuits and mechanics, illustrated by experiment. They are designed to teach specific experimental skills and techniques e.g., experimental data collection and analysis, ethical standards in a scientific investigation through individual experiments drawn from various topics in physics.

The objectives of physics practical labs are as follows:

1. to introduce and develop group-working skills and enhance writing and written presentation skills
2. to develop the appropriate skills and confidence to use computers for the tasks required in laboratory work
3. to introduce the basic concepts and methods required for laboratory data analysis.
4. to develop sound judgement in interpreting experimental results and uncertainties.
5. to develop the skills required for good scientific communication.

Learning outcomes

On completion successful students will be able to:

1. Link the experimental findings to underlying physics in lecture courses, textbooks and scientific journals and apply their physics knowledge and problem-solving skills to model problems in science
2. recognize a wide range of measurement instrumentation, develop and extend prescribed experimental procedures
3. use and measure with common instrumentation and handle sophisticated apparatus with confidence
4. work independently and also co-operatively with colleagues
5. keep professional quality systematic records of laboratory work in a log book while demonstrating high ethical standards during a scientific investigation
6. critically evaluate the results of an experiment, assess the significance of the experimental results compared to expected outcomes and draw valid conclusions
7. appreciate the importance of uncertainties in experimental measurements and be able to apply them in an appropriate manner
8. estimate the precision of experimental results, from an understanding of the experimental procedure and from a statistical analysis of repeated measurements
9. describe the sources of random and systematic error, calculate their effects on the results and evaluate ways of reducing the dominant error
10. use specific computer applications to manipulate and present experimental data in the form of graphs and tables and to describe experiments in coherent, structured formal written reports based on their experiments

Feedback methods

Feedback will be offered orally by demonstrators in lab sessions, orally by demonstrators when they mark each experiment and in writing for all lab reports.

Lab: Laboratory group will be allocated, and supported by, a demonstrator who will monitor progress and provide continuous feedback. A demonstrator is assigned to each group of students for the duration of each experiment. The demonstrator gives guidance and instruction and may be consulted at any time during the laboratory hours. Each laboratory has attendant/technicians who maintain the equipment and have a pool of special items (such as stopwatches) for loan.

During discussions, advice on how to improve the measurement, analysis and presentation of results will be given orally and also written on the assessment sheets, copies of which will be given to the student.

In written reports, detailed comments on how the report might be improved are written on the reports. More general comments are written on the marked sheets, copies of which are returned to the students along with the marked reports. Students are strongly encouraged to collect their marked reports from the markers, when any written comments can be elaborated upon.

Organization

The first year teaching laboratories are located on the 3rd floor (properties of matter, waves and oscillation, electrical measurements).

Assessment

The demonstrator assesses each group of students during the course of the experiment by considering physics understanding, experimental results, quality of data analysis, innovation, quality of notes in laboratory book and a short interview at the end. During the year students are required to submit written reports on all of the experiments undertaken. The total laboratory mark for the year is based on the experiments and the written reports. Failure to submit such a report will constitute a failure to satisfy the work and attendance requirements and hence the student will not be allowed to proceed to the second year.

(**A student will be required to perform two experiments in the final examination taking one from each group**).

LIST OF EXPERIMENTS

GROUP-A

A1. Experiment with spring:

a. To verify Hooke's law for a spring.
b. To determine the modulus of rigidity of the material of the spring.
c. To observe the harmonic motion of the spring for different loads attached to it.

A2. To determine the acceleration due to gravity, **'g'** by a compound pendulum.

A3. To determine the acceleration due to gravity, **'g'** by Kater's pendulum.
A4. To determine the surface tension of water by capillary rise method.
A5. To determine Young's modulus of the material of a wire by Searle's apparatus.
A6. To determine rigidity modulus of the material of a wire by dynamic method.
A7. To determine the coefficient of viscosity of water at room temperature.
A8. To determine the moment of inertia of a flywheel.
A9. To determine the surface tension of mercury by Quincke's method and hence to determine the angle of contact.

Group-B

B1. To verify Ohm's law by using a tangent galvanometer.
B2. To verify laws of series and parallel resistances by a P. O. Box.
B3. Experiment with sonometer:

   a. To draw $n-l$ and $n-\frac{1}{l}$ curves and hence to determine the unknown frequency of a tuning fork.
   b. To verify the laws of a stretched string from the $n-l$ curve.

B4. a. To determine the resistance of a voltmeter.

   c. To determine the resistance of a galvanometer by half deflection method.

B5. To determine the horizontal component of the earth's magnetic field and the magnetic moment of a bar magnet by magnetometer.
B6. To determine the internal resistance of a cell by using a potentiometer.
B7. To determine the frequency of a tuning fork by Melde's experiment.
B8. To determine the end-corrections of a meter bridge and hence to determine the specific resistance of wire.
B9. To compare the E. M. F. of two cells and to determine the E. M. F. of the cells by using a standard cell.

N.B.: In addition to the above experiments the Department may include/exclude some experiments.

Recommended Books

Each experiment is described in a laboratory script which is provided for the student. References to relevant text-books for background reading are given in the script.

The following is the recommended book for a discussion of general experimental techniques:

- Taylor, John Robert. An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements. University Science Books, 1997.
- Bevington, Philip R., and D. Keith Robinson. Data Reduction and Error Analysis for the Physical Sciences. McGraw-Hill, 2003.
- Squires, G.L. Practical Physics, 4th edition (Cambridge, 2001).
- Melissinos, Adrian Constantin, and Jim Napolitano. Experiments in Modern Physics. Academic Press, 2003.
- Preston, Daryl, and Eric Dietz. The Art of Experimental Physics. John Wiley & Sons, 1991.
- Ahmed, G and Uddin, MS, Practical Physics
- H D Young, R A Freedman, University Physics with Modern Physics, Pearson, 14th Ed., 2015

Syllabuses for Sophomore Year (Second Year) Courses of Studies

PHY-201: Thermal Physics	**Theory: 60 Lectures**	**Credit: 4**
Physics Core Course	**Contact Hours: 60**	**Full Marks: 100**
Pre-requisites: PHY-102, 104	**Lectures: 3 (1 hour) sessions/week**	

Aims and objectives

The course aims to teach a working knowledge and understanding of various fundamental thermal properties of matter and relate these to the fundamental mechanical properties of these systems. In particular the objectives are:

1. to develop the ideas of classical thermodynamics and their consequences.
2. to provide an appreciation for the use of thermodynamic potentials and associated thermodynamic relations to describe thermal behavior;
3. to provide a basic knowledge of phase transition and their classification;

Learning outcomes

On completion successful students will be able to:

1. appreciate the role of thermodynamics in describing macroscopic physical situations.
2. display a familiarity with fundamental thermal phenomena;
3. demonstrate an understanding of the basic concepts through which the phenomena are described, in particular those of temperature, work, heat, internal energy, the laws of thermodynamics, and of the concept of entropy;
4. explain and derive the fundamental thermodynamic relation;
5. use the formalism of thermodynamics, including the thermodynamic potentials and Maxwell's relations, and apply these tools to simple systems in thermal equilibrium;
6. apply their knowledge to modelling real phenomena and situations.

	Course Contents	No. of lectures
	PART-A	
1.	**Zeroth and First Law of Thermodynamics:** Thermodynamical Equilibrium. Zeroth Law of Thermodynamics and Concept of Temperature. Work and Heat Energy. State Functions. First Law of Thermodynamics. Differential form of First Law. Internal Energy. First Law and Various Processes. Applications of First Law: General Relation between Cp and Cv. Work Done during Isothermal and Adiabatic Processes. Compressibility and Expansion Coefficient. Atmosphere and Adiabatic Lapse Rate.	**06**
2.	**Second Law of Thermodynamics:** Reversible and Irreversible Changes. Conversion of Work into Heat and Heat into Work. Heat Engines. Carnot Cycle. Carnot Engine and its Efficiency. Refrigerator and its Efficiency. Second Law of Thermodynamics: Kelvin-Planck and Clausius Statements and their Equivalence. Carnot Theorem. Applications of Second Law of Thermodynamics: Thermodynamic Scale of Temperature and its Equivalence to Perfect Gas Scale.	**07**
3.	**Entropy:** Change in Entropy. Entropy of a State. Clausius Theorem. Clausius	**08**

Inequality. Second Law of Thermodynamics in terms of Entropy. Entropy of a Perfect Gas. Entropy of the Universe. Entropy Changes in Reversible and Irreversible Processes. Principle of Increase of Entropy. Impossibility of Attainability of Absolute Zero: Third Law of Thermodynamics. Temperature-Entropy Diagrams. First and second order Phase Transitions.

4. **Thermodynamic Potentials:** Extensive and Intensive Thermodynamic Variables. Thermodynamic Potentials U, H, F and G: Their Definitions, Properties and Applications. Surface Films and Variation of Surface Tension with Temperature. Magnetic Work. Cooling due to Adiabatic Demagnetization. Approach to Absolute Zero. **07**

5. **Maxwell's Thermodynamic Relations:** Derivations of Maxwell's Relations. Applications of Maxwell's Relations: (1) Clausius Clapeyron equation, (2) Values of Cp-Cv, (3) Tds Equations, (4) Joule-Kelvin Coefficient for Ideal and Van der Waal Gases, (5) Energy Equations and (6) Change of Temperature during an Adiabatic Process. **08**

PART-B

6. **Heat and Transfer of Heat:** Newton's law of cooling; Heat capacities; Conduction; Thermal conductivity and thermal diffusivity; Fourier's equation for heat conduction – its solution for rectilinear and radial (spherical and cylindrical) flow of heat. Heat flow through a compound wall; Experimental measurements of thermal conductivity; Convection; Wiedemann-Franz law. **07**

7. **Radiation**: Spectral emissive and absorptive powers, Kirchoff's law, blackbody radiation, energy density, radiation pressure. Stefan-Boltzmann law; Wien's displacement law; Rayleigh-Jeans formula; Planck's radiation law; Solar constant; Temperature of the sun; Application of radiation laws. **07**

8. **Transport Phenomena in Gases:** Mean Free Path. Collision Probability. Estimates of Mean Free Path. Transport Phenomenon in Ideal Gases: (1) Viscosity, (2) Thermal Conductivity and (3) Diffusion. Brownian Motion and its Significance. Deviations from the Ideal Gas Equation. The Virial Equation. Van-der Waal's Equation of State for Real Gases. Values of Critical Constants. Gibbs' phase rule and simple applications. P-V Diagrams. Joule's Experiment. Free Adiabatic Expansion of a Perfect Gas. Joule-Thomson Effect for Real and Van der Waal Gases. Temperature of Inversion. Joule-Thomson Cooling. **10**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. Thermodynamics By Enrico Fermi (Courier Dover Publications, 1956)
2. Heat and Thermodynamics; 7th edition, Zemansky, M.W. & Dittman, R.H.; McGraw-Hill.
3. H D Young, R A Freedman, University Physics with Modern Physics, Pearson, 14th Ed., 2015
4. Thermodynamics, Kinetic Theory, and Statistical Thermodynamics by Francis W. Sears & Gerhard L. Salinger. (Narosa, 1986).
5. Mechanics, Wave Motion & Heat; Sears, F.W.; 3rd edition, Addison-Wesley Publishing Company, Inc. (London).
6. A Treatise on Heat : Including Kinetic Theory of Gases, Thermodynamics and Recent Advances in Statistical Thermodynamics By Meghnad Saha, B. N. Srivastava (Indian Press, 1958)
7. Thermal Physics – S. Garg, R. M. Bansal, C. K. Ghosh (Tata Mc Graw Hill).
8. Heat Transfer; Holman, J.P; 5th Edition McGraw-Hill Book Company.

PHY-202: Optics	**Theory: 60 Lectures**	**Credit: 4**
Physics Core Course	**Contact Hours: 60**	**Full Marks: 100**
Pre-requisites: PHY-102, 104, 203	**Lectures: 3 (1 hour) sessions/week**	

Aims

To develop the concepts of wave optics and establish a firm grounding in modern optics.

Learning outcomes

On completion successful students will be able to:

1. demonstrate an understanding of the application of waves in optics and be competent in the use of complex notation.
2. analyze simple examples of interference and diffraction phenomena.
3. be familiar with a range of equipment used in modern optics, particularly the Michelson interferometer and the Fabry-Perot etalon.
4. demonstrate an understanding of the physical processes involved in producing laser radiation

	Course Contents	**No. of lectures**
	PART-A	
1.	**Interference (** Division of wavefront **):** Huygen's principle; Superposition of waves; Young's experiments; Theory of interference; Fringe width; Fringe shape; Intensity distribution curve; Conditions of interference; Fresnel's biprism; Lloyd's mirror.	**09**
2.	**Interference (** Division of amplitude **):** Stoke's treatment; Reflectance, reflectivity, etc.; Reflection from a film of varying thickness; Color of thin films; Antireflection coating; Interference filters; Newton's ring; Michelson's interferometer; Multiple beam interferometry; Fabry-Perot interferometer; Co-efficient of fineness, fringe half-width. Microscope; Telescope.	**09**
3.	**Diffraction (Fresnel Class):** Two classes of diffraction phenomena; Half period zones and strips; Area of half-period zones and strips; Diffraction at a straight edge; Diffraction by a circular aperture; Diffraction by a circular obstacle; Zone plates; Cornu's spiral; Fresnel's integrals.	**09**
4.	**Diffraction (Fraunhofer Class):** Diffraction by a single slit; Diffraction by double slit; Diffraction by Plane diffraction grating, formation of spectra; Spectrometer; Dispersive and resolving power of grating; Rayleigh's criterion for resolution; Resolving power of a prism.	**09**
5.	**Polarization:** Concept of Polarization of light; Methods of obtaining polarized light; Brewster's law; Double refraction axes of crystals and their types ; Nicol Prism; Analysis of polarized light; Elliptical & circular polarization; Retardation plates; Optical activity. Polarimeter; Polarising Microscope.	**07**

PART-B

6.	**LASER:** Fundamental principles; Stimulated emission; Einstein's relations; Population inversion; Optical feedback; Classification of LASERs; Types of LASERs; Practical LASERs (Ruby, Nd-YAG, He-Ne, CO_2, Argon-ion, Dye, Semiconductor); Applications of LASERs.	**07**
7.	**Fourier Optics:** Fourier transforms in two dimensions; Inverse transforms, examples; Dirac delta function; optical applications; Convolution and convolution theorem; Fourier methods in diffraction theory; Lens as a Fourier transformer; Fraunhofer diffraction single and double slits; spectra and correlation; Interpretation of Parseval's formula; auto-correlation and cross-correlation; Wiener-Khintebine theorem, Example in Optics.	**10**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. Jenkins, F.A and White, H.E.; Fundamentals of Optics. 4th ed. McGraw-Hill Intl. Ed.
2. Hecht, E., Optics, (Addison Wesley)
3. Smith, F.G. & King, T.A. Optics and Photonics - An Introduction (Wiley)
4. F L Pedrotti & L S Pedrotti, Introduction to Optics, Prentice Hall.
5. Lasers, Milloni, P.W. & Eberly, J.H.
6. Morgan, J.; Introduction to Geometrical & Physics Optics. McGraw-Hill.
7. Sears, F.W. and Zemansky, M.W.; University Physics; 6th Ed.;
8. H D Young & R A Freedman University Physics, Addison-Wesley.

PHY-203: Mathematical Physics	**Theory: 60 Lectures**	**Credit: 4**
Physics Core Course	**Contact Hours: 60**	**Full Marks: 100**
Pre-requisites: PHY-101, 104	**Lectures: 3 (1 hour) sessions/week**	

Aims and objectives

The aim of this course is to achieve an understanding and appreciation, in as integrated a form as possible, of some mathematical techniques which are widely used in theoretical physics and to introduce and develop the mathematical skills and knowledge needed to understand classical fields and quantum mechanics. The objective of this course are as follows:

1. To develop a knowledge of series and functions.
2. To introduce partial differential equations and train in methods of their solution.
3. To introduce students to complex variable theory and some of its many applications.
4. To introduce the concepts of complex functions and relate these to applications in modelling physical ideas.
5. To introduce the concept of vector space and provide a basic working knowledge of linear algebra, transformations, matrices and matrix operations.
6. To introduce Pauli matrices, eigenvalues, eigenvectors and commutation relations.
7. To provide skills and techniques for solving various common types of linear equations.

Learning outcomes

On completion successful students will be able to:

1. solve partial differential equations using the method of separation of variables and use them to model wave, heat flow and related phenomena.
2. state how a Fourier transform differs from a Fourier series, and solve linear ODE's and PDE's using Fourier techniques.
3. calculate the Fourier series associated with periodic functions and apply them to selected physical problems and Fourier transforms of simple functions.
4. recognize when a Green's function solution is appropriate and construct the Green's function for some well-known physical equations.
5. have an understanding of complex variable theory.
6. solve a variational problem by constructing an appropriate functional, and solving the Euler-Lagrange equations.
7. know how to evaluate integrals using the residue theorem, and understand how this can also be used to evaluate certain integrals along the real axis.
8. understand the basic concepts of vector spaces and the relation between vectors and operators and their representations in a given basis.
9. define the term “orthogonality” as applied to functions, and recognize sets of orthogonal functions which are important in physics (e.g. trigonometric functions and complex exponentials on appropriate intervals, Legendre polynomials, and spherical harmonics).
10. represent a given function as a linear superposition of orthogonal basis functions (e.g. a Fourier series) using orthogonality to determine the coefficients.
11. derive the eigenfunctions and eigenvalues of operators in particular cases and solve eigenvalue problems (differential equations subject to boundary conditions) either in terms of standard functions or as power series.

12. describe the basic properties of the eigenfunctions of Sturm-Liouville operators and make basic use of Dirac notation.
13. solve some common types of linear equations, such as the wave equation in 3D using Cartesian, cylindrical and spherical polar coordinates.
14. solve problems involving systems of coupled linear equations and display a basic competency in matrix manipulations;

Course Contents		**No. of lectures**
	PART-A	
1.	**Partial Differential Equations:** Power series solutions; Solution of the differential equations by the method of separation of variables; Solution of Laplace's equation in spherical polar and cylindrical coordinates: and their applications. Solution of Poisson's equation, Solution of heat flow equation. Solution of wave equations.	**12**
2.	**Special Functions:** Gamma and beta functions; Orthogonal functions; Legendre; Bessels; Laguerre and Hermite polynomials; Generating functions and recurrence relations; Fourier series and integrals; Fourier and Laplace's transform; Inverse Laplace's transform; Hypergeometric functions.	**12**
3.	**Theory of Complex Variables:** Complex functions; Analytic function; Harmonic functions; Cauchy-Riemann equations; Cauchy's integral theorem; Cauchy's integral formulas; Taylor's Series; Lorentz theorem; Differentiation of complex functions; Residue theorem and evaluation of residues; Evaluations of definite integrals.	**12**
	PART-B	
4.	**Theory of Matrices:** Different types of matrices and their definitions; Determinants of a square matrix; Adjoint and inverse of a square matrix; Solution of linear equations by matrix method and by Cramer's rule: Caley-Hamilton theorem: Similarity transformation.	**12**
5.	**Tensor Analysis:** Definition; Contra variant and covariant tensors; Invariance of tensors; Addition: subtraction: multiplication of tensors; Differentiation of tensors; Kronecker delta; Invariance of Kronecker delta; Kronecker delta as a mixed tensor.	**12**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. Boas, M.L. Mathematical Methods for Physical Sciences, 3rd edn. (Wiley, 2006)
2. Mathematical Methods for Physicists, G.B. Arfken, H.J. Weber, and F.E. Harris (AP).
3. Martin, B.R. & Shaw, G, Mathematics for Physicists. (Wiley 2015)
4. Riley, K.F. Hobson, M. P. Mathematical Methods for Physics and Engineering (CUP)
5. Special Functions By George E. Andrews, Richard Askey, Ranjan Roy (CUP, 2000)
6. Fourier series and Boundary value problems, R. V. Churchill (McGraw Hill).
7. Differential Equations with Applications, G. Simmons (Pearson Education).
8. Partial differential equations for scientists and engineers, Stephenson, G. (Imperial College)
9. Theory of Complex Variables; Schaum's Outline Series, McGraw-Hill International.
10. Theory of Matrices; Schaum's Outline Series, McGraw-Hill International.
11. Tensor Analysis for Physicists, J. A. Schouten (Dover).

PHY-204: Classical Mechanics	**Theory: 60 Lectures**	**Credit: 4**
Physics Core Course	**Contact Hours: 60**	**Full Marks: 100**
Pre-requisites: PHY-101, 102, 104, 203	**Lectures: 3 (1 hour) sessions/week**	

Aims and objectives

To introduce the Lagrangian and Hamiltonian formulations of classical mechanics. To develop the knowledge and skills required to solve a variety of dynamical problems involving more than one degree of freedom.

The objective of this course are as follows:

1. to give on overview of theoretical methods used in classical mechanics. In particular: to teach methods of integration of equations of motion for dynamical problems in classical mechanics.
2. to train in using variational calculus in application to functionals.
3. to exploit the generality of Lagrangian and Hamiltonian techniques by using an appropriate generalized coordinates.
4. to acquaint students with the concept of the phase space, stability of motion and chaos.
5. to describe rotation of a rigid body.
6. to enhance problem-solving and mathematical skills by requiring students to apply their mathematical skills to mechanics examples.
7. to provide students with a working knowledge of Einstein's theory of Special Relativity, both conceptually and mathematically.

Learning outcomes

On completion successful students will be able to:

1. choose an appropriate set of generalized coordinates to describe a dynamical system and obtain its Lagrangian in terms of those coordinates and the associated 'velocities'.
2. derive and solve the corresponding equations of motion and treat small oscillations as an eigenvalue problem.
3. obtain generalized momenta and thus the Hamiltonian of a dynamical system.
4. derive and solve the equations of motion in Hamiltonian form.
5. apply a variational principle to solve simple problems involving constraints.
6. appreciate symmetries and how they manifest themselves in terms of constants of the motion and integrate equations of motion in one and two dimensions.
7. use variational methods and to relate Hamiltonian and Lagrangian approach to theoretical mechanics and canonical transformations.
8. understand the notion of an inertial frame and the concept of an observer.
9. appreciate the failure of classical relativity theory and explain how Einstein's theory of Special Relativity replaces the Newtonian concepts of absolute space and absolute time.
10. understand and use the Lorentz transformation formulae with particular emphasis on the breakdown of simultaneity, time dilation and length contraction.
11. appreciate the role of energy and momentum in a relativistic context.
12. understand the idea of spacetime and the role of four-vectors
13. solve problems in relativistic mechanics.

	Course Contents	**No. of lectures**
	PART-A	
1.	**Review of Elementary Principles:** Mechanics of a system of particles; Generalized co-ordinates; D'Alembert's principle & Lagrange's equations; The Lagrangian; Velocity dependent potentials and dissipation function.	**06**
2.	**Variational Principle and Lagrange's Equations:** Hamilton's principle; Derivation of Lagrange's equations from Hamilton's principle; Extension of Hamilton's principle to non-conservative and non-holonomic systems. Application of Lagrange's equations.	**08**
3.	**Central Force:** Two-body central force problem; Reduction to equivalent one-body problem; Differential equation of orbit; Kepler's law and classification of orbits; The Virial theorem; Scattering in a central force field; Transformation of scattering problem to laboratory co-ordinates.	**08**
4.	**The Rigid Body Motion:** Independent co-ordinates and generalized co-ordinates for rigid body; Orthogonal transformation & transformation matrices; Eulerian angles; Euler's theorem; Concepts of matrix, tensors and dyadic. Euler's equation of motion for solving rigid body problems; Finite & infinitesimal rotations; Symmetrical top.	**08**
	PART-B	
5.	**Hamilton's Equations of Motion:** The Hamiltonian; Configuration space and phase space; Legendre transformation & Hamilton's equations of motion; Application of Hamilton's equations. Variational principles and the principle of least action.	**08**
6.	**Canonical Transformations:** Equations of Canonical transformations; Legendre transformations; Lagrange and Poisson's brackets; Equations of motion in Poisson's bracket notation. The integral invariance of Poincare; The Jacobian.	**07**
7.	**Special Theory of Relativity:** Michelson and Morley experiment; Galilean transformations; Postulates of special theory of relativity; Lorentz transformations; Length contraction and time dilation.	**07**
8.	**Relativistic Mechanics:** Basic postulates; Four-dimensional (World / Minkowski) space; Space-like and time-like intervals; Relativity of mass and momentum; Relativistic energy; Equivalence of mass and energy; Momentum-energy four-vector; Relativistic force law.	**08**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. Goldstein, H., Poole, C. & Safko, J. Classical Mechanics, 3rd edition (Addison-Wesley)
2. Kibble, T.W.B. & Berkshire, F.H. Classical Mechanics, 5th edition (Longman)
3. John R. Taylor; Classical Mechanics, Univ Science Books; null edition edition (January 1, 2005)
4. Landau, L.D. and Lifshiftz, E.M. Course on Theoretical Physics: Mechanics (Pergamon Press)
5. Stephen T. Thornton, Jerry B. Marion, Classical Dynamics of Particles and Systems 5th Edition
6. Patrick Hamill; A Student's Guide to Lagrangians and Hamiltonians (Student's Guides), CUP.
7. Symon, K. R.; Mechanics; Addison Wesley Publishing Company.
8. Rindler, W. Relativity: Special, General & Cosmological (Oxford)
9. Resnick, R.; Introduction to Special Relativity; John Wiley and Sons.
10. French, A.P.; Special Relativity ELBS/Van Nostrand Reinhold.
11. Adler, Bazin, Schiffer; Introduction to General Relativity, McGraw-Hill.
12. Bergmann, P. G.; Introduction to the Theory of Relativity

PHY-205: Basic Electronics	**Theory: 60 Lectures**	**Credit: 4**
Physics Core Course	**Contact Hours: 60**	**Full Marks: 100**
Pre-requisites: PHY-101,103, 104	**Lectures: 3 (1 hour) sessions/week**	

Aims and objectives

To provide an insight into common electronic materials and devices in everyday life, with reference to; solid state lighting, solar energy, security & infrared imaging, mobile communications and computing technologies. To understand the relevant properties of semiconductor materials and physical principles of device operation in this extremely active and interesting research area. To understand how analogue signals may be amplified, manipulated and generated in a controlled manner, and how they may be interfaced to digital systems for subsequent processing.

Learning outcomes

On completion successful students will be able to:

1. give a quantitative description of the operating principles of different modern semiconductor devices.
2. explain the principles of today's semiconductor devices such as diodes and transistors in particular their I-V (current-voltage) and C-V (capacitance-voltage) characteristics
3. understand the behavior of an ideal amplifier under negative feedback.
4. apply the developed theory to simple circuits; adders, integrators and phase shifters.
5. understand the limitations of a real amplifier in terms of its gain, bandwidth, and input/output impedance.
6. understand positive feedback, especially the schmitt trigger.
7. understand basic methods of communication.

	Course Contents	**No. of lectures**
	PART-A	
1.	**Semiconductor diode, Rectifier and Filter Circuits:** Semiconductors; Energy Band Description of semiconductors; Effect of temperature on semiconductors; Hole current; Intrinsic semiconductor; Extrinsic semiconductors; P-type semiconductors; N-Type semiconductor; Properties of PN junction; Half-wave rectifier; Full-wave rectifier; Filter circuits; Ripple Factor Capacitor filter; L-section filter; Pi-section filter; Zener diode; Voltage stabilization.	**10**
2.	**Transistor Devices and Circuits:** Transistors: Naming the transistor terminals; Transistor action; Transistors connections; Common base, common emitter, common collector connections, and their characteristics; Transistor load line analysis; Transistor biasing; Methods of transistor biasing: base resistor method, biasing with feedback resistor, voltage divider biasing method; Field effect transistors: Construction and characteristics of JFET; Construction and characteristics of depletion and enhancement type MOSFET.	**12**
3.	**Power Electronics:** SCR: Construction, V-I characteristics and applications; UJT: Construction, V-I characteristics and applications; Triac: Construction and	**06**

characteristics; Diac: Operation, characteristics and applications.

PART-B

4.	**Transistor Amplifier:** Classifications of amplifiers: Single stage and multi-stage transistor amplifiers; R-C coupled and transformer coupled transistor amplifiers; Power amplifier: Class A, class B, and class C amplifiers; Push-pull amplifier.	**08**
5.	**Feedback and Oscillators:** Positive feedback; Negative feedback: Voltage feedback, current feedback; Oscillators: Tuned collector oscillator, Colpitts oscillator, Hartley oscillator, phase shift oscillator, Wien bridge oscillators, Crystal oscillator.	**08**
6.	**Modulation, Demodulation and Radio Receivers:** Radio broadcasting: Transmission and reception; Modulation: Amplitude modulation, frequency modulation, modulation factor; analysis of amplitude modulated wave; Sideband frequencies in AM wave; Transistor AM modulator; Power in AM wave; Frequency modulation; Demodulation: Essentials in demodulation; AM diode and transistor detectors; Types of AM radio receivers: Straight radio receiver, superheterodyne radio receiver.	**10**
7.	**Basic Operational Amplifier:** Ideal Op-amp; Inverting and non-inverting Op-amp; Adder and subtractor; Integrator; Differentiator.	**06**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. James J. Brophy; Basic Electronics for Scientists; McGraw-Hill Company Limited.
2. Jacob Millman and Arvin Grabel; Microelectronics; McGraw-Hill Company Limited.
3. Robert L. Boyelstad, Louis Nashelsky; Electronic Devices and Circuit Theory.
4. Agarwal, Anant, and Jeffrey H. Lang. Foundations of Analog and Digital Electronic Circuits
5. Horowitz P., Hill W., The Art of Electronics (3th ed., 2015), Cambridge University Press.
6. Paul Scherz, Simon Monk; Practical Electronics for Inventors, Fourth Edition, McGraw-Hill.
7. S.M. Sze and K. Ng, Physics of Semiconductor Devices, Wiley, 2006.
8. Cathey, Jimmie J. Schaum's Outlines Electronic Devices and Circuits. 2nd ed., McGraw-Hill.
9. Neamen, Donald. Electronic Circuit Analysis and Design. 2nd ed., McGraw Hill.
10. Johnson, D. E., and V. Jayakumar. Operational Amplifier Circuits. Prentice Hall
11. B. Streetman and S. Banerjee, Solid State Electronic Devices, Prentice Hall, 2005.

PHY-206: Computer Programming and Numerical Methods	**Theory: 30 Lectures**	**Credit: 2**
Physics Core Course	**Contact Hours: 30**	**Full Marks: 50**
Pre-requisites: PHY-101, 104	**Lectures: 2 (1 hour) sessions/week**	

Aims and objectives

The aim of the course is to give a practical introduction to computer programming for physicists assuming little or no previous programming experience. The objective of this course are as follows:

1. To learn the fundamentals of Object Oriented Analysis and Design.
2. To become fluent in the C++ programming language.
3. To develop good programming style.
4. To be able to apply coding quickly and efficiently to realistic (physics) applications.

Learning outcomes

On completion successful students will be able to:

1. write programs in C++ to aid them in practical situations they will face in their degree course and future work in physics or in other fields.
2. have an understanding of programming appropriate to writing code in C++, but also be able to transfer this understanding to other languages.
3. use numerical methods to find solutions of ordinary differential equations and to analyze the behavior of a physical system (such as a driven oscillator).

	Course Contents	**No. of lectures**
	PART-A	
1.	**Programing Concepts:** Concepts of Algorithm, Good algorithm Vs. bad algorithm; Flowchart, Pseudopodia, Program Control Structure, Programming Paradigms and Languages, Types of computer languages; Generation of Programming Languages, Compilers, Interpreters, Program design: structured programming; Representation of Numbers: Fixed and floating point numbers, Overflow and underflow, Machine precision.	**15**
2.	**Programming with C++:** Principles of object oriented programming; Basic data types; Choice and decisions; Loops, array and string; Pointer; Functions; Program files and the preprocessor; Class; Operator overloading; Inheritance; Virtual functions and polymorphisms; Constructor and destructors; Program errors and exception handling; Class templates; Input and output operations; Introduction to standard template library etc.	**15**
	PART-B	
3.	**Transcendental Equations:** Error Analysis; Classification and Order of Algorithms; First and Second Order Iteration Methods; Rate of Convergence; Acceleration of the Convergence; Efficiency of a Method.	**6**

4.	**System of Linear Equations:** Matrix Representation; Basic Matrix Operations; Direct Methods - Matrix Inversion; Gauss Elimination Methods; Gauss-Jordon Method; Triangularization Method; Iterative Methods - Jacobi Method; Gauss-Seidel Method.	**6**
5.	**Interpolation and Curve Fitting:** Newton's Forward and Backward Difference Interpolation Formula; Hermite and Lagrange's Interpolation Formula; Spline Interpolation; Linear and Polynomial Least Squares Curve Fitting.	**6**
6.	**Numerical Differentiation and Integration:** Numerical Differentiation using Interpolation; Cubic Spline Method; Numerical Integration: Trapezoidal Method; Simpson's Method; Errors in these Methods; Romberg Method.	**6**
7.	**Ordinary Differential Equations:** Solution by Taylor Series; Euler's Method; Runge-Kutta Methods; Predictor-Corrector Methods: Adams-Moulton; Milne-Simpson.	**6**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. Kernigham & Ritchie; C programming language, 2nd Ed. 2004 (PH).
2. Tondo & Gimped; C Answer Book, 2nd Ed., PHE.
3. Herbert Schildt; C++ The Complete Reference, 4th edition, 2000.
4. Balagurusamy, E.; Introduction to C++, Tata McGraw-Hill, 2000
5. A. Koenig and B. E. Moo. Accelerated C++ (Addison Wesley, 2000)
6. Jain, MK et al. Numerical Methods for Sc. and Eng Computation
7. Hamming, RW Numerical Methods for Scientists and Engineers
8. Scheid, F Introduction to Numerical Analysis.
9. Scarborough, JB Numerical Mathematical Analysis
10. Titus, A.B. Introduction to Numerical Programming: A Practical Guide for Scientists and Engineers
11. Garcia, A.L. Numerical Methods for Physics (Prentice Hall)
12. Bau III, David, and Lloyd N. Trefethen. Numerical Linear Algebra.

PHY-207: Chemistry -II	**Theory: 30 Lectures**	**Credit: 2**
Physics Core Course	**Contact Hours: 30**	**Full Marks: 50**
Pre-requisites: PHY-105	**Lectures: 2 (1 hour) sessions/week**	

Aims and objectives

The course aims to help the students to review undergraduate organic chemistry and inorganic chemistry and prepare them for advanced graduate courses.

Learning outcomes

Upon completion of this class, students will be able to predict bonding and three-dimensional structure, including chirality of organic compounds. Students will be able to predict the reactivity of specific functional groups, and construct efficient, simple mechanistic pathways for the synthesis of a given compound.

	Course Contents	No. of lectures
	PART-A	
1.	**The Chemical Bonds:** Electronic theory of valency; Types of bonds; ionic bonds, covalent bond and coordinate covalent bond; Electronegativity; Metallic bond; Hydrogen bond; Vander Waal forces.	5
2.	**Molecular Geometry and Covalent Bond:** Resonance; Hybrid orbitals; Valence shells; Electronic pair repulsion theory and molecular geometry; Molecular orbitals.	5
3.	**Chemistry of Elements:** **a.** Group III Elements: General remarks: Occurrence; isolation and properties; Chemistry of boron. **b.** Group IV Elements: General remarks: occurrence, isolation and preparation of the metals as semiconducting materials. **c.** Group V Elements: General remarks; Occurrence, Preparation and properties; Allotropic forms; Binary compounds; Oxides and oxiacids. **d.** Transition of Rare-earth Elements.	5
	PART-B	
4.	**A Brief Introduction to Organic Chemistry:** Elements of organic chemistry; Orbital representation of aliphatic and aromatic hydrocarbons; Nomenclature, structural formula and important properties of simple organic compounds belonging to the following classes; Alkanes, amides, amino acids, proteins and carbohydrates.	5
5.	**Elements of Biochemistry:** Cell sand tissue; structure and function; lon and pH balance of the body fluid; Blood constituents; Metabolism of protein and carbohydrate; DNA, RNA.	5
6.	**Synthesis:** Synthesis Involving Grignard Reagent; Malonic Ester; Aceto-Acetic Ester and Diazonium Salts.	5

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. K. Peter C. Vollhardt and Neil E. Schore, W. H. Freeman, Organic Chemistry, 6th Edition;
2. Bodie E. Douglas, Darl H. McDaniel, John J. Alexander, Concepts and Models of Inorganic Chemistry, John Wiley and Sons; 3rd edition.
3. L. G. Wade, Jr. Organic Chemistry. 5th ed.
4. Haider, S. Z.; Introduction to Inorganic Chemistry; S. Chand and Company Ltd.
5. Cotton and Wilkinson; Basic Inorganic Chemistry; John Wiley and Sons Inc.
6. Mortimer, C.; Chemistry-A Conceptual Approach, D. Van Nastrond Company.
7. Sienke and Plane; Chemistry: Principles and Properties, McGraw-Hill 1966.

PHY-208: Physics Lab–II	**Lab: 20 Sessions**	**Credit: 4**
Physics Core Practicals	**Contact Hours: 120 hr**	**Full Marks: 100**
Pre-requisites: PHY-103,201,202,205	**Practical: 1 (6hr) session/week**	

Aims and objectives

To teach basic laboratory skills and illustrate physics topics such as basic principles of electric circuit analysis, damping and resonance in electric circuits and mechanics, illustrated by experiment. They are designed to teach specific experimental skills and techniques e.g., experimental data collection and analysis, ethical standards in a scientific investigation through individual experiments drawn from various topics in physics.

The objectives of physics practical labs are as follows:

1. to introduce and develop group-working skills and enhance writing and written presentation skills
2. to develop the appropriate skills and confidence to use computers for the tasks required in laboratory work
3. to introduce the basic concepts and methods required for laboratory data analysis.
4. to develop sound judgement in interpreting experimental results and uncertainties.
5. to develop the skills required for good scientific communication.

Learning outcomes

On completion successful students will be able to:

1. Link the experimental findings to underlying physics in lecture courses, textbooks and scientific journals and apply their physics knowledge and problem-solving skills to model problems in science
2. recognize a wide range of measurement instrumentation, develop and extend prescribed experimental procedures
3. use and measure with common instrumentation and handle sophisticated apparatus with confidence
4. work independently and also co-operatively with colleagues
5. keep professional quality systematic records of laboratory work in a log book while demonstrating high ethical standards during a scientific investigation
6. critically evaluate the results of an experiment, assess the significance of the experimental results compared to expected outcomes and draw valid conclusions
7. appreciate the importance of uncertainties in experimental measurements and be able to apply them in an appropriate manner
8. estimate the precision of experimental results, from an understanding of the experimental procedure and from a statistical analysis of repeated measurements
9. describe the sources of random and systematic error, calculate their effects on the results and evaluate ways of reducing the dominant error
10. use specific computer applications to manipulate and present experimental data in the form of graphs and tables and to describe experiments in coherent, structured formal written reports based on their experiments

Feedback methods

Feedback will be offered orally by demonstrators in lab sessions, orally by demonstrators when they mark each experiment and in writing for all lab reports.

Lab: Laboratory group will be allocated, and supported by, a demonstrator who will monitor progress and provide continuous feedback. A demonstrator is assigned to each group of students for the duration of each experiment. The demonstrator gives guidance and instruction and may be consulted at any time during the laboratory hours. Each laboratory has attendant/technicians who maintain the equipment and have a pool of special items (such as stopwatches) for loan.

During discussions, advice on how to improve the measurement, analysis and presentation of results will be given orally and also written on the assessment sheets, copies of which will be given to the student.

In written reports, detailed comments on how the report might be improved are written on the reports. More general comments are written on the marked sheets, copies of which are returned to the students along with the marked reports. Students are strongly encouraged to collect their marked reports from the markers, when any written comments can be elaborated upon.

Organization

The second year teaching laboratories are located on the ground floor and hosts experiments on heat and thermodynamics, electricity and magnetism, and optics. The laboratory unit includes packages on wave optics PHY-202, Basic Electronics PHY-205 and Circuits PHY-103.

Assessment

The demonstrator assesses each group of students during the course of the experiment by considering physics understanding, experimental results, quality of data analysis, innovation, quality of notes in laboratory book and a short interview at the end. During the year students are required to submit written reports on all of the experiments undertaken. The total laboratory mark for the year is based on the experiments and the written reports. Failure to submit such a report will constitute a failure to satisfy the work and attendance requirements and hence the student will not be allowed to proceed to the second year.

(**A student will be required to perform two experiments in the final examination taking one from each group**).

LIST OF EXPERIMENTS

GROUP A

A1. Determination of the mechanical equivalent of heat, ‘J’ by electrical method.
A2. Determination of the specific heat of a liquid by the method of cooling.
A3. Determination of the thermal conductivity of a good conductor by Searle’s apparatus.
A4. Determination of the thermal conductivity of a bad conductor by Lee’s method.
A5. Investigation of the variation of the resistance of a Copper wire with temperature and determination of its temperature coefficient of resistance.

A6. Investigation of the variation of the capacitive and inductive reactance's with frequencies.
A7. Investigation of the properties of an LRC series resonance circuit.
A8. Investigation of the characteristics of a junction diode.
A9. Investigation of the properties of a parallel LRC resonance circuit.
A10. To use resistance thermometer in particular to measure (a) the room temperature and (b) the boiling point of a liquid.
A11. To measure a small thermoelectric e.m.f and its variation with temperature using a milli-ammeter and a standard resistance.
A12. To construct and calibrate a direct reading thermoelectric thermometer and to measure; (a) the room temperature (b) the body temperature (c) the boiling point of a saturated brine solution and (d) the melting point of solder.

GROUP B

B1. Determination of the refractive index of water and glycerine by pin method.
B2. Determination of the (i) refractive index and (ii) the dispersive power of the material of the prism by a spectrometer.
B3. Investigation of the principal types of optical spectra, calibration of the spectrometer and hence to determine the unknown wavelength.
B4. Determination of the Cauchy's constant and the resolving power of a prism using a spectrometer.
B5. Determination of the thickness of a paper and a wire by means of interference fringes in air wedge.
B6. Determination of the radius of curvature of a plano-convex lens and the wavelength of sodium light by Newton's rings method.
B7. Determination of the unknown wavelength by using discharge tubes and diffraction grating.
B8. (A) Investigation of the voltage-current relationship for a simple ac inductive circuit and hence determination of the inductance.
(B) Investigation of the voltage-current relationship for a simple ac capacitive circuit and hence determination of the capacitance.

N.B.: In addition to the above experiments the Department may include/exclude some experiments.

Recommended Books

Each experiment is described in a laboratory script which is provided for the student. References to relevant text-books for background reading are given in the script.

The following is the recommended book for a discussion of general experimental techniques:

- Taylor, John Robert. An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements. University Science Books, 1997.
- Bevington, Philip R., and D. Keith Robinson. Data Reduction and Error Analysis for the Physical Sciences. McGraw-Hill, 2003.
- Squires, G.L. Practical Physics, 4th edition (Cambridge, 2001).
- Melissinos, Adrian Constantin, and Jim Napolitano. Experiments in Modern Physics. Academic Press, 2003.
- Preston, Daryl, and Eric Dietz. The Art of Experimental Physics. John Wiley & Sons, 1991.
- Thomas C. Hayes, Paul Horowitz; Learning the Art of Electronics: A Hands-On Lab Course, CUP.
- Paul B. Zbar and Albert Paul Malvino, Basic Electronics: A Text-Lab Manual
- Ahmed, G and Uddin, MS, Practical Physics
- H D Young, R A Freedman, University Physics with Modern Physics, Pearson, 14th Ed., 2015

PHY-209: Computer Programming Lab	**Lab: ~ 30 Sessions**	**Credit: 2**
Physics Allied Practical	**Contact Hours: ~ 150**	**Full Marks: 50**
Pre-requisites: PHY-205, 207	**Practical: 1 sessions/week, 3-4 hour/session**	

Aims and objectives

The objective of this course are as follows:

1. To learn the fundamentals of Object Oriented Analysis and Design.
2. To become fluent in the C++ programming language.
3. To develop good programming style.
4. To be able to apply coding quickly and efficiently to realistic (physics) applications.

Learning outcomes

On completion successful students will be able to:

- design and write programs in C++ using a wide range of ANSI standard features.
- write computer programs that can be used for numerical simulation and data analysis

(**A student will be required to solve two problems in the final examination- one program from each group**).

Group A: Structured Programming

1. Introduction to Computer and C programming.
2. Implementation of Branching. Looping Control Statements
3. Programming with Array and Strings.
4. Declaring and Defining Functions and Parameter Passing.
5. Programming with Structures and unions.
6. Implementation of different sorting algorithms: Bubble sort, Insertion, Selection sort, and Radix sort.

Group B: Programming for Numerical Analysis

1. Implementation of the Solution of Linear Algebra and Nonlinear Algebraic Equations.
2. Implementation of Linear and Cubic-Spline Interpolation.
3. Implementation of Curve Fitting: Linear and Polynomial Regression.
4. Implement of Numerical Differentiation.
5. Implement of Numerical Integration- Trapezoidal Rule and Simpson's Rule.
6. Solution of Ordinary Differential Equation.
7. Implementation of Runge-Kutta Method.

Recommended Books

1. Bjarne Stroustrup; The C++ Programming Language (4th Edition).
2. A. Koenig and B. E. Moo. Accelerated C++ (Addison Wesley, 2000)
3. Balagurusamy, E.; Numerical Methods, Tata McGraw-Hill, 2000.
4. Titus, A.B. Introduction to Numerical Programming: A Practical Guide for Scientists and Engineers
5. Robert J. Schilling, Sandra L Harries; Applied Numerical Method for Engineers, Thomson Books.
6. Bau III, David, and Lloyd N. Trefethen. Numerical Linear Algebra.

PHY-210: Chemistry Laboratory for Physics	**Lab: ~ 12 Sessions**	**Credit: 2**
Physics Allied Practical	**Contact Hours: ~ 90**	**Full Marks: 50**
Pre-requisites: 105,208	**Practical: 1 sessions/week, 4 hour/session**	

Aims and objectives

The general aim for the students of the practical course in chemistry is to get familiar with simple experimental procedures in a chemical laboratory. In general, first experiences with the principal reaction behavior of a variety of different substances will be made. The chemical characteristics of these will be elucidated by a series of quantitative experiments alongside with the corresponding qualitative analyses. In order to get an overview of classes of substances as well as some general phenomena in chemistry suitable experiments have been chosen.

Learning outcomes

On completion successful students will be able to:
1. recognize and follow principals of laboratory safety
2. conduct basic scientific measurements of mass, volume and temperature
3. analyze and interpret data associated with the following concepts:
   - density of solids and liquids
   - reactions in aqueous solutions
   - stoichiometry
4. students should be able to use the ideal gas law to determine the molar mass of an unknown liquid.

LIST OF EXPERIMENTS

5. Calibration of volumetric glassware (pipette)
6. Determination of gram equivalent weight of magnesium
7. Determination of Avogadro's number
8. Determination of:
   a) Molar volume of oxygen
   b) Molecular weight of condensable vapor
9. Experiment on preparation of sodium thiosulphate
10. Experiment on preparation of ferrous ammonium sulpahte
11. Standardization of approximately 0.1N HCl by titration with standard 0.1N NaOH (acid-bases titration)
12. Determination of (a) ferrous and (b) ferric ion by oxidation with $K_2Cr_2O_7$ solution (oxidation-reduction titration)
13. Investigation of the stoichiometry of potassium chlorate

Recommended Books

1. Practical Inorganic Chemistry B. Pass & H. Sutcliffe, Chapman and Hall.
2. Practical Physical Chemistry, Alexander Friendly, Longmans
3. Practical Physical Chemistry, S.R. Pall, Science Book Agency, Calcutta.

N.B.: In addition to the above experiments the Department may include/exclude some experiments.

Syllabuses for Junior Year (Third Year) Courses

PHY-301: Quantum Mechanics-I	**Theory: 60 Lectures**	**Credit: 4**
Physics Core Course	**Contact Hours: 60 hours**	**Full Marks: 100**
Pre-requisites: PHY-101, 104, 203	**Lectures: 3 (1 hour) sessions/week**	

Aims and objectives

The course aims to describe the quantum world, introducing the uncertainty principle and the probabilistic description furnished by quantum mechanics.

The objective of this course are as follows:

1. to teach the fundamentals of quantum mechanics and the skills necessary to solve some common types of physical problems.
2. to provide basic working knowledge of nonrelativistic quantum mechanics and the Schrodinger equation.
3. to provide the skills necessary to apply quantum mechanics to simple, exactly solvable problems, including the hydrogen atom, piecewise constant potentials and the quantum harmonic oscillator.
4. to provide the skills necessary to evaluate expectation values and probabilities in the context of experiments on quantum systems, and to understand the significance of these quantities.

Learning outcomes

On completion successful students will be able to:

1. appreciate that the ultimate description of the physical universe requires quantum not classical mechanics.
2. display a familiarity with the specific experiments which led to the breakdown of classical physics.
3. understand the basic ideas of wave mechanics, especially wave particle duality, the probabilistic nature of phenomena, and the uncertainty principle.
4. demonstrate an understanding of how quantum states are described by wave functions.
5. solve the Schrödinger equation and describe its solution for simple situations such as the properties of a particle in simple potential wells.
6. solve one-dimensional problems involving transmission, reflection and tunneling of quantum probability amplitudes.
7. demonstrate an understanding of the significance of operators and eigenvalue problems in quantum mechanics.
8. demonstrate an understanding of how quantum mechanics can be used to describe the hydrogen and helium atoms.
9. apply their knowledge to modelling real phenomena and situations.

	Course Contents	No. of lectures
	PART-A	
1.	**Physical Basis**: Failures of classical mechanics and emergence of quantum mechanics; Bohr atom and old quantum theory; Domain of quantum mechanics; Heisenberg uncertainty principle.	**08**
2.	**Formulation**: Concepts and postulates of quantum mechanics; Operators and commutation of operators; State function and state function space; Hilbert space; Eigenvalue equations; Eigenfunctions and basis vectors; Hermitian operators; Measurements in quantum mechanics: Expectation values; Orthogonality and the sharing of eigenfunction sets.	**10**
3.	**Schrödinger's Equation**: Hamiltonian operator; Time-dependent and time-independent Schrödinger's equations; Time variation of expectation values; Probability current density; Ehrenfest's theorems.	**12**
	PART-B	
4.	**Problems in One-dimension**: Potential step; Potential barrier; Potential well; Quantum mechanical tunneling.	**08**
5.	**Harmonic Oscillator:** Solution of Schrödinger's equation for the one-dimensional harmonic oscillator; Eigenenergies and eigenfunctions of harmonic oscillator; Expectation values of some observables for the pure and mixed states of harmonic oscillator.	**11**
6.	**Hydrogen atom :** Schrödinger's equation for the hydrogen atom in spherical coordinates; Angular momentum; Operators in Cartesian coordinates; Commutation relations; Angular momentum operators in spherical polar coordinates; Solution of the angular and radial part of the Schrödinger's equation of the hydrogen atom.	**11**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. Griffiths, David J. *Introduction to Quantum Mechanics*. Pearson Prentice Hall, 2004.
2. Shankar, Ramamurti. *Principles of Quantum Mechanics*. Plenum Press, 1994.
3. Feynman, R. P. *Feynman Lectures On Physics*. Vol. 3. Addison Wesley Longman, 1970.
4. Cohen-Tannoudji, et al. *Quantum Mechanics, Vols. 1 & 2*. Wiley, 1991.
5. Liboff, Richard L. *Introductory Quantum Mechanics*. Addison Wesley, 2002.
6. Messiah, P.T.; Quantum Mechanics.
7. Powell, J. L. & Crasemann, B.; Quantum Mechanics; Narosa Publishing House.
8. Sherwin, C.W.; Introduction to Quantum Mechanics.
9. H D Young, R A Freedman, University Physics with Modern Physics, Pearson, 14th Ed., 2015

PHY-302: Electrodynamics	**Theory: 60 Lectures**	**Credit: 4**
Physics Core Course	**Contact Hours: 60 hours**	**Full Marks: 100**
Pre-requisites: PHY-101,103,104,203,204	**Lectures: 3 (1 hour) sessions/week**	

Aims and objectives

The course aims to cover theoretical aspects of electromagnetic fields and radiation by providing an understanding of the basic principles of electrodynamics and the skills required to solve some common electromagnetic problems. The objective of this course are as follows:

1. to provide an understanding of Maxwell's equations, in various forms, and the basic laws of electromagnetism;
2. to provide the skills and techniques for using vector calculus in electromagnetism and to solve Maxwell's equations in some common physical problems;
3. to provide a understanding of electromagnetic fields and waves;
4. to provide a knowledge of the effects of media on the propagation of electromagnetic waves.
5. to provide the skills and techniques for using Maxwell's equations to derive properties of electromagnetic waves and to introduce simple models for the interaction of electromagnetic fields with matter.

Learning outcomes

On completion successful students will be able to:

1. know and demonstrate an understanding of Maxwell's equations , in various forms, for the description of electromagnetic phenomena and their derivation from the empirical laws of electromagnetism.
2. to appreciate and utilize the power of vector calculus to solve Maxwell's equations in some common physical problems
3. use the fundamental laws of electromagnetism to solve simple problems of electrostatics, magnetostatics and electromagnetic induction in a vacuum.
4. understand how to formulate Maxwell’s laws in the presence of simple materials and solve simple problems involving them.
5. to understand the effects of media on the propagation of electromagnetic waves.
6. know and understand the electromagnetic boundary conditions which apply at the interface between two simple media, and to use them to solve simple problems.
7. demonstrate understanding of the properties of plane electromagnetic waves in a vacuum and in simple media and to be able to derive these properties from Maxwell's equations.
8. to describe electromagnetic fields and waves created by various simple configurations of charges and currents;
9. calculate the radiated power produced by accelerating charges.
10. distinguish between radiation fields and other electromagnetic fields.

	Course Contents	**No. of lectures**
	PART-A	
1.	**Electromagnetic Field Equations:** Maxwell’s modification of Ampere’s law; Equation of continuity; Maxwell’s equations; Energy in electromagnetic fields; Poynting vector.	**10**

2.	**Propagation of Electromagnetic Waves:** Wave equations for **E** and **H** and their solutions; Propagation of electromagnetic waves in free space; Propagation of electromagnetic waves in isotropic non-conducting media; Propagation of electromagnetic waves in conducting media; Skin depth; Propagation of electromagnetic waves in ionized gases.	**10**
3.	**Waves in Bounded Regions:** Boundary conditions on the field vectors; Reflection and refraction at the boundary of two non-conducting media (normal and oblique incidence); Total internal reflection; Metallic reflection; Propagation between parallel conducting plates; Wave guides; Cavity resonators.	**10**

PART-B

4.	**Potentials, Fields and Radiation:** Scalar and vector potentials; Retarded potentials; Lienard-Wiechert potentials; Field of a moving point charge; Fields of an accelerated charge; Electric dipole radiation; Magnetic dipole radiation; Radiation fields of charges moving with low velocities; Radiation from an oscillating dipole; Radiation from a half-wave antenna; Radiation from a group of moving charges.	**12**
5.	**Scattering:** Scattering cross section; Scattering by a free electron; Forced vibration; Scattering by a bound electron; Resonance scattering.	**09**
6.	**Dispersion:** Normal and anomalous dispersion; Drude-Lorentz harmonic oscillator model; Resonance absorption by bound charges; The Drude free electron theory; Dispersion in gases; Dispersion in liquids and solids.	**09**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. Jackson, J.D.; Classical Electrodynamics; 3rd edition, John Wiley & Sons, Inc.
2. Griffiths, D.J.; Introduction to Electrodynamics; 3rd edition, Prentice Hall.
3. Reitz, J. R., Milford, F. J. and Christy, R. W.; Foundation of Electromagnetic Theory; Narosa Publishing.
4. Lorrain, P and Corson, D.; Electromagnetic fields and Waves; 2nd edition, CBS Publishers.
5. Heald, M.A. & Marion, J.B. Classical Electromagnetic Radiation, (Academic Press).
6. Feynman, The Feynman Lectures on Physics, Vol II (Addison Wesley, 1964)
7. Schwartz, M., Principles of Electrodynamics, (Dover Publications, 1972)
8. Grant, I.S. & Phillips, W.R. Electromagnetism (2nd ed.) (Wiley)
9. L.D. Landau & E.M. Lifshitz, Mechanics and Electrodynamics, Pergamon Press.

PHY-303: Atomic and Molecular Physics	**Theory: 60 Lectures**	**Credit: 4**
Physics Core Course	**Contact Hours: 60**	**Full Marks: 100**
Pre-requisites: PHY-101, 104, 203, 301	**Lectures: 3 (1 hour) sessions/week**	

Aims and objectives

To use the results of basic quantum mechanics to explain the basic characteristics of atomic structure and to describe the processes of atomic transitions.

The objective of this course are as follows:

1. To explain the need for and introduce the principles of the Special Theory of Relativity.
2. To develop the ability to use the Special Theory of Relativity to solve a variety of problems in relativistic kinematics and dynamics.
3. To explain the need for a Quantum Theory and to introduce the basic ideas of the theory.
4. To develop the ability to apply simple ideas in quantum theory to solve a variety of physical problems.

Learning outcomes

On completion successful students will be able to:

1. understand the notion of an inertial frame and the concept of an observer.
2. appreciate the failure of classical relativity theory and explain the principles of special relativity.
3. understand and use the Lorentz transformation formulae with particular emphasis on the breakdown of simultaneity, time dilation and length contraction.
4. appreciate the role of energy and momentum in a relativistic context.
5. understand the idea of space-time and the role of four-vectors.
6. solve problems in relativistic mechanics.
7. appreciate the failure of classical mechanics and the need for a quantum theory.
8. understand and use the ideas of wave-particle duality and the uncertainty principle to solve simple problems in quantum mechanics.
9. appreciate the existence of atomic spectra and perform simple calculations relating to the quantum behavior of atoms.
10. have an elementary understanding of the role of the wave function in the quantum theory.
11. explain how quantum mechanics can be used to describe the ground states and excited states of atoms with two electrons in the outer shell, and how these ideas can be extended to describe the states of atoms with several such electrons via the Russell-Saunders and j - j approximations.
12. apply quantum mechanics to the transitions between atomic states and to explain the origin of selection rules.
13. use their understanding of atomic states to explain chemical bonding.

	<u>Course Contents</u>	**No. of lectures**
	PART-A	
1.	**Special theory of Relativity:** Inertial systems; Michelson and Morley experiment; Galilean transformations; Basic Postulates of special theory of relativity; Minkowskian space time and four vectors; Four velocity; Lorentz transformations; length contraction and time dilation; Velocity addition; Space like; Time like and Light like separated events; Light cone; Proper frame; Proper length; Proper time; Covariance of Maxwell's Field equations; Relativistic Mass and Energy.	**11**

2.	**Particle Properties of Waves:** Particles and waves in nature; Electromagnetic radiation; Photoelectric effect and its important features; Compton effect; Pair production and pair annihilation; Concept of light; Photons and gravity; Black holes; X-rays: Production of continuous and characteristic X-rays; X-ray diffraction.	**12**
3.	**Wave Properties of Particles:** de Broglie's hypothesis; Phase velocity and group velocities of matter waves; Particle diffraction; Davission-Germer experiment; Uncertainty principle and its applications.	**07**

PART-B

4.	**Atomic Structure:** Thomson model of atom; Alpha-particle scattering experiment and Rutherford model; Nuclear dimensions, Electron orbit; Atomic spectra-the Bohr atom, Energy levels and spectra; Atomic excitation-Frank-Hertz experiment; Nuclear motion and reduced mass.	**08**
5.	**Quantum Concepts and Detailed Atomic Structure:** Schrodinger equation; Four quantum numbers; Normal Zeeman effect; Stern-Gerlach experiment; Electron Spin, Fine structure and anomalous Zeeman effect; Pauli exclusion principle and the periodic table; Vector atom model *l-s* and *j-j* coupling; Many-electron atoms and atomic spectra.	**12**
6.	**Molecular Physics:** Molecular bonds; Electron sharing; The H_2 molecular ion; the hydrogen molecule; Complex molecules; Rotational and vibrational energy levels; Electronic spectra of molecules; Types of spectra; Raman effect.	**10**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. Beiser, A.; Concepts of Modern Physics; McGraw-Hill International.
2. R M Eisberg and R Resnick Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles, Wiley.
3. Semat, H.; Introduction to Atomic and Nuclear Physics.
4. Weidner, R.T. and Sells R.L.; Elementary Modern Physics; Allyn and Bacon Inc.
5. White, H. E.; Introduction to Atomic Spectra; McGraw-Hill.
6. Beiser, A.; Perspective of Modern Physics; McGraw Hill International.
7. Forshaw, J. R. & Smith, G, Dynamics & Relativity (John Wiley & Sons)
8. Cox, B. E. & Forshaw, J. R. Why does E=mc2? (and why should we care?) (Da Capo)
9. Cox, B. E. & Forshaw, J. R. The Quantum Universe (Allen Lane)
10. Rindler, W. Relativity: Special, General & Cosmological (Oxford)
11. H D Young, R A Freedman, University Physics with Modern Physics, Pearson, 14th Ed., 2015

PHY-304: Statistical Mechanics	**Theory: 60 Lectures**	**Credit: 4**
Physics Core Course	**Contact Hours: 60**	**Full Marks: 100**
Pre-requisites: PHY-106, 203, 204, 301	**Lectures: 3 (1 hour) sessions/week**	

Aims and objectives

The course aims to demonstrate the power of statistical methods in physics and provide a unified survey of the statistical physics of gases, including a full treatment of quantum statistics. Basic principles are examined in this course, such as the laws of thermodynamics and the concepts of temperature, work, heat, and entropy. The objective of this course are as follows:

1. to deepen the appreciation of the link between the microscopic properties of individual atoms or other particles and the macroscopic properties of many-body systems formed from them.
2. to provide an appreciation of the links between microscopic physics and thermal behavior.
3. to give fuller insight into the meaning of entropy.
4. to show how fundamental properties of solids can be described in statistical terms.
5. to show how the properties of macroscopic bodies can be derived from the knowledge that matter is made up from atoms.
6. to discuss applications of statistics to various types of gas.
7. to use the methods of quantum mechanics and statistical physics to calculate the behavior of gases of identical particles and to apply the results to some important physical systems.

Learning outcomes

On completion successful students will be able to:

1. describe the role of statistical concepts in understanding macroscopic systems;
2. techniques for finding appropriate averages to predict macroscopic behavior and how these techniques are applied to the calculation of the properties of matter;
3. use the formalism of thermodynamics, including the thermodynamic potentials and Maxwell's relations, and apply these tools to simple systems in thermal equilibrium;
4. demonstrate an understanding of the first and second laws of thermodynamics, and of the concept of entropy, including the derivation of the general formula for entropy in terms of the ensemble partition function;
5. explain the statistical origin of the laws of thermodynamics and construct a partition function for a system in thermal equilibrium and use it to obtain thermodynamic quantities of interest.
6. demonstrate an understanding of the implications of particle indistinguishability for the properties of systems of non-interacting particles.
7. deduce the Boltzmann distribution for the probability of finding a system in a particular quantum state;
8. write down the Bose-Einstein and Fermi-Dirac distribution functions and apply them to calculate the properties of ideal Bose and fermi gases.
9. compare and contrast the properties of the ideal Bose gas with those of real Bose systems, in particular black body radiation, phonons in solids.
10. compare and contrast the properties of the ideal fermi gas with those of real fermi systems, in particular electrons in metals.
11. deduce the equation of state and the heat capacity of an ideal gas and an electron gas;
12. deduce the Einstein and Debye expressions for the heat capacity of an insulating solid and compare the theory with accepted experimental results;
13. describe super fluidity in liquid helium, Bose-Einstein condensation;
14. describe different transport phenomena and phase transition of a macroscopic system.

Course Contents		**No. of lectures**

PART-A

1.	**Classical Statistical Mechanics:** The scope of statistical physics; Assemblies; Phase Space and Phase Trajectory; Volume in Phase Space; Specification of States of a System; Density of States and its General Behavior; Liouville's theorem and its Consequences; The Postulates of Classical Statistical Mechanics; Stirling Approximation; Thermodynamic Probability; Statistical Equilibrium; Macrostates and Microstates;	**08**
2.	**Statistics and Thermodynamics**: Statistical concept of Temperature; Ensembles: Microcanonical Ensemble, Canonical Ensemble-its Connection with thermodynamic parameters and grandcanonical ensemble; Entropy, Free energy and other thermodynamic functions and their equilibrium conditions; Statistical Distribution Function; The Boltzmann partition function; Maxwell velocity distribution and mean values; Maxwell-Boltzmann Statistics and its Applications; Ideal monatomic gas; Harmonic oscillator; Specific heat of solids.	**10**
3.	**Quantum Statistical Mechanics:** Postulates of Quantum Statistical Mechanics; Transition from Classical to Quantum Statistical Mechanics; Particle Statistics: Principle of indistinguishability for quantum particles, Spin-statistics connection, Exchange degeneracy; Average value and Quantum Statistics; The Density Matrix; Statistics of various Ensembles.	**10**

PART-B

4.	**Fermi Systems:** Fermi-Dirac distribution function; Fermi-Dirac gas; Fermi Energy; Fermi Temperature; Fermi Velocity and Mean Velocity of a free electron in a Metal; Degenerate Fermi systems; Landau Diamagnetism; Pauli Paramagnetism; Thermionic Emission; Statistical equilibrium in White Dwarfs.	**08**
5.	**Bose Systems:** Bose-Einstein distribution function and it's application; Planck’s radiation law; The Photon Gas; The Specific heat of Solids; The Phonon gas; Bose-Einstein Condensation; Superfluidity in Liquid He; Thermodynamics of Bose systems; Thermodynamic Properties of Diatomic Molecules; Nuclear Spin Effects in Diatomic Molecules.	**08**
6.	**The Condensed State:** Solids at low and high temperature; Debye’s interpolation formula; Thermal expansion of solids; Quantum liquids with Bose-type spectrum; Quantum liquids with Fermi-type spectrum; the electronic spectra of metals; the electronic spectra of solid dielectrics.	**08**
7.	**Transport Phenomena and Phase Transition:** Boltzmann transport equation; H-theorem, validity of the equation; Mean free path, Viscosity and Diffusion; Electrical Conductivity, Brownian motion. Thermodynamic classification of Phase transition; Difference between first and second order phase transition; Mean-field theory.	**08**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. Reif, Frederick, ed. Fundamentals of Statistical and Thermal Physics. McGraw-Hill, 1965.
2. L.D. Landau and E.M. Lifshitz, Statistical Physics I, Pergamon Press (any edition)
3. Huang, Kerson. Statistical Mechanics. 2nd ed. Wiley, 1987.
4. Mandl, F. *Statistical Physics*, (Wiley)
5. Bowley, R. & Sanchez, M. *Introductory Statistical Mechanics,* (Oxford)
6. S.J. Blundell and K.M. Blundell, Concepts in Thermal Physics (Oxford Univ. Press 2006)
7. Pathria, R. K. Statistical Mechanics. Pergamon Press, 1972.
8. A M Guenault Statistical Physics (2nd ed), Chapman and Hall (1995)
9. Kittel, D. & Kroemer, H. Thermal Physics, (Freeman)
10. Hook, J.R. and Hall, H.E, Solid State Physics, (Wiley)
11. D. Yoshioka, Statistical Physics: An Introduction (Springer 2007)
12. M. Gitterman and V. Halpern, Phase transitions: A brief account with modern applications, World Scientific (2004).
13. D. Chandler, Introduction to Modern Statistical Mechanics, Oxford University Press.
14. D.J. Amit, Statistical physics: An introductory course, World Scientific.
15. Harald J. W. Muller-Kirsten, Basics of Statistical Physics – A Bachelor Degree Introduction, World Scientific 2010.

PHY-305: Solid State Physics-I	**Theory: 60 Lectures**	**Credit: 4**
Physics Core Course	**Contact Hours: 60 hours**	**Full Marks: 100**
Pre-requisites: PHY-102, 203, 301, 304	**Lectures: 3 (1 hour) sessions/week**	

Aims and objectives

The course aims to provide a general introduction to theoretical and experimental topics in solid state physics. This course deals with crystalline solids and is intended to provide students with basic physical concepts and mathematical tools used to describe solids. The course deals with groups of materials, as in the periodic table, in terms of their structure, electronic, optical, and thermal properties.

The objective of this course are as follows:

1. to introduce the fundamental principles of solid state physics, taking wave motion in a crystal as the unifying concept; the waves include X rays, lattice vibrations and de Broglie waves of electrons.
2. to show how crystal symmetry leads to substantial mathematical simplifications when dealing with solids.
3. to describe basic experimental measurements, to show typical data sets and to compare these with theory.
4. to show how the form of the electron wave functions, their energies, and their occupation by electrons help us to understand the differences between metals, insulators and semiconductors.
5. to introduce models which describe the structure, properties and interactions of one-electron and many-electron atoms.
6. to allow the students to understand the fundamentals of semiconductor behavior and the operation of basic semiconductor devices.

Learning outcomes

On completion successful students will be able to:

1. identify lattice and basis for simple crystal structures and construct the reciprocal lattices.
2. describe the main features of crystal lattices and phonons and the thermal properties of solids;
3. describe the main features of the physics of electrons in solids, show an understanding of how electron wave functions and energies are changed by the presence of the periodic crystal potential;
4. demonstrate an understanding of wave motion in periodic structures leading to an understanding of the temperature dependence of specific heat, as well as being able to calculate the phonon dispersion relation for a chain of atoms;
5. describe and make use of the relationship between bonding and electronic structure of semiconductors, metals and metal alloys.
6. demonstrate a detailed understanding of the quantum-mechanical description of one-electron and multi-electron atoms
7. describe major pieces of experimental evidence supporting the key theoretical ideas, including the experimental techniques used;
8. demonstrate an understanding of the Fermi surface and how it is modified by the presence of a weak crystal potential.
9. demonstrate an understanding of the semiclassical dynamics of electrons in solids.

10. describe the main features of the optical properties of solids
11. explain how the electrical properties of metals, insulators and semiconductors are related to their electronic structure.
12. demonstrate an understanding of the functionality of the p-n junction and low dimensional system, e.g., quantum dots.

	Course Contents	**No. of lectures**
	PART-A	
1.	**Crystal Structure:** The Crystalline State of Solids; Unit Cell; Bravais Lattice; Symmetry operations; Miller Indices; Simple Crystal Structures; Packing Factor; Inter-planar Spacing; Concept of Reciprocal Lattice; Bragg Diffraction in Reciprocal Lattice; Brillouin Zones; Diffraction of X-rays by crystals; Laue equations and Bragg law; Experimental diffraction methods-Laue method: Rotating crystal method and power methods. Defects;	**10**
2.	**Crystal Bonding:** Interatomic forces and crystal bonding; Ionic crystals; Calculation of electrostatic energy, binding energy, Madelung constant and bulk modulus; Covalent crystals; Crystals of inert gases; Van der Waals` and repulsive interactions; Metal crystals and hydrogen bonded crystals.	**10**
3.	**Lattice Vibrations and Thermal Properties:** Vibrations of monatomic linear lattice; Vibrations of diatomic linear lattice; Nonelectronic dynamical properties: Phonon; Phonon momentum; Elastic vibration of a continuous medium; Enumeration of normal modes; neutron scattering by a crystal; Theories of lattice specific heat - Einstein model and Debye model; Lattice thermal resistivity; Anharmonicity; Thermal expansion; Heat conductivity; Normal and Umklapp processes.	**10**
4.	**Multi-electron atoms:** Wave functions of identical particles. Exchange symmetry. Pauli exclusion principle. Helium atom; Hartree approximation; X-ray spectra. Hund's rules. Molecular orbital theory applied to covalent bonding. Hydrogen ion. Hydrogen molecule.	**6**
	PART-B	
5.	**Free Electron Theory of Metals:** Drude phenomenology of electronic properties, Fermi gas, Energy levels and density of states in one dimension; Free electron gas in three dimensions; Heat capacity of the electron gas; Effect of temperature on F-D distribution; Electrical conductivity and Ohm's law; Hall effect; Wiedmann-Franz law; Electrical and thermal conductivity: scattering of electrons from crystal defects and phonons, Pauli paramagnetism, Sommerfeild theory of conduction in metals.	**10**
6.	**Electronic structure of solids:** Wave functions of electrons in a one-dimensional crystal; crystal momentum. Modification of free-electron dispersion relation; energy bands and band gaps; Classification of solids by their electrical properties at zero temperature: metals and insulators; Nearly Free electrons model of electronic structure, The tight binding approximation; Fermi surfaces, Properties of the fermi surface; band structures; Semi-classical dynamics of Bloch electrons;	**10**

concept of hole charge carriers and effective mass, dynamics in presence of magnetic field; Semiclassical transport; Optical properties.

7. **Dielectric Properties:** Macroscopic Electric Field; Local Electric Field at an Atom; Dielectric Constants and Polarizabilities; Clausius-Mossotti Relation; Dielectric Phenomena in an Ac Field; Debye Equations for Dielectric Constant and Dielectric Loss; Dielectric Response of an Electron Gas - Concept of Plasmon and Calculation of Plasma Frequency; Screened and Unscreened Coulomb Potential; Motion in Magnetic Fields; Pyro, piezo and Ferroelectricity; Light propagation in solids. **8**

8. **Semiconductors:** general properties and band structures, impurities, intrinsic and doped semiconductors, concept of hole charge carriers and effective mass, Electron statistics; carrier concentration and transport; conductivity; mobility; Impurities and defects; Magnetic field effects: cyclotron resonance and Hall effect; Optical properties; absorption, photoconductivity, luminescence and excitons, p-n junctions; Basic semiconductor devices: light-emitting diodes, photovoltaic cells, transistors, quantum dots: elements of quantum confinement and quantum transport. **6**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. Kittel, C.; Introduction to Solid State Physics; Wiley India.
2. N. W. Ashcroft and N.D. Mermin, Solid State Physics (Thomson Press).
3. J.R. Hook and H.E. Hall, Solid State Physics, (Wiley).
4. Eisberg, R.M. & Resnick, R. Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles.
5. Mckelvey, JP; Solid State and Semiconductor Physics
6. Steven H. Simon; The Oxford Solid State Basics
7. Dekker, A. J.; Solid State Physics; S.G. Wasani for Macmillan India.
8. Omar, M. Ali; Elementary Solid State Physics; Addison Wesley.

PHY-306: Nuclear Physics-I	**Theory: 60 Lectures**	**Credit: 4**
Physics Core Course	**Contact Hours: 60 hours**	**Full Marks: 100**
Pre-requisites: PHY-203, 301, 302, 304	**Lectures: 3 (1 hour) sessions/week**	

Aims and objectives

The course introduces the fundamentals of nuclear physics and applications, as well as mathematical tools needed to grasp these concepts.

The objective of this course are as follows:

1. To introduce the fundamental constituents of matter and the forces between them, and to explore how these lead to the main features of the structure and interactions of subatomic systems (particles and nuclei).
2. To develop the ability to look for patterns and similarities in various nuclear and particle interactions in order to unpack and simplify seemingly-complicated problems.
3. To describe radioactivity and related phenomena and explain the various interactions of nuclear radiation with matter
4. To introduce the main features of the reactions between nuclei, and to link nuclear physics to other areas of physics.
5. To understand nuclear interactions and elementary particles involved in the interactions

Learning outcomes

On completion successful students will be able to:

1. outline the basic constituents of matter and the fundamental forces between them and use simple models to explain the patterns of nuclear masses, sizes and understand the mechanisms behind nuclear decay processes.
2. use the quark model to explain the patterns of light hadrons.
3. explain basic properties of excited states in nuclei using simple models and describe the shell and liquid drop models of the nucleus.
4. describe radiations from the nucleus and use radioactivity disintegration laws to solve problems.
5. identify and decide the type of equilibrium for a given series decay and apply the radioactivity law (half-life) in carbon dating.
6. describe interaction of light and heavy charged particles with matter.
7. understand the general features of nuclear reactions and use symmetries and conservation laws to identify the forces responsible for particular reactions and decays.
8. show how simple models can explain the main features of nuclear reactions and explain how specific nuclear reactions are responsible for the formation of the elements.
9. identify and describe the four major interactions of photons with matter.
10. describe the neutron interaction and the slowing down of fast neutron to be thermal by scattering process.
11. describe gas filled, scintillation and semiconductor detector.
12. describe the main features of the forces between protons and neutrons, and their relation to the underlying forces between quarks.

Course Contents | **No. of lectures**

PART-A

	Course Contents	No. of lectures
1.	**Nuclear Properties:** Constitution of the nucleus; Quarks, hadrons and leptons; Measurements of nuclear mass and charge radii: electron scattering, muonic atoms; Mirror nuclei; Coulomb displacement energy; Semi-empirical mass formula; Mass defect; Binding energy: Binding energy curve; Semi-empirical mass formula; Angular momentum: Spin, parity and symmetry; Magnetic dipole moment and electric moments; Electromagnetic moments: hyperfine structure. Nuclear deformation; Mirror Nuclei; Coulomb energy; Nuclear forces; Liquid drop model and Shell model.	**07**
2.	**Radioactivity:** Nuclear stability; Natural and artificial radioactivity; Radioactive decay law; Successive radioactive transformations; Radioactive equilibrium; Radiometric dating, Types of decay.	**08**
3.	**Mechanisms of Nuclear Decay:** α decay: Alpha decay properties; Condition of alpha decay; Fine structure; Measurement of alpha-particle energies; Geiger-Nuttal law and theory of alpha decay.	**08**
	β decay: Introduction; Conservation of energy; Conservation of angular momentum; Neutrino hypothesis; Measurement of disintegration energies; Fermi theory of beta decay and selection rules.	**07**
	γ decay of excited states: Properties of gamma rays; Interaction and absorption of gamma rays; multipolarity, selection rules and decay probabilities; measurements of gamma-ray energies and life-times of excited states; Internal conversion; Photon interactions - photoelectric effect, Compton scattering, pair production and annihilation.	**07**

PART-B

	Course Contents	No. of lectures
4.	**Nuclear Reactions:** Nuclear and chemical reactions, Reaction dynamics; The Q-value equation and threshold energy; Neutron and neutron flux; Reaction cross sections, Resonances, Optical potential, Direct and compound-nuclear mechanisms; Fission and fusion reactions; Fission energy and thermonuclear energy.	**08**
5.	**Stopping and Detecting Nuclear Radiations:** Stopping power, range and strangling for charged nuclear particles; Stopping of neutrons; Gas-filled counters - ionization chambers, proportional and Geiger-Müller counter; Solid state counter; Scintillators - properties of different phosphors; Semiconductor detectors: silicon, germanium, HPGe detector; neutron detection; Counting statistics; Neutron scattering and absorption; Attenuation and shielding.	**09**
6.	**Accelerators and Sources of Atomic Particles:** Van de Graff accelerator; Cyclotron; Betatron; Proton synchrotron; Neutron sources; Standard Model of Particle Physics, Three generations of particles; Flavours and flavour mixing, Quark model with three flavours, Heavy-quark hadrons, CP violation, The origin (s) of mass.	**07**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. Krane, K. S. Introductory Nuclear Physics (Wiley)
2. B. R. Martin, Nuclear and Particle Physics: An Introduction, 2nd ed. (Wiley)
3. Wong, S. S. M. Introductory Nuclear Physics (Wiley)
4. Bertulani, C. Nuclear Physics in a Nutshell (Princeton University Press)
5. Martin B. R. and Shaw, G. Particle Physics (Wiley)
6. Hodgson, P.E., Gadioli, E. & Gadioli Erba, E. Introductory Nuclear Physics, (OUP)
7. Perkins, D. H. Introduction to High Energy Physics (CUP)
8. Enge, H. A.; Introduction to Nuclear Physics; Addison-Wesley Publishing Company; 4th Edition.
9. W S C Williams, Nuclear and Particle Physics (Clarendon)
10. Lilley, J. Nuclear Physics Principles and Applications (Wiley)
11. Burcham, W.E. Elements of Nuclear Physics, (Longman)
12. Bennet, D.J. & Thompson, J.R. Elements of Nuclear Power, (Longman)
13. David Griffiths, Introduction to Elementary Particles (Wiley)
14. Kaplan, I.; Nuclear Physics; Norosa Publishing House; 2nd Edition.

PHY-307: Digital Electronics	**Theory: 60 Lectures**	**Credit: 4**
Physics Core Course	**Contact Hours: 60**	**Full Marks: 100**
Pre-requisites: PHY-103, 205, 206, 209	**Lectures: 3 (1 hour) sessions/week**	

Aims and objectives

To achieve a basic understanding of logic systems and to use this understanding in simple circuit designs. The objective of this course are as follows:

1. Develop an ability to design and build basic digital circuits: logic gates (NAND/NOR/Inverter, etc.)
2. Design and analyze synchronous sequential logic circuits
3. Develop an ability to perform basic time-domain and frequency-domain analysis of these circuits
4. Understand the function and construction of basic memory circuits: DRAM, SRAM, non-volatiles
5. Understand the basics of integrated semiconductor electronics
6. Understand the basic functional elements of an integrated circuit (current sources, active loads)

Learning outcomes

On completion successful students will be able to:

1. design combinational and sequential logic circuits.
2. show familiarity with basic logic gates, Boolean algebra and binary numbers.
3. understand how particular logical functions may be implemented and to design systems to implement simple truth tables.
4. illustrate how binary addition may be implemented using logic gates.
5. describe latches and simple memory devices.
6. categorize the progression from latches to flip-flops and understand the operation of the J-K flip-flop.
7. be able to use and predict the behavior of simple circuits involving J-K flip-flops.
8. understand basic methods of ADC (analogue-to-digital conversion) and be able to build 2-bits ADC.
9. apply the developed theory to simple circuits; adders, integrators and phase shifters (requiring complex number analysis).
10. design interfaces to digital computer systems.

.	<u>**Course Contents**</u>	**No. of lectures**
	PART-A	
1.	**Numbers and Binary Codes:** Different number systems: Binary numbers; Decimal numbers; Octal numbers; Hexadecimal numbers; Number base conversion. Weighted codes: The 8421 code; Other 4-bit BCD codes; The parity bit; The Gray code; Hamming code; Error detection and correction; The ASCII code; Code conversion.	**08**
2.	**Boolean Algebra and Logic Gates:** Laws and theorems of Boolean algebra; Boolean functions; Simplification of Boolean functions; De Morgan's theorems; Digital Logic gates: AND gate; OR Gate; NOT gate; NOR gate; The universal building block; XOR and XNOR gates; TTL circuits.	**08**

3.	**Simplifying Logic Circuits:** Minterm and maxterm; SOP and POS circuits; Algebraic simplification; Map method: Truth table to Karnaugh maps; Simplifications; Tabulation method: Determination and selection of Prime-Implicants. Arithmetic Circuits: Complements: The r's and (r-1)'s complements; Subtraction with r's and (r-1)'s complements; Adders: half-adder and Full-adder; Binary parallel adder, Decimal adder, BCD adder; Subtractors: Half-subtractor and full subtractor; Binary multiplier.	**10**
4.	**Flip-Flops: SR Latches:** Transistor latch; NAND and NOR latch; Clocked SR flip-flop; D-type flip-flop: Unclocked and clocked D flip-flop; JK flip-flop: Edge-triggered JK flip-flop; Jk master-slave flip-flop; Multivibrators.	**08**

PART-B

5.	**Counters and Registers:** Ripple counter, Design of synchronous counter, Parallel Counter; Combination counter; BCD shift registers; Decoders: BCD- to decimal decoder; Demultiplexers; Encoders; Multiplexers.	**07**
6.	**D/A and A/D Conversion:** Variable-resistor network; Binary ladder, D/A converter; D/A accuracy and resolution; A/D converter, A/D accuracy and resolution; Advanced A/D techniques.	**06**
7.	**Memory Devices**: Semiconductor memory technologies; Memory addressing; ROM architecture; Types of PROMS and EPROMs; RAM architecture; Static and dynamic RAM; DRAM; SDRAM; Magnetic Core and bubble memory Cache memory.	**05**
8.	**Integrated Circuit Technology:** Integrated Circuit; IC Fabrication: Purification and preparation of silicon wafer; Epitaxial growth; Oxidization; Photolithographic process; Isolation diffusion; Base and emitter diffusion; Metallization; Encapsulation; Formation of integrated circuit elements; Transistors, capacitors and resistors for integrated circuits; Sheet resistance.	**08**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. Malvino, A. P., and Leach, D. P.; Digital Principles and Applications; Tata McGraw-Hill.
2. Tocci; Digital Systems, Principles and Applications; Prentice Hall.
3. Floyd, T. L., Digital Fundamentals, Merrill.
4. Malvino, A. P.; Digital Computer Electronics; Tata McGraw-Hill Publishing Company.
5. Horowitz, Paul and Hill, Winfield, The Art of Electronics, Cambridge University Press; 3rd edition.
6. Safa O. Kasap; Principles of Electronic Materials and Devices 3rd Edition, McGraw-Hill Education
7. Mano, M. Morris; Digital Logic and Computer Design.
8. Nashelsky, L.; Introduction to Digital Computer Technology.
9. Agarwal, Anant, Jeffrey H. Lang. Foundations of Analog & Digital Electronic Circuits. Elsevier.
10. Katz, R. H., Contemporary Logic Design, Benjamin.
11. Cahill, S. J., Digital and Microprocessor Engineering, Ellis-Horwood.
12. Peatman, J. B., Design of Digital Systems.
13. Pappas, N. L., Digital Design.
14. Charles Platt, Make: Electronics: Learning Through Discovery, Maker Media, Inc.
15. Charles Platt, Make: More Electronics: Journey Deep Into the World of Logic Chips, Amplifiers, Sensors, and Randomicity, Maker Media, Inc.

PHY-308: Computational Physics	**Theory: 60 Lectures**	**Credit: 4**
Physics Core Course	**Contact Hours: 60**	**Full Marks: 100**
Pre-requisites: PHY- 104, 203, 206, 209	**Lectures: 3 (1 hour) sessions/week**	

Course Description

The use of computers in physics, as well as most other branches of science and engineering, has increased many times along with the rapid development of faster and cheaper hardware. This course aims to give the student a thorough grounding in the main computational techniques used in modern physics. It is particularly important in this course that the students should learn by doing. The course is therefore designed such that a significant fraction of the students' time is spent actually programming specific physical problems rather than learning abstract techniques. The course will cover problems in 4(5) broad sections:

- Ordinary differential equations, such as those of classical mechanics.
- Partial differential equations, such as Maxwell's equations and the Diffusion and Schrödinger equations.
- Matrix methods, such as systems of equations and eigenvalue problems applied to Poisson's equation and electronic structure calculations.
- Monte Carlo and other simulation methods, such as the Metropolis algorithm and molecular dynamics.
- Computer Application; a number of examples illustrate the utility of numerical computations in various domains of physics.

This is **not** a short course in computing science, nor in programming. It focuses specifically on methods for solving physics problems. There is no requirement that the practical work be done using FORTRAN/Python/Matlab/C++ on the departmental computers, but anyone wishing to use some other programming language or computer should consult the lecturer beforehand. This is to make sure there is both help available from demonstrators and that it will be possible to assess the work satisfactorily.

Aims and objectives

The aim of the course is to introduce the techniques of computational physics and dynamic high-level scripting programming languages. This course teaches the students practical skills needed for solving modern physics problems by means of computation. A number of examples illustrate the utility of numerical computations in various domains of physics.

Learning outcomes

On completion successful students will be able to:

(a) model a physical problem of temporal or spatial evolution
(b) choose or select an appropriate numerical method, design a numerical code implementing the method and evaluate the quality of the numerical solution obtained
(c) choose the most suitable algorithm for solving given problem and integrate algorithms in computer codes and evaluate their performance
(d) write programs using dynamic high-level scripting programming languages and carry out data analysis in them.
(e) compare numerical solution and analytical solution if it exists
(f) use classical numerical methods (Euler and higher order) to find solutions of ordinary differential equations and to analyze the behavior of a physical system (a driven oscillator)

(g) use Monte Carlo techniques and associated statistical methods
(h) understand and use the principles underlying particle transport calculations.
(i) use current computer tools as well as those specific to their discipline.
(j) solve actual physics problems using numerical tools
(k) compile a scientific report presenting the results and analyzes

	Course Contents	**No. of lectures**
	PART-A	
1.	**Review of Numerical Methods and the Solution of Ordinary Differential Equations** Introduction to Numerical Computing; Errors in Numerical Methods, Numerical Instabilities; Discretization, integration and differentiation; disintegrations. Movement of particles in various fields of forces. Oscillations, resonances, chaos. Gravitational problem with N body. Movement of rigid solids; Numerical Methods for Solving Ordinary Differential Equations; Euler's Method; Higher-Order Methods; The Leap-Frog Method; The Runge-Kutta Method; The Predictor-Corrector Method; The Intrinsic Method; Stability analysis of numerical schemes; Implementation of Numerical Methods in dynamic high-level scripting programming languages; Adaptive Integration Methods; Advanced Integration Methods; The Chaotic Pendulum; Phase Space; Conserved Quantities; Analytic Solution; Numerical Solution; Sources of Simulation Error; The Poincaré Section; Spatial Symmetry Breaking; The Fast Fourier Transform and applications; Map-Based Schemes; Introduction to Nonlinear Systems -- Period-Doubling Bifurcations, The Route to Chaos, Sensitivity to Initial Conditions, The Definition of Chaos, Periodic Windows.	**12**
2.	**Partial Differential Equations:** Types of Equations; Elliptic Equations -- Laplace's Equation; Hyperbolic Equations -- Wave Equations, wave propagation, initial conditions and limits, modes, Eigen frequencies, stability analysis; The 1-D Advection Equation, The Lax Scheme, The Crank-Nicholson Scheme, Upwind Differencing, The 1-D Wave Equation, The 2-D Resonant Cavity; Waves in inhomogeneous medium; Eulerian and Lagrangian Methods; Parabolic Equations – Diffusion; The Diffusion Equation -- 1-D Problem With Dirichlet, Neumann, Mixed Boundary Conditions, Explicit schemes, finite differences. Von Neumann Stability Analysis, 1-D, 2-D And 3-D Solution Of the Diffusion Equation; Courant-Friedrichs-Lewy Condition. Conservative Methods -- The Equation Of Continuity, Maxwell's Equations; Dispersion.	**12**
3.	**Matrix Algebra:** Introduction; Types of Matrices; Simple Matrix Problems; Elliptic Equations -- Poisson's Equation, 1-D Problem with Dirichlet Boundary Conditions, 2-D Problem with Neumann Boundary Conditions, Example Solution of Poisson's Equation in 1-D, 2-D And 3-D; Two-dimensional case: equations of electrostatics and magnetostatics; Finite Difference and Finite Element Schemes; Systems of Equations and Matrix Inversion -- Exact Methods, Iterative Methods, The Jacobi Method, The Gauss-Seidel Method; Matrix Eigenvalue Problems -- Schrödinger's Equation, General Principles, Full Diagonalization, The Generalized	**12**

Eigenvalue Problem, Partial Diagonalization, Sturm Sequence, Sparse Matrices and The Lanczos Algorithm, Numerical Solution of Schrodinger Equation for Spherically Symmetric Potentials – Scattering States, Calculation of Phase Shifts, Resonance.

PART-B

4. **The Monte Carlo Methods and Simulation:** Monte Carlo - Random Number Generators, Distribution Functions; Monte-Carlo Integration; Diffusion and random walk; Stochastic Processes, Markov Chain; The Metropolis Algorithm -- The Ising Model, Thermodynamic Averages; Quantum Monte-Carlo; Molecular Dynamics -- Interacting Particles with Lennard-Jones Potentials, Classical and Tight Binding Molecular Dynamics, Simulation of Ar; Introduction to Particle Transport Simulation -- Cross-Sections; Simulation of Neutron Transport and Scattering -- Nuclear Criticality with Monte Carlo. **12**

5. **Computer Applications:** Particle-In-Cell Codes --Introduction, Normalization Scheme, Solution of Electron Equations of Motion, Evaluation of Electron Number Density, An Example 1D PIC Code; The theory of quantum mechanics. From many-body to single-particle: Quantum modeling of molecules; Density Functional Theory, Car-Parrinello Simulation; Hubbard Model -- Motivation, Representation of Sz Basis, Generation of Basis States, Construction of Hamiltonian. Exact Diagonalization, Calculation of Correlation Function. Lanczos Method and Applications to Tight Binding Hamiltonians, Calculation of Spectral Properties. Quantum modeling of solids: Basic properties. Electrons in Periodic Potential, Calculation of Band Structure using Plane Wave Methods. **12**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. Chapman, S.J. MATLAB Programming for Engineers (Brooks and Cole 2000)
2. Higham, D.J. & Higham, N.J. MATLAB Guide 2nd edition (2005)
3. Garcia, A.L. Numerical Methods for Physics (Prentice Hall 1994)
4. A first course in Numerical Methods, U.M. Ascher and C. Greif, 2012, PHI Learning
5. Press, W.H. 2007. Numerical recipes: the art of scientific computing. 3rd ed. CUP
6. Elementary Numerical Analysis, K.E. Atkinson, 3rd Edn., 2007, Wiley India Edition.
7. A first course in Computational Physics, Paul, L. Pavries (John Wiley & Sons).
8. Monte Carlo Methods, M. H. Kalos and P. A. Whitelock (John Wiley & Sons).
9. Understanding Molecular Simulation, Daan Frenkel and B. Smit (Academic Press).
10. Computational Physics, J. M. Thijssen (Cambridge University Press).
11. A Guide to Monte Carlo Simulations in Statistical Physics, Landau & Binder (CUP).
12. Statistical Mechanics - Algorithms and Computations, Krauth (Oxford University Press).
13. Molecular Dynamics Simulation, Haile (Wiley Professional).
14. N. J. Giordano, Computational Physics, Pearson Prentice Hall 2006
15. F.J. Vesely, Computational Physics, an Introduction, Kluwer Academic Plenum 2001
16. Titus, A.B. Introduction to Numerical Programming: A Practical Guide for Scientists and Engineers

PHY-309: Physics Lab – III	**Lab: 20 Sessions**	**Credit: 4**
Physics Core Practical	**Contact Hours: 120**	**Full Marks: 100**
Pre-requisites: PHY-103,202,205,305,306	**Practical: 1 session/week, 6 hour/session**	

Aims and objectives

To teach basic laboratory skills and illustrate physics topics such as basic principles of electric circuit analysis, damping and resonance in electric circuits, optics, solid state physics and nuclear physics, illustrated by experiment. They are designed to teach specific experimental skills and techniques e.g., experimental data collection and analysis, ethical standards in a scientific investigation through individual experiments drawn from various topics in physics.

The objectives of physics practical labs are as follows:

1. to introduce and develop group-working skills and enhance writing and written presentation skills
2. to develop the appropriate skills and confidence to use computers for the tasks required in laboratory work
3. to introduce the basic concepts and methods required for laboratory data analysis.
4. to develop sound judgement in interpreting experimental results and uncertainties.
5. to develop the skills required for good scientific communication.
6. to ensure that students can competently use an oscilloscope and to foster an understanding of the way electrical signals are shaped by passive circuit elements.
7. to understand how simple optical instruments work.

Learning outcomes

On completion successful students will be able to:

1. Link the experimental findings to underlying physics in lecture courses, textbooks and scientific journals and apply their physics knowledge and problem-solving skills to model problems in science
2. recognize a wide range of measurement instrumentation, develop and extend prescribed experimental procedures
3. use and measure with common instrumentation and handle sophisticated apparatus with confidence
4. work independently and also co-operatively with colleagues
5. keep professional quality systematic records of laboratory work in a log book while demonstrating high ethical standards during a scientific investigation
6. critically evaluate the results of an experiment, assess the significance of the experimental results compared to expected outcomes and draw valid conclusions
7. appreciate the importance of uncertainties in experimental measurements and be able to apply them in an appropriate manner
8. estimate the precision of experimental results, from an understanding of the experimental procedure and from a statistical analysis of repeated measurements
9. describe the sources of random and systematic error, calculate their effects on the results and evaluate ways of reducing the dominant error
10. use specific computer applications to manipulate and present experimental data in the form of graphs and tables and to describe experiments in coherent, structured formal written reports based on their experiments

Feedback methods

Feedback will be offered orally by demonstrators in lab sessions, orally by demonstrators when they mark each experiment and in writing for all lab reports.

Lab: Laboratory group will be allocated, and supported by, a demonstrator who will monitor progress and provide continuous feedback. A demonstrator is assigned to each group of students for the duration of each experiment. The demonstrator gives guidance and instruction and may be consulted at any time during the laboratory hours. Each laboratory has attendant/technicians who maintain the equipment and have a pool of special items (such as stopwatches) for loan.

During discussions, advice on how to improve the measurement, analysis and presentation of results will be given orally and also written on the assessment sheets, copies of which will be given to the student.

In written reports, detailed comments on how the report might be improved are written on the reports. More general comments are written on the marked sheets, copies of which are returned to the students along with the marked reports. Students are strongly encouraged to collect their marked reports from the markers, when any written comments can be elaborated upon.

Organization

The third year teaching laboratories are located on the second floor and hosts experiments on electricity and magnetism, electronics, solid state physics and nuclear physics. The laboratory unit includes packages on wave optics Circuits PHY-103, PHY-202, Basic Electronics PHY-205, Solid State Physics PHY-305 and Nulcear Physics PHY-306.

Assessment

The demonstrator assesses each group of students during the course of the experiment by considering physics understanding, experimental results, quality of data analysis, innovation, quality of notes in laboratory book and a short interview at the end. During the year students are required to submit written reports on all of the experiments undertaken. The total laboratory mark for the year is based on the experiments and the written reports. Failure to submit such a report will constitute a failure to satisfy the work and attendance requirements and hence the student will not be allowed to proceed to the second year.

(**A student will be required to perform two experiments in the final examination taking one from each group**).

Part A: LIST OF EXPERMENTS

1. Determination of the logarithmic decrement of a ballistic galvanometer and hence determining its critical damping resistance.
2. Determination of the absolute capacitance of a condenser.
3. Determination of the self-inductance of a coil by Rayleigh's method.
4. For a series LRC circuit, determine the following (a) The phenomenon of resonance (b) The effect of variation of R on the frequency response curve (c) The effect of variation of L/C ratio on the frequency response curve.

5. To construct a full-wave bridge rectifier and observe the filtering action of capacitors.
6. To study the output and transfer characteristics of a p-n-p (or n-p-n) transistor in common emitter circuit.
7. To construct of a T.R.F. receiver and to explore the functions of the various components of the receiver.
8. To study the characteristics of a vacuum triode valve and to determine the plate resistance r_P, mutual conductance g_m and amplification factor μ.
9. Determination of mutual inductance by direct throw method.
10. Determination of the resistance of an inductive coil and loss factor of a capacitor by voltmeter measurements.
11. Construction of a transistor radio transmitter.
12. Construction of a two stage R-C coupled transistor voltage amplifier.
13. Polarization of light by 4 plates and investigation of intensity of polarized light (I) as a function of the position of the analyzer and (ii) also as a function of the angle between the optic axis of the 4 plate and that of the analyzer.
14. To study the characteristics of a junction diode.
15. To study the characteristics of a p-n-p transistor in common emitter circuit.

Part B: LIST OF EXPERMIENTS

1. Experiment with a cathode ray oscilloscope
   (a) Synchronizing the time base of an oscilloscope.
   (b) Calibration of a cathode ray tube for both d.c. and a.c. sources.
   (c) Measurement of an unknown frequency using Lissajou's figures.

2. To study the characteristics of GM tube and find the resolution time of the GM tube.

3. To demonstrate the random nature of the emission of γ-particles from radioactive source and to introduce statistical methods of predicting and interpreting the results of radioactive measurements.

4. (a) To study the temperature dependence of resistance of a noble metal (Platinum). (b) To study the temperature dependence of resistance of a semiconductor and to find the energy gap of the semiconductor.

5. To determine the inter planer distance'd' and index an of X-ray powder diffraction photograph and hence determine the cell constant "a".

6. To determine of specific rotation of sugar solution using a polarimeter and to find the concentration of an unknown sugar solution.

7. Determination of e/m of an electron by Helmholtz coil.

8. Charging and discharging of condensers and studying their various characteristics.

9. (a) Measurement of the background radiation using a G-M tube with a scalar.
   (b) Detection and elementary identification of principal nuclear radiations.
   (c) Demonstration of the directional emission from a radioactive source.

10. Determination of the current-voltage characteristics of an ionization chamber and the range of alpha particles.

11. Measurement of electrical conductivity of electrolytes of different concentration by Kohlrauch's method.

12. Measurement of thermal and electrical conductivity of metals and verification of the Wiedemann-Franz law.

13. Measurement of magnetic flux density between the poles of an electromagnet.

14. Exploration of the magnetic field along the axis of a solenoid and measurement of the self inductance of the solenoid coil.

N.B.: In addition to the above experiments the Department may include/exclude some experiments.

Recommended Books

Each experiment is described in a laboratory script which is provided for the student. References to relevant text-books for background reading are given in the script.

The following is the recommended book for a discussion of general experimental techniques:

- Taylor, John Robert. An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements. University Science Books, 1997.
- Bevington, Philip R., and D. Keith Robinson. Data Reduction and Error Analysis for the Physical Sciences. McGraw-Hill, 2003.
- Squires, G.L. Practical Physics, 4th edition (Cambridge, 2001).
- Melissinos, Adrian Constantin, and Jim Napolitano. Experiments in Modern Physics. Academic Press, 2003.
- Preston, Daryl, and Eric Dietz. The Art of Experimental Physics. John Wiley & Sons, 1991.
- Thomas C. Hayes, Paul Horowitz; Learning the Art of Electronics: A Hands-On Lab Course, CUP.
- Paul B. Zbar and Albert Paul Malvino, Basic Electronics: A Text-Lab Manual
- George H. Stout and Lyle H. Jensen, Practical Structure Determination X-Ray Structure Determination: A Practical Guide, 2nd Edition, Wiley-Interscience.
- Ahmed, G and Uddin, MS, Practical Physics
- H D Young, R A Freedman, University Physics with Modern Physics, Pearson, 14th Ed., 2015

Syllabuses for Senior Year (Fourth Year) Courses

PHY-401: Quantum Mechanics-II	**Theory: 60 Lectures**	**Credit: 4**
Physics Core Course	**Contact Hours: 60**	**Full Marks: 100**
Pre-requisites: PHY-203, 301, 303, 304	**Lectures: 3 (1 hour) sessions/week**	

Aims and objectives

This course is a continuation of 301 Quantum Mechanics-I, and will introduce some of the important model systems studied in contemporary physics, including two-dimensional electron systems, the fine structure of Hydrogen, lasers, and particle scattering.

The objective of this course are as follows:
1. To deepen understanding of Quantum Mechanics.
2. To prepare students for courses in quantum field theory and gauge theory.

Learning outcomes

On completion successful students will be able to:
1. Use Dirac notation to represent quantum-mechanical states and manipulate operators in terms of their matrix elements.
2. Interpret and analyze a wide range of quantum mechanical systems using both exact analytic techniques and various approximation methods.
3. Demonstrate familiarity with angular momentum in quantum mechanics at both a qualitative and quantitative level.
4. Add angular momenta and apply to the fine-structure of atomic energy levels.
5. Calculate first-order shifts in energy levels produced by external fields.
6. Use perturbation theory and other methods to find approximate solutions to problems in quantum mechanics, including the fine-structure of energy levels of hydrogen.
7. Solve simple eigenvalue problems, calculate expectation values and probabilities for systems of trapped particles and describe features arising from the associated shell structure.
8. Apply the basic concepts of quantum mechanics to two-state systems to solve eigenvalue problems, calculate expectation values and probabilities.
9. Understand the mathematical underpinnings of quantum mechanics and solve a variety of problems with model and more realistic Hamiltonians.

	Course Contents	**No. of lectures**
	PART-A	
1.	**Matrix Formulation of Quantum Mechanics:** Slit experiments; State Vectors in Hilbert Space; Dirac Bra and Ket Notations; Operators and their Representation; Space as a Continuum; Transformation Theory; Schrödinger, Heisenberg and Dirac Representation; Parity Operators; Density Matrix; Harmonic Oscillator.	**08**
2.	**Approximate Methods** I) Perturbation Method: Time Independent Perturbation Theory: Nondegenerate Case; First-Order Perturbation; Second-Order Perturbation; Degenerate Case, Examples. Time-dependent Perturbation Theory: Principle of the Method; Constant and Harmonic Perturbations; Fermi's Golden Rule; Radiative and Dipole Transitions; Selection Rules.	**15**

II) Variational Method: Necessity of variational method; Basic principle of variation method; Description of variation method; Expectation Value of the Energy; Application to Excited States; Linear Variation Function; Application to Harmonic Oscillator; Hydrogen Atom and Helium Atom.
III) W.K.B. Method: The Classical Limit; Approximate Solutions and Asymptotic Nature of Solutions; Validity Criterion; Solutions near a Turning Point; Connection Formulae; Application to Bound States.
IV) Other Methods: Adiabatic Approximation; Sudden Approximation.

3.	**Quantum Dynamics:** Schrödinger, Heisenberg and Dirac pictures; Equations of motion in Schrödinger, Heisenberg and Dirac pictures; Linear harmonic oscillator.	**07**

PART-B

4.	**Theory of Angular Momentum:** Orbital angular momentum operators and their representation in spherical polar co-ordinates; Eigenvalues and Eigen functions of Angular Momentum; Commutation relations among orbital angular momentum operators; Ladder operators; Spin angular momentum; Addition of Angular Momenta; Eigenvalues and Eigen functions of total angular momentum operators; Angular momentum matrices. Clebsch-Gordon Coefficients; Pauli's Exclusion Principle and Spin Matrices. Wigner-Eckert theorem.	**08**
5.	**Identical Particles:** States of Non-Interacting Identical Particles; Pauli Principles; Fermions and Bosons; Degenerate Fermi gas; Charged particles in a magnetic field; Scattering of Two Bosons; Symmetries of Two Nucleon System; Slater determinant.	**06**
6.	**Theory of Scattering:** Quantum mechanical description of scattering cross-section - Differential and total scattering cross-section, Center of mass and laboratory coordinates; Scattering by spherically symmetric potential: Partial wave analysis; Application to Scattering by Square Well Hard Sphere and Coulomb Potential; Resonance Scattering; Optical Theorem; S-matrics; Green's Function Technique of Solving the scattering Schrodinger Equation; Lippmann-Schwinger Equations; Formal Solution in the form of Von Neumann Series; Born Approximation; Validity Criterion, Examples.	**10**
7.	**Relativistic Quantum Mechanics:** Importance of the theory of relativity in quantum mechanics; Schrödinger's relativistic equation - Klein-Gordan Equation, Dirac equations; Solution of Free Particle Equations; Electron spin; Electron Magnetic Moment; Positive energy solution, Negative energy states and hole theory.	**06**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. D. Griffith; Introduction to Quantum Mechanics
2. R. Shankar; Principle of Quantum Mechanics
3. J. J. Sakurai; Modern Quantum Mechanics
4. C. Cohen Tannoudji; Quantum Mechanics
5. Nouredine Zettili; Quantum Mechanics
6. L. D. Landau and E. M. Lifshitz; Quantum Mechanics
7. E. Merzbacher; Quantum Mechanics
8. A. Messiah; Quantum Mechanics
9. Bransden, B. H., and Joachain, C. J. (2000) Quantum Mechanics 2nd ed., (Pearson)
10. Gasiorowicz, S. (2003) Quantum Physics 3rd ed. (Wiley)
11. W. Greiner; Quantum Mechanics
12. P. A. M. Dirac; Principles of Quantum Mechanics
13. C. W. Sherwin; Introduction to Quantum Mechanics

PHY-402: Astrophysics	**Theory: 30 Lectures**	**Credit: 2**
Physics Core Course	**Contact Hours: 30**	**Full Marks: 50**
Pre-requisites: PHY-102, 104	**Lectures: 2 (1 hour) sessions/week**	

Course Description

Astrophysics is a branch of space science that applies the laws of physics and chemistry to explain the birth, life and death of stars, planets, galaxies, nebulae and other objects in the universe. It has two sibling sciences, astronomy and cosmology, and the lines between them blur.
In the most rigid sense:

- Astronomy measures positions, luminosities, motions and other characteristics
- Astrophysics creates physical theories of small to medium-size structures in the universe
- Cosmology does this for the largest structures, and the universe as a whole.

In practice, the three professions form a tight-knit family. Ask for the position of a nebula or what kind of light it emits, and the astronomer might answer first. Ask what the nebula is made of and how it formed and the astrophysicist will pipe up. Ask how the data fit with the formation of the universe, and the cosmologist would probably jump in. But watch out — for any of these questions, two or three may start talking at once!

Aims and objectives

This course presents a broad introduction to the science of astrophysics and cosmology and describes in a simple way the physical processes that explain the universe in which we live. The intent of this course is to give students a solid background in the primary physical concepts relevant to astrophysics and cosmology, and a broad exposure to the astronomical universe covering a wide range of topics such as the quantitative introduction to the physics of the solar system, stars, the interstellar medium, the galaxy, and the universe, as determined from a variety of astronomical observations and models, the aim of the course is also to give a general overview of the astrophysical objects around us. In addition to learning about our universe, a primary goal of this course is to develop scientific thinking and problem-solving abilities.

The objective of this course are as follows:

1. to demonstrate how the basic physical laws explain the properties of astronomical objects and the Universe and how these properties are measured.
2. to describe the physical properties of stars and review the astronomical techniques by which they are determined.
3. to show how classical physics is successful in modelling many properties of main sequence stars and in explaining their formation and evolution.
4. to show how many Solar System phenomena may be understood in terms of the physics already known to first year students.
5. to provide a good understanding of the structure and properties of the presently observed Universe as well as its evolution.
6. to introduce main ideas about the early Universe.

Learning outcomes

On completion successful students will be able to:

1. be familiar with our understanding of planets, stars and galaxies and how this developed;
2. the structure of the Universe from the modern perspective,
3. explain how astronomical distances are measured;
4. carry out calculations in using common astrophysical units;
5. understand the properties and uses of electromagnetic radiation in an astronomical context;
6. describe and explain the physics of detectors and telescopes including geometric optics;
7. use the basic laws of physics to explain the global properties and basic evolution of stars;
8. know how to characterize and classify stars and have a broad knowledge of the physical characteristics of the different types of star and nebulae, and the techniques by which they are determined.
9. relate observed to physical properties of distant objects given the luminosity and angular size distances.
10. describe, as far as is possible using only classical physics, how stars are born and evolve.
11. understand the basic physical principles of stellar stability, energy production and energy loss.
12. perform simple calculations relating to gravitational collapse, stability, lifetime and energy generation in well-behaved main sequence stars and in nebulae.
13. understand the physical laws of orbital motion and the phenomena which they give rise to;
14. derive Kepler's Laws and apply them with Newton's laws and theorems to a range of astrophysical objects including extrasolar planets;
15. describe the structure of the Milky Way and other galaxies;
16. describe the fundamental constituents of the Universe: baryons, dark matter and dark energy, and the observational evidence for their presence;
17. describe and explain the evolution of our Universe and summarize the main evidence in favor of the Big Bang, inflation, dark matter and dark energy.
18. describe the expansion of the Universe and its ultimate fate, cosmological parameters and models, phenomena in the very early Universe, the Big Bang.
19. relate the density of the universe to its rate of expansion and understand how this relation is modified by a cosmological constant.
20. be aware of our current understanding of the observed Universe and the early Universe.
21. describe the main events of the universe's history and locate them approximately in time and redshift.
22. follow new developments at the level of journals like Nature and Scientific American.

	Course Contents	No. of lectures
	PART-A	
1.	**Introduction:** Modern astronomy; Astronomical coordinates; Rough scales of the astronomical universe; Contents of the universe.	**06**
2.	**Stars :** Properties of stars; Formation of stars; The end states of stars; White dwarfs; Neutron stars; The sun as a star, Surveying the solar system; The interior of the sun; The sun's outer layers; The source of energy of the sun.	**06**
3.	**Galaxies :** Formation and classification of galaxies; Cosmic rays; The milky way system; Spiral structure; Density wave theory; Active galaxies; Peculiar galaxies and quasars; Clusters of galaxies.	**06**

PART-B

4.	**Expansion of the Universe:** Red shifts; Hubble's law regarding expansion of the universe; Age of the universe.	**06**
5.	**Big Bang Theory and Cosmology:** Static cosmological models; Expanding cosmological models and the Big bang theory; Early universe; The universe and the subatomic; Life and intelligence in the universe.	**06**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. Carroll, B.W. and Ostlie, D.A., An Introduction to Modern Astrophysics (Pearson)
2. Maoz, D, Astrophysics in a Nutshell, 2nd edition (Princton University Press)
3. Shu, F. H.; The Physical Universe: An Introduction to Astronomy, University Science Books.
4. Kippenhahn, Rudolf, and Alfred Weigert. Stellar Structure and Evolution. Springer-Verlag
5. Clayton, D.D. Principles of Stellar Evolution and Nucleosynthesis (University of Chicago 1984)
6. Phillips, A.C. The Physics of Stars (Wiley)
7. Rothery, McBride & Gilmour, An Introduction to the Solar System, 2011 (CUP).
8. Binney, James, and Michael Merrifield. Galactic Astronomy. Princeton University Press
9. Liddle, A., An Introduction to Modern Cosmology 2nd ed. (Wiley)
10. Binney, James, and Scott Tremaine. Galactic Dynamics. Princeton University Press
11. Ryden, B., Introduction to Cosmology (Addison Wesley)
12. Unsold, Albrecht. The New Cosmos. Springer, 2001.
13. Sparke, L.S. & Gallagher, J.S. Galaxies in the Universe (CUP)
14. Harrison, E., Cosmology: the Science of the Universe, 2nd ed. (CUP)
15. Hawley, J.F and Holcomb, K.A., Foundations of Modern Cosmology (Oxford)
16. M Roos, Introduction to Cosmology, Wiley (3rd edition).
17. Mo, van den Bosch & White, Galaxy Formation and Evolution, CUP, 2010.
18. M Berry, Principles of Cosmology and Gravitation, CUP.
19. Shapiro, Stuart L., and Saul A. Teukolsky. Black Holes, White Dwarfs, and Neutron Stars. Wiley
20. Longair, Malcolm S. Galaxy Formation. New York: Springer-Verlag
21. Hawking, S. W.; A Brief History of Time; Bantam Books.
22. Weinberg, Steven. The First Three Minutes. Basic Books
23. W J Kaufmann & R A Freedman, W H Freeman, Universe.

PHY-403: Plasma Physics	**Theory: 60 Lectures**	**Credit: 4**
Physics Core Course	**Contact Hours: 60**	**Full Marks: 100**
Pre-requisites: PHY-203, 301, 302, 401	**Lectures: 3 (1 hour) sessions/week**	

Aims and objectives

Plasma physics is one of the advanced field in physics. Plasma is a fourth state of the matter. However, the studying of this course will identify the student with this new advanced branch in physics and its technologies as well as understanding many of other related topics and fields.

Learning outcomes

The main learning outcomes for students enrolled in this course are:

1. Students will be able to understand the explanation of plasma in nature, ionization concept and plasma formation.
2. Students will understand the concept of plasma definition, plasma parameters and plasma formation conditions.
3. Students will recognize the electron motion and gas discharge.
4. Students will be able to know the basics of the particle motion in presence of magnetic field.
5. Students will learn the concept of plasma as a fluid.
6. Students will learn how to produce plasma state in lab and study different plasma experiments and its applications in different fields.

	Course Contents	**No. of lectures**
	PART-A	
1.	**Introduction:** Occurrence of plasma in nature; Definition of plasma; Basic concepts of temperature; Debye length; Plasma parameters; Distribution function; Plasma frequency; Criteria for plasmas; Plasma production; Application of plasma physics.	**12**
2.	**Single-particle Motions:** The equations of motion; Motion of charged particles in static homogeneous electric and magnetic fields; Motion of charged particles in nonuniform **E** and **B** fields; Motion of charged particles in time-varying **E** and **B** fields; Adiabatic invariants.	**12**
3.	**Plasma as a Fluid:** Relation of plasma physics to ordinary electromagnetic; The fluid equation of motion; The complete set of fluid equations; Fluid drifts; Plasma approximation.	**12**
	PART-B	
4.	**Waves in Plasmas:** Representation of waves; Group velocity and phase velocity; Plasma oscillations; Electron plasma waves; Sound waves; Ion waves; Comparison of ion and electron waves; Electrostatic electron and ion waves in magnetic fields; Electromagnetic waves in magnetic fields.	**12**

5. **Kinetic Theory:** The meaning of distribution function f (v); Equations of kinetic theory; Derivations of fluid equations; Plasma oscillations and Landau damping. **12**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. Krall, N. A and Tricvelpiece, A.W.; Principles of Plasma Physics.
2. Chen, F. F.; Introduction to Plasma Physics and Controlled Fusion; Plenum Press.
3. Bittencourt, J. A.; Fundamentals of Plasma Physics.
4. Ichimau, S.; Plasma Physics.
5. Arimovich, L. A.; Elementary Plasma Physics.

PHY-404: Solid State Physics – II	**Theory: 60 Lectures**	**Credit: 4**
Physics Core Course	**Contact Hours: 60**	**Full Marks: 100**
Pre-requisites: PHY-203, 301, 304, 305	**Lectures: 3 (1 hour) sessions/week**	

Aims and objectives

This is the second part of a theoretical treatment of the physics of solids. This course offers an introduction to the basic concepts of the quantum theory of solids.

The objective of this course are as follows:

1. To further develop the understanding of periodicity in solids and how this periodicity and bonding governs electronic properties.
2. To teach students the basic principles of semiconductor physics and related semiconductor devices.
3. To describe how quantum mechanics defines magnetic properties on a microscopic scale.
4. To describe and explain the unique properties of superconductors and to show how they exhibit quantum mechanical phenomena on a macroscopic scale.

Learning outcomes

On completion successful students will be able to:

1. demonstrate how the electrical properties of metals, insulators and semiconductors are related to their electronic structure.
2. explain how simple semiconductor devices (such as the p-n junction) work.
3. characterize intrinsic and doped semiconductors.
4. demonstrate an understanding of the semiclassical dynamics of electrons in solids.
5. describe the microscopic origins of the magnetic properties of solids and explain some ground-state and finite-temperature properties of ferromagnets.
6. describe and characterize magnetism.
7. explain the electromagnetic properties of superconductors including the Meissner effect and the distinction between type I and type II behaviour, including the vortex state.
8. use Ginzburg-Landau theory and the fundamentals of BCS theory.
9. explain the DC and RF Josephson effects and use the Josephson equations.
10. describe and explain the applications of superconductors.
11. use the concepts of excitations and optical properties of solids and crystal defects.
12. describe major pieces of experimental evidence supporting the key theoretical ideas, including the experimental techniques used.
13. compute band structures using the tight-binding approximation, density functional theory etc.

	<u>**Course Contents**</u>	**No. of lectures**
	PART-A	
1.	**Band Theory of Solids:** Electrons in a Periodic potential, E vs. k dispersion, crystal momentum k, conditions for Bragg reflection of electrons; formation of band gap; Nearly Free Electron Model; Bloch theorem; Kronig-Penney model; Motion of Electrons in One and Three Dimensions in a Periodic Potential; Band Theory; Distinction among metals, insulators and intrinsic semiconductors; Concept of holes and effective mass.	**10**

2.	**Band Theory of Insulators and Semiconductors:** A simplified model of an insulator and intrinsic semiconductors; Improved model of an insulator and intrinsic semiconductors; direct and indirect fundamental bandgap, valence and conduction bands; Models for an impurity semiconductor; Hall effect in semiconductors. Hall Effects for One and Two-carrier Systems.	**10**
3.	**Magnetism:** Origin of magnetism and its classification; Diamagnetism; Paramagnetism; Ferromagnetism; Langevin equation for diamagnetism and paramagnetism; Curie Law; Quantum theory of paramagetism; Weiss theory of ferromagnetism; Curie-Weiss law; Nature and origin of Weiss molecular field; Concept of domains and hysteresis; Antiferromagnetism; Neel`s theory; Ferrimagnetism and structure of ferrites; Use of various magnetic materials. Magnetic resonance; Multiferroic Materials.	**10**

PART-B

4.	**Superconductivity:** Basic properties of superconductors; Meissner effect; Type-I and type-II superconductors; Thermodynamics of superconductivity; London equation; BCS theory; Ginzburg-Landau theory and coherence length, flux quantization, vortex state; Tunneling and Josephson Effect; High-T_c superconductors; SQUID.	**10**
5.	**Excitons, Photoconductivity, Luminescence and Defects in Solids:** Excitons; Photoconductivity in crystals; Traps; Space charge effects, Point defects in solids: Lattice vacancies; Schottky defects; Frenkel defects; Diffusion; Color centers.	**10**
6.	**Theory of band structures in crystals:** Electron-Electron Interaction: The Hartree and Hartree-Fock approximations, linear response theory, Lindhard dielectric response function, Thomas-Fermi static screening, Kohn anomaly, the Friedel sum rule; Fermi Surface of Metals: Wannier States, Fermi Surface, Wigner-Seitz Cells, Brillouin Zones; Band Structure Calculations: Revision of the tight binding model, Wigner-Seitz, Pseudopotentials, Density-functional theory, Hubbard model, Green's function methods and the ab initio GW approximation; Superlattices, Mott insulators.	**10**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. N. W. Ashcroft and N.D. Mermin, Solid State Physics (Thomson Press).
2. Kittel, C.; Introduction to Solid State Physics; Wiley.
3. J.R. Hook and H.E. Hall, Solid State Physics, (Wiley).
4. Marder, Michael P. Condensed Matter Physics. New York: Wiley, 2000.
5. Eisberg, R.M. & Resnick, R. Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles.
6. Dekker, A. J.; Solid State Physics; Prentice-Hall, NJ.
7. Omar, M. Ali; Elementary Solid State Physics; Addison Wesley.
8. McKelvey; Solid State and Semiconductor Physics.
9. Stephen Blundell, Magnetism in Condensed Matter (Oxford Master Series in Physics) 1st Edition

PHY-405: Nuclear Physics -II	**Theory: 60 Lectures**	**Credit: 4**
Physics Core Course	**Contact Hours: 60**	**Full Marks: 100**
Pre-requisites: PHY-203, 301, 306, 401	**Lectures: 3 (1 hour) sessions/week**	

Aims and objectives

The course gives an overview of modern nuclear and particle physics, as well as mathematical tools needed to grasp these concepts. The goal of this class is to give you the tools to further continue student's exploration in nuclear and particle physics.

The objective of this course are as follows:

1. To introduce the fundamental constituents of matter and the forces between them, and to explore how these lead to the main features of the structure and interactions of subatomic systems (particles and nuclei).
2. To understand the basic properties of two nucleon bound system (i.e., deuteron)
3. To explain the fundamental theories and application of neutron-proton scattering
4. To acquire fundamental concepts of nuclear forces and their properties
5. To describe and explain the various interactions of nuclear radiation with matter
6. To understand the basic nuclear models for nuclear structure and their applications
7. To develop the ability to look for patterns and similarities in various nuclear and particle interactions in order to unpack and simplify seemingly-complicated problems.
8. To introduce the main features of the reactions between nuclei and models to describe nuclear reactions, and to link nuclear physics to other areas of physics.
9. To understand nuclear interactions and elementary particles involved in the interactions.

Learning outcomes

On completion successful students will be able to:

1. describe the nuclear properties of ground and excited state of deuteron.
2. demonstrate knowledge of and apply the basic models used to describe nuclear structure
3. describe the neutron interaction and the slowing down of fast neutron to be thermal by scattering process.
4. explain the neutron-proton scattering at low and high energy
5. describe interaction of light and heavy charged particles with matter.
6. understand the general features of nuclear reactions and use symmetries and conservation laws to identify the forces responsible for particular reactions and decays.
7. show how simple models can explain the main features of nuclear reactions and explain how specific nuclear reactions are responsible for the formation of the elements.
8. identify the interactions in nature and explain their fundamental four forces
9. describe the main features of the forces between protons and neutrons, and their relation to the underlying forces between quarks.
10. describe elementary particles and use the quark model to explain the patterns of light hadrons.

	Course Contents	**No. of lectures**
	PART-A	
1.	**The Deuteron Problem:** Ground state of the deuteron; Excited state of the deuteron; Electric quadrupole moment and deuteron wave function; Radius of deuteron. Photodisintegration.	**08**

2.	**Two Body Problems:** Neutron-proton scattering at low energy; Spin dependence of neutron-proton scattering; Phase shift; Scattering lengths; Effective range theory in n-p scattering; Neutron-proton scattering at intermediate and high energies; Coherent and incoherent scattering at low energy neutrons; Ortho- and para hydrogen.	**10**
3.	**Nuclear Force:** General properties and characteristics; Symmetries in nuclear physics; From quarks to pions and nucleons; Exchange of virtual particles. Exchange forces; Yukawa potential; Meson theory of nuclear forces.	**08**
4.	**Interaction of Nuclei with Electromagnetic Radiation:** Introduction; Multiple radiation and selection rules; Probability of multiple emission and absorption; Radiative transition in the two body problem; Internal conversion; Transition between two low-lying states of nuclei; Transition involving highly excited states.	**08**

PART-B

5.	**Nuclear Structure Models:** (a) Nuclear Shell Model: Independent particle shell model; Fermi gas model; Single particle potentials; Spin-orbit interaction & potential; Magic numbers; Shell model predictions; Ground state spins; Spin and magnetic moments of nuclei; Schmidt curves. (b) Collective Phenomena in nuclei: Liquid drop model; Fermi gas; Mean field; Deformation; Vibrational and rotational motion; Super and hyper deformation.	**05**
6.	**Nuclear Scattering and Reactions:** Optical Model: Complex Potential; Nuclear reaction cross-section; Energy Averaged Cross-sections; Phenomenological Optical Model Cross-sections by the Method of Partial Waves; Elastic and inelastic processes; Direct and compound-nuclear mechanisms; Continuum Theory; Resonance; Breit-Wigner dispersion formula for an s-state.	**09**
7.	**Elementary Particles I:** Strong, electromagnetic and weak interactions; Particle-antiparticle; Classification and general properties; Conservation laws: Angular momentum, Baryon number, lepton number, Strangeness, Isospin, Parity, charge conjugation and CP; CPT theorem; The quark model; Weak interactions: CP violation in kaons, Parity violation in β Decay.	**06**
8.	**Elementary Particles II:** Spectrum and Interactions of Known Particles; Conservation or Violation of Isospin; Strangeness and Charm in Particle Interactions; Hadron Spectroscopy and Resonances; $SU(3)_{Flavour}$ Classification of the Lightest Hadrons; Introduction to the Standard Model and Ideas of Unification; Neutrino Masses.	**06**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. B. R. Martin, Nuclear and Particle Physics: An Introduction, 2nd ed. (Wiley)
2. Krane, K. S. Introductory Nuclear Physics (Wiley)
3. Wong, S. S. M. Introductory Nuclear Physics (Wiley)
4. Bertulani, C. Nuclear Physics in a Nutshell (Princeton University Press)
5. W S C Williams, Nuclear and Particle Physics (Clarendon)
6. Blatt and Weisskopf; Theoretical Nuclear Physics.
7. Martin B. R. and Shaw, G. Particle Physics (Wiley)
8. Hodgson, P.E., Gadioli, E. & Gadioli Erba, E. Introductory Nuclear Physics, (OUP)
9. Perkins, D. H. Introduction to High Energy Physics (CUP)
10. Enge, H. A.; Introduction to Nuclear Physics; Addison-Wesley Publishing Company; 4th Edition.
11. Lilley, J. Nuclear Physics Principles and Applications (Wiley)
12. Burcham, W.E. Elements of Nuclear Physics, (Longman)
13. Halzen and Martin, Quarks and Leptons (Wiley).

PHY-406: Reactor Physics	**Theory: 60 Lectures**	**Credit: 4**
Physics Core Course	**Contact Hours: 60**	**Full Marks: 100**
Pre-requisites: PHY-203, 301, 306, 405	**Lectures: 3 (1 hour) sessions/week**	

Aims and objectives

The objectives of this course are to provide students a thorough understanding of the elementary key elements of nuclear reactor physics. It will also provide basic idea on simple reactor geometries and describe and understand the main reactivity feedback mechanisms, and their significance, on reactor design and control. Key concepts such as neutron flux and diffusion are also introduced. These are then utilized to demonstrate multiplication and criticality. The neutron life cycle in thermal reactors is described along with fast and delayed neutron production. Reflected reactors and reactor kinetics are discussed including doubling times, reactivity feedback mechanisms, power and temperature coefficients and Xenon poisoning.

Learning outcomes

On completion successful students will be able to:

1. discuss aspects of reactor physics and the implications that reactor physics has on the
2. engineering of nuclear systems.
3. perform analyses on simple reactor geometries and describe and understand the main reactivity feedback mechanisms, and their significance, on reactor design and control.
4. explain the concept of criticality, and its estimation in various idealised geometries.
5. describe basic point kinetics concepts, and prompt and delayed criticality.
6. describe the main reactivity feedback mechanisms and their significance.
7. calculate basic parameters of reactor physics, e.g. multiplication factors, critical sizes.
8. perform point-kinetics reactor transient analyses, and explain the importance of prompt
9. criticality and neutron lifetime.

	<u>Course Contents</u>	**No. of lectures**
	PART-A	
1.	**Introduction:** Nuclear reactor physics; Nuclear reactor; Fusion reactor; Nuclear energy; Nuclear force; Nuclear fission; Fissionable materials; Fissile materials; Fertile materials; Breeding reaction; Doubling time; Mass and energy; Nuclear reactions; Fundamental laws governing nuclear reactions; nuclear Binding energy: mass defect, separation energy, Maxwellian distribution of gas, atoms or nuclei; Atom density: For elements, for isotopes, for chemical composition.	**08**
2.	**Neutron:** Discovery; Sources of neutrons; Properties of neutrons; Neutron reaction; Slow neutron reaction; Neutron cross section; Microscopic and macroscopic cross sections; Determination of cross section; Mean free path; Attenuation of Neutrons; Neutron flux; Reaction rate; Classification of neutron according to energy; Energy dependence of neutron cross section; Fission cross section.	**08**
3.	**Nuclear Reactors:** Classification of reactors according to the mean energy of neutrons causing fissions; Classification of reactors according to the material used; Classification by structure; Classification of reactors according to the purpose; Basic components of a nuclear reactor**:** Reactor core, cladding, coolant, moderator, control rod or control system, blanket, reflector, reactor vessel, shielding, reactor building.	**07**
4.	**Nuclear Fission:** Classification of fissile; Fissionable materials; The mechanism of fission; Practical fission fuels; Products of fission; Yields and mass distribution	**07**

of fission products; Energy distribution of fission fragments; Energy release from fission; Neutron yield and neutron production ratio; Prompt and delayed neurons; Energy distribution of fission neutrons; Reactor power; Fissions rate; Fuel burn up; Fuel consumption.

PART-B

5. **Moderation or Slowing Down of Reactor Neutrons:** Neutron moderation by elastic scattering; Collision kinematics; Differential elastic scattering cross section; Isotropic scattering; Scattering angles in L and C.M systems; Angular and energy distribution; Forward scattering in the L System; Average energy loss per collision and average cosine of scattering angle; Average logarithmic energy decrement; Description of the dynamics of elastic collision in terms of lethargy; Transport mean free path and transport cross section; Slowing down power and moderating ratio; Slowing down time; Slowing down density; Resonance escape probability; The effective resonance integral. **07**

6. **Neutron Diffusion:** Neutron transport equation: Basic definitions, assumptions; derivation of transport equation; Meaning of neutron diffusion; Fick's law, Equation of continuity, One speed diffusion equation; Steady-state diffusion equation, boundary conditions, solution of diffusion equation for different geometry; The thermal diffusion length; The exponential piles; The diffusion length for a fuel moderator mixture; Multi-region problem; Fast neutron diffusion and Fermi age equation; Assumptions; Slowing down density and derivation of Fermi age equation, Fermi age, τ; Fast diffusion length, L_f; Physical significance of age, τ; Migration area and length. **07**

7. **Neutron Chain Reaction:** Introduction; Neutron cycle and multiplication factors; Four factor formula; Neutron leakage and critical size; Six factor formula; Nuclear reactors and their classifications; Homogenous and heterogeneous reactor system; Effect of heterogeneous arrangement on η, p, f, and ε. **05**

8. **The Reactor Critical Equation:** Introduction; Diffusion equation applied to a thermal reactor; One-group reactor equation; Solution of one-group reactor equation: For the slab reactor, for a spherical reactor, for an infinite cylindrical reactor, for a rectangular parallelepiped reactor, for a finite cylindrical reactor; Minimum critical volume of a reactor; Maximum to average fluxes and power; One-group critical equation; Criticality calculations: The group diffusion method, two-group critical equations, modified one-group critical equation; Critical equation for continuous slowing down; Thermal neutron diffusion; Critical equation and reactor buckling; The non-leakage factor; Criticality of large thermal reactors; Critical size and geometrical buckling; Effect of reflector; Reflected reactors; Reflector savings. **07**

9. **Reactor Control:** Control and reactor kinetics; Fission product poisoning, ^{135}Xe poisoning, ^{149}Sm poisoning; Control rod worth; Cylindrical rod; Burnable poisons; Effects of temperature on reactor kinetics; General feature of reactor control. **05**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. Liverhant, S. E.; Elementary Introduction to Nuclear Reactor Physics.
2. Glasstone, S. and Edelund M. G.; Elementary of Nuclear Reactor Theory; CBS Publishing and Distributions.
3. Lamarsh, J. R.; Introduction to Nuclear Reactor Theory; Addison Wesley Publishing Company.
4. Lamarsh. J. R.; Nuclear Reactor Engineering; Addison Wesley Publishing Company.
5. Glasstone, S. and Sessonske, A.; Nuclear Reactor Engineering; CBS Publishing and Distributions.
6. Beck L. K.; Nuclear Reactor for Research.
7. Bennet, D.J. & Thompson, J.R. Elements of Nuclear Power, (Longman)

PHY-407: Geophysics	**Theory: 30 Lectures**	**Credit: 2**
Physics Core Course	**Contact Hours: 30**	**Full Marks: 50**
Pre-requisites: PHY-102, 203, 204, 303	**Lectures: 2 (1 hour) sessions/week**	

Aims and objectives

This course is designed to be a survey of the various sub-disciplines of geophysics (geodesy, gravity, geomagnetism, seismology, and geodynamics) and how they might relate to or be relevant for other planets. No prior background in Earth sciences is assumed, but students should be comfortable with vector calculus, classical mechanics, and potential field theory. Geophysicists are employed in a wide range of industries, including petroleum and mineral exploration, groundwater, contaminants and salinity evaluation, state and government geological surveys, defence science and academic research. This course provides the background for a career in solid-earth, exploration and environmental geophysics.

Learning outcomes

On completion successful students will be able to:

1. demonstrate proficiency in common practical skills in geophysics;
2. describe the difference between a potential field, diffusive field, and a wave field;
3. explain how geophysics is used to predict rock chemistry and/or mineralogy;
4. discuss advantages and limitations to various geophysical methods with respect to sensitivities and geologic conditions;
5. discuss the differences between the oceanic and continental lithospheres in a variety of geophysical contexts;
6. discuss the assumptions applied to Maxwell's equations and the conditions under which they apply that result in fundamentally different geophysical phenomena;
7. predict the geophysical response to simplified geological structures;
8. develop relationships for characteristic temporal and spatial scales from more complex mathematical relationships;
9. design an appropriate set of geophysical surveys to investigate a potential subsurface target.

	Course Contents	**No. of lectures**
	PART-A	
1.	**The Earth in the Solar System:** Solar System Formation, Accretion, and the Early Thermal State of the Earth; Rotation and Angular Momentum; The Sun; Planetary Formation; Early Thermal State of the Earth; Meteorites and the Bulk Composition of the Earth; Chondrites; Secondary Processing; Achondrites; Irons and Stony-Irons; Cosmic ray exposures of meteorites; Pointing-Robertson effect; Compositions of terrestrial planets; One-dimensional Earth's Structure; Lateral Heterogeneity in the Mantle.	**08**
2.	**Rotation and Figure of the Earth:** Figure of the earth; Precession of the equinoxes; The Chandler wobble; Tidal friction and the history of the Earth-Moon system; Fluctuations in rotation and the excitation of the wobble.	**08**
3.	**The Earth's Gravitational Field:** Gravity as a gradient of the geopotential, Potentials, Figure of the Earth; Satellite Geoid; Crustal structure and the principle of isostasy; Gravitational Potential due to Nearly Spherical Body; Earth tides; The Poisson and Laplace Equations; Cartesian and Spherical Coordinate Systems; Spherical Harmonics; Global Gravity Anomalies; Gravity Anomalies and the	**08**

Reduction of Gravity Data; Correlation between Gravity Anomalies and Topography; Flexure and Gravity.

4. **Seismology and the Internal Structure of the Earth:** Seismicity of the earth: Historical Perspective, Introduction; Elastic waves and seismic rays : Strain, Stress, Equations of Motion, Wave Equation, P and S-waves, From Vector to Scalar Potentials – Polarization, Solution by Separation of Variables, Plane Waves, Some Remarks, Nomenclature of Body Waves in Earth's Interior, More on the Dispersion Relation, The Wave Field - Snell's Law, Fermat's Principle and Snell's Law, Ray Geometries of the Wave Field, Travel Time Curves and Radial Earth Structure, Radial Earth Structure, Surface Waves, Sensitivity Kernels, Excitation of Surface Waves, Dispersion: Phase and Group Velocity, Dispersion Curves; Internal density and composition; Seismology: Free Oscillations. **10**

PART-B

5. **Geomagnetism:** The Magnetic Field of the Earth; The Main Field; The Internal Field; The External Field; The Magnetic Induction due to a Magnetic Dipole; Magnetic Potential due to More Complex Configurations; Power Spectrum of the Magnetic Field; Downward Continuation; Secular Variation; Source of the Internal Field: The Geodynamo; Crustal Field and Rock Magnetism; Magnetization; Other Types of Magnetization; Magnetic Cleaning Procedures; Paleomagnetism; Field Reversals; Qualitative Arguments that explain the need for Core-mantle Coupling; Magnetic Anomalies; Magnetic Anomaly Profiles; Fundamental equations; Measurement of the magnetic field; Method of Gauss; Saturation induction magnetometer; Proton precession magnetometer, Alkali vapor magnetometer. **10**

6. **Geodynamics (The Earth’s Internal Heat):** Heat Flow, Geothermal Gradient, Diffusion, Thermal Structure of the Oceanic Lithosphere, Bending, or Flexure, of Thin Elastic Plate; The Upper Mantle Transition Zone; The geothermal flux; Thermal conduction in the mantle; Temperatures in the interior of the earth; Energy source for the geomagnetic dynamo. **08**

7. **Radioactivity and the Age of the Earth:** The pre-radioactivity age problem; Radioactive Decay; Radioactive elements and the principle of radiometric dating; Radioactivity as a Heat Source; Age of the earth and meteorites; Dating the nuclear synthesis. **08**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. Sleep, Norman H., Kazuya Fujita, and K. Fujita. Principles of Geophysics. Blackwell Science.
2. Lowrie, William. Fundamentals of Geophysics. Cambridge University Press, September 1997.
3. Fowler, C. M. R. The Solid Earth: An Introduction to Global Geophysics. Second Edition. CUP.
4. Stacey, F. D.; Physics of the Earth; John Wiley and Sons, New York
5. Turcotte, Donald L., and Gerald Schubert. Geodynamics. 2nd ed. Cambridge University Press.
6. Garland, G. D.; Introduction to Geophysics: Mantle, Core and Crust; W. B. Saunders Company.
7. Grant, F. S. and G.F. West; Interpretation Theory in Applied Geophysics.
8. Parasnis, D. S.; Principles of Applied Geophysics; Chapman and Hall.
9. Telford, F. M., Geldart, L. P., Sheriff, R. E. and. Keyes, D. A.; Applied Geophysics; CUP.
10. Stein, Seth, and Michael Wysession. An Introduction to Seismology, Earthquakes and Earth Structure. Blackwell Science, 2002.

PHY-408: Renewable Energy	**Theory: 30 Lectures**	**Credit: 2**
Physics Core Course	**Contact Hours: 30**	**Full Marks: 50**
Pre-requisites: PHY-102, 103, 204, 305	**Lectures: 2 (1 hour) sessions/week**	

Aims and objectives

This course provides an introduction to energy systems and renewable energy resources, with a scientific examination of the energy field and an emphasis on alternate energy sources and their technology and application. The class will explore society's present needs and future energy demands, examine conventional energy sources and systems, including fossil fuels and nuclear energy, and then focus on alternate, renewable energy sources such as solar, biomass (conversions), wind power, geothermal, and hydro. Energy conservation methods will be emphasized. In the interest of time some mathematical criteria will be covered, e.g. Betz limit for wind, limit of efficiency of WEC point absorber.

Learning outcomes

On completion successful students will be able to:

1. List and generally explain the main sources of energy and their primary applications in Bangladesh, and the world.
2. Describe the challenges and problems associated with the use of various energy sources, including fossil fuels, with regard to future supply and the environment.
3. Discuss remedies/potential solutions to the supply and environmental issues associated with fossil fuels and other energy resources.
4. List and describe the primary renewable energy resources and technologies.
5. Explain the technological basis for harnessing renewable energy sources.
6. Describe/illustrate basic electrical concepts and system components.
7. Convert units of energy—to quantify energy demands and make comparisons among energy uses, resources, and technologies.
8. Collect and organize information on renewable energy technologies as a basis for further analysis and evaluation.
9. Compare different renewable energy technologies and choose the most appropriate based on local conditions
10. Design renewable/hybrid energy systems that meet specific energy demands, are economically feasible and have a minimal impact on the environment
11. Suggest the best combination of technological solutions to minimize the emission of greenhouse gases and increase the sustainability of the energy system in specific areas/regions
12. Discuss how to utilize local energy resources (renewable and non-renewable) to achieve the sustainable energy system

	Course Contents	**No. of lectures**
	PART-A	
1.	**Renewable Energy Sources:** Introduction: Energy: Past, Today, and Future, A brief history of energy consumption, Energy & Environment, Non-renewable energies; Lifetime of Fossil Fuels, Sustainability and Energy Use, Energy Conversion Technologies; Solar energy, Wind energy, Hydroelectric energy, Ocean energy, Tidal energy, Wave energy, Geothermal energy, Ocean thermal energy conversion (OTEC).	**05**

2. **Solar Energy:** World Energy Requirement and Reserve; Solar Radiation; Solar Constant Solar Geometry; Azimuth; Declination; Day Length; Solar Time; Solar Radiation of Tilted Surface; Monthly Average Solar Radiation; Measurement of Solar Radiation. **10**

a) Basic Concept of Heat Transfer**:** Conduction, Convection and Radiation; Heat Conduction through Different Surfaces; Natural and Forced Convection; Heat Transfer Coefficients.

b) Solar Collectors: Flat Plate Collectors; General Description of Flat Plate Collector; Heat Transfer Properties of the Flat Plate Collector; Energy Balance; Temperature Distribution; Collector Overall Heat Transfer Coefficient; Collector Efficiency Factor; Heat Removal Factor and Flow Factor.

c) Energy Storage: Applications of Energy Storage; Storage Characteristics; Energy Storage Technologies; Types of Energy Storage; Sensible Heat Storage; Latent Heat Storage; Thermochemical Storage; Battery Examples; Sustainability.

d) Solar Photovoltaics: Interaction of Light with Semiconductor; Absorption and Recombination Process; Photovoltaic Principles; Semiconductor Junction; Power Output and Conversion Efficiency; Efficiency Limit. Basic Photovoltaic System for Power Generation; Solar Modules; Module Circuit Design; Application of Photovoltaic System.

3. **Wind Energy:** Wind power, Suitability of Wind Power; Estimation of wind power; Factors of Wind Speed; Wind behavior and site selection, Wind power variations with time, Wind and energy roses, Wind power distribution, Local power variations with height and terrain; Betz' Law; Basic Wind Power System; Wind Generators; Basic wind turbine aerodynamics; Dynamic Modeling of Wind Turbines; Control of Wind Turbines; Wind Energy and the environment. **05**

PART-B

4. **Water Power (Hydro, Tidal & Wave):** Introduction, Methodology for Pelamis to convert wave energy into electricity, Methodology for the LIMPET (Land Installed Marine Power Energy Transformer) to convert wave energy into electricity, Methodology for the floating wave power vessel (FWPV) to convert wave energy into electricity, Methodology for the stingray tidal stream generator to convert wave energy into electricity, Floating wind mill to convert wind energy into electricity. Ocean Energy: Ocean Energy Potential against Wind and Solar, Wave Characteristics and Statistics, Wave Energy Devices, Introduction to Tidal Power, Tide characteristics and Statistics, Tide Energy Technologies, Ocean Thermal Energy, Osmotic Power, Ocean Bio-mass; Hydropower: Basic properties of water energy, Available energy of water flow, Transformation of water energy, Hydropower plants, Small hydropower plants, Special hydropower plants, Utilization of hydropower – examples, trends in hydropower utilization. **05**

5. **Bioenergy:** Introduction, Biogas technology, Mechanism of biogas formation, Design of fixed dome biogas plant, Maintenance of biogas plant, Construction material and cost of a family size fixed dome biogas plant; Types of biomass and their basic properties, Transformation of biomass energy, Biomass gasification process, Types of gasifier, Problems with gasification, Prospects and potential of **03**

biomass gasification, Biomass gasifier stove and its design, Applications of biomass, Technologies for utilization of biomass – examples, Economics of biomass, Trends in biomass energy utilization.

6.	**Other Non-conventional Systems:** Geothermal Energy: Principles, Geothermal Resources, Electricity Production, Geothermal Technologies, Challenges, Economics; Fuel Cells; Transportation - hybrids, flexfuels, fuel cells; Hydrogen Energy: Basic properties of hydrogen, Technologies of hydrogen production, Fuel Cell – operating principle, main parts, properties and types, Chemical Energy Conversions, Fuel Cell Integration, Modeling of Fuel Cells, Control of Fuel Cells.	**03**

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. Schaeffer, John. 2007. Real Goods Solar Living Sourcebook: The Complete Guide to Renewable Energy Technologies and Sustainable Living (30th anniversary edition). Gaiam.
2. Boyle, Godfrey. Renewable Energy: Power for a Sustainable Future, Third Edition. Oxford University Press, 2012.
3. Bob Everett, Boyle, Godfrey, and Janet Ramage (eds.) 2004. Energy Systems and Sustainability: Power for a Sustainable Future. Oxford University Press
4. Tester, et al. Sustainable Energy: Choosing Among Options, 2nd Edition. MIT Press, 2012.
5. Aldo V. da Rosa, "Fundamentals of Renewable Energy Processes", 2005, Academic Press.
6. Gilbert M. Masters, "Renewable and Efficient Electric Power Systems", 2004, Wiley.
7. Bent Sorensen, "Renewable energy: its physics, engineering, use, environmental impacts, economy, and planning aspects" Elsevier Academic Press.
8. John Twidell, Tony Weir, Anthony D. Weir "Renewable Energy Resources", Taylor & Francis.
9. John. A. Duiffie and Willium A. Beckman; Solar Engineering of Thermal Process, 3 edition, Wiley. .
10. K. Sukhatme, Suhas P. Sukhatme; Solar Energy: Principles of Thermal Collection and Storage. Tata McGraw-Hill Education.

PHY-409: Biophysics and Medical Physics	**Theory: 30 Lectures**	**Credit: 2**
Physics Core Course	**Contact Hours: 30**	**Full Marks: 50**
Pre-requisites: PHY-102, 207, 304, 306	**Lectures: 2 (1 hour) sessions/week**	

Aims and objectives

There is an increasing recognition that physics can provide a very real - and very valuable - insight into the behavior of complex biological systems, and that a physical approach to biological problems can provide a new way of looking at the world. This course will introduce the students to the basics of biological systems, and then provide examples of how familiar physical principles (thermodynamics, statistical mechanics) underlie complex biological phenomena. This course will introduce the wonders of biology: the organisms, cells, and molecules that make up the living world. We will demonstrate the power of physical concepts to understand and make powerful predictions about biological systems, the motions of proteins to drive biological processes. The physical concepts will be substantially familiar, but their applications will be novel. Students will be taught how to interpret experimental observations of various biomedical systems by using their physics and mathematics knowledge and by applying problem solving skills. They will acquire new knowledge and skills that will be applicable to complex systems quite generally, not only in biomedicine. Where possible, examples will be drawn from the recent scientific literature.

The objective of this course are as follows:

1. To introduce the topic of biomedical physics, and to show how physical principles help one to understand the function of living systems at all levels of complexity - starting at the molecular, via the cellular, to the organ and system levels.
2. To introduce stability analysis of thermodynamically open systems.
3. To convey an appreciation that living systems are structures in time as much as structures in space.
4. To provide an introduction to coupled oscillatory processes characteristic of living systems.
5. To introduce some analytical techniques for analysis of data related to complex, oscillatory systems.
6. To introduce to key physical principles as applied to medical imaging and radiation therapy.
7. To develop basic understanding of medical physics concepts.

Learning outcomes

On completion successful students will be able to:

1. describe the building units of a living cell at an organelle level and in some cases at a molecular level and know about the functionality of these units.
2. understand basic atom and binding theory and can describe the electron configuration of simple molecules, and see this in connection to larger molecules such as proteins and amino acids.
3. explain the physical principles of the functioning of a cell, how cells make ensembles (tissues and organs), and how they interact within larger biological systems;
4. demonstrate an understanding of the structure of cells, and the major components within a cell and recognize that biological systems are far from equilibrium

5. explain DNA and DNA replication, as well as the role of RNA in the DNA translation and transcription.
6. apply their knowledge of physics and mathematics to the understanding of basic principles of living systems - starting from a cell to the cardiovascular system and the brain;
7. discuss the importance of diffusion, random walks, entropy and self-assembly in biological systems
8. describe electrical signals from cells and how electromagnetic signals are transmitted through biological tissue.
9. explain the basic characteristics of living systems as thermodynamically open systems and general physiological processes and how thermodynamics, hydrodynamics and electromagnetism may describe these processes.
10. explain the difference between imaging with ionising and non-ionising and describe the principles of a variety of biophysics and medical imaging concepts for each of the imaging modalities covered including NMR spectroscopy and optical microscopy, computed tomography (CT), magnetic resonance imaging (MRI), ultrasound imaging and positron emission tomography (PET) and the basic principles of spectroscopic methods like UV-VIS, EPR and NMR/MRI.
11. compare and contrast the medical imaging techniques that are available in a hospital setting and explain their relative merits
12. understand the general principles of medical image reconstruction and registration and identify the key factors that affect image quality and address these factors for the different imaging modalities;
13. learn to communicate the physical principles behind medical technology, radiation safety, and relevant applications, radiation in the context of radiation dosimetry and risk
14. describe radioactivity, radiation doses, RBE, radiation quality, radiation weight factors, organ weight factors, the oxygen effect, Bq, Gy, Sv, sensing and therapeutic applications of physics in medicine and able to make simple calculations of radiation doses.

Section A: Biophysics

1. **Properties and Structure of Macromolecules:** Atomic and molecular forces; Stability and synchronization in complex and open interacting systems; Nucleic Acids (DNA, RNA); Entropy and information; DNA as an information storage system; Fundamental rate processes: Boltzmann equation; Methods of replication; Amino-acids.

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2. **The Cell Membrane:** Properties of membrane; Molecular diffusion and Brownian motion; Transport and diffusion of ions and molecules through the cell membrane; Ion channel dynamics; Cellular structure and function: passive and active transport across a cell membrane; Basic physics of membrane potentials: Nernst-Planck and Goldman equations; Oscillatory dynamics of membrane potential; Measurement of membrane potentials; Membrane model.

3. **Basic Enzyme Behavior:** Michelis Manten mechanism and MWC model.

4. **Neuromuscular Physics:** Overview of the central nervous system; Origin of resting and action potentials in neurons and muscle fibers; Propagation of action potentials through neuromuscular system; Hodgkin-Huxley model; Neurotransmitters. Integrate and fire model and functioning of the brain as an information-processing system.

5. **Physics of the Cardiovascular System:** Introductory concepts; Functioning of the cardiovascular system as a system that provides energy and matter to cells; Physics of Cardiovascular System: Work Done by Heart, Blood Pressure, Bernoulli’s principle applied to cardiovascular system;

Generation of Korotkoff sound and indirect measurement of blood pressure; Oscillations and turbulence in blood flow; Electricity within Body: Electrical Potential of Nerves, Electromyogram, Electrocardiogram; Interactions between cardiovascular oscillations and brain waves.

Section –B: Medical Physics

6. **Physics of the Heart:** Mechanical and electrical properties of the heart; Electrical activity of heart; ECG/EKG measurement; Typical waveforms and physiological origins of the major peaks in the wave form; Artificial pacemaker.

7. **Medical Imaging Techniques:** Gamma Camera; Imaging with ionizing radiation: X-ray, CT, nuclear medicine, SPECT and PET; Imaging with non-ionizing radiation: MRI and ultrasound; Ultrasound Imaging: Nature, Production and detection of ultrasounds, A-scan, B-scan, M-scan, Clinical applications.

8. **Image Processing and analysis:** Digital image fundamentals; General principles of image reconstruction and registration of images over time and between modalities; Image smoothing; Restoration and enhancement; Image segmentation and pattern recognition.

9. **Nuclear Medicine:** Principle, choice of radionuclide and radiopharmaceuticals; Technetium generator; Imaging and function test of thyroid gland, liver, spleen, kidney, lungs, brain, heart, and bone.

10. **X-rays and Radiation Therapy:** Production and clinical applications of X-rays; Principles of radiation therapy; Radiotherapy treatment planning; Isodose curve; Simulator; Teletherapy; LINAC; Brachytherapy; Radiation Detectors: Scintillation Detector; Semiconductor Detectors; Radiation Dosimetry: Radiation Units; RBE; QF Absorbed Dose; Bragg-Gray Principle; Kerma, Internally Deposited Radioisotope; Calculation of Dose Rate from a Point and Distributed Sources.

N.B. (A student will have to answer at least 2 questions from PART-A and 2 questions from PART-B in the final exam)

Recommended Books

1. Rob Phillips, Jane Kondev, Julie Theriot, and Hernan Garcia; Physical Biology of the Cell, Second Edition (Garland Science, 2012).
2. W.R Hendee and E.R. Ritenour, Medical Imaging Physics 4th Edition, Wiley-Liss Inc. (2002)
3. Brown B.H. and Small Wood R.H.; Medical Physics and Physiological Measurements.
4. R Glaser, Biophysics, Springer, 2005.
5. Cotterill, R. Biophysics: An Introduction (Wiley 2002)
6. P Nelson, Biological Physics: Energy, Information, Life, 2008.
7. Nelson, P. Physical Models of Living Systems (Freeman, 2015)
8. Cameron J.R. and J. Skofronick; Medical Physics.
9. Brown B.H. and Small Wood R.H; Medical Physics and Biomedical Engineering.
10. Cromwell; Biomedical Instrumentation and Measurement.
11. Guyton; Textbook of Medical Physiology.
12. Sprawls, P; Physical Principle of Medical Imaging.
13. Refael C. Gonzalez, R.E. Woods; Digital Image Processing.
14. Hande, W.R.; Medical Physics of Radiation Physics.
15. Johns and Cunnighum; Physics of Radiology.
16. Cesareo, R. et al.; Nuclear Analytical Techniques in Medicine.

PHY-410: Senior Honors Project

Credit: 2 **Contact Hours: 100**

Physics Core Course **Full Marks: 50**

Supervised reading, weekly meetings with Supervisor and research work over senior year

Aims and objectives

This course aims to develop independence in the skills of experimental design and project management, develop oral reporting skills, and to encourage high quality technical presentation and written summaries. The course includes a substantial experimental or theoretical research project and a related topic in advanced physics. Project work is student's main chance to work on their own topic of interest and to show their own initiative, theoretical and experimental skills.

In this course, students may select any potential topics including but not limited to, depending on the nature of the project and subject to availability (and not already undertaken by other students): Astrophysics, Atmospheric Physics, Computational Physics, Electronics, Electrodynamics, General Relativity, Mathematical Physics, Nonlinear Optics, Nuclear and Radiation Physics, Photonics, Plasma Physics, Quantum Field Theory and Particle Physics. Students must consult the Senior Honors Project Coordinator and project supervisor regarding the selection of the topics as it must be unique to other students' project topics. The project work provides the opportunity to study a topic in depth that has been chosen or which has been suggested by a faculty member. The research project is selected at the start of the Senior Honors year following consultation with the Senior Honors Project Coordinator and depends on availability of research supervisors in the department in any particular year.

The educational objectives of the senior honors project are to:

1. enable students to explore in depth a topic of personal interest in the physical sciences.
2. enhance information search and selection skills specific to a particular project.
3. develop such transferable skills as scientific report writing and oral presentation.
4. facilitate self-reliance and the application of project management skills (i.e. time management, use of resources) to the successful completion of the project.

Learning outcomes

Upon successful completion of the course, it is expected that students will be able to:

1. demonstrate a detailed physical and mathematical understanding of an advanced topic in physics;
2. apply the concepts and theories of an advanced topic in physics and solve new problems
3. demonstrate specialized analytical skills and techniques necessary to carry out research in an advanced topic in physics;
4. undertake independent research in an area of advanced physics;
5. demonstrate initiative and intellectual independence in scientific work;
6. conduct a comprehensive search of the literature relevant to a research topic and to select and summarize the crucial aspects of the relevant literature
7. use a range of primary source material including library and on-line resources.
8. apply knowledge of physical science to the planning and development of a research/technical project.
9. critically evaluate information and techniques when deciding upon research methodologies and analysis, using criteria that can be defended.

10. gain experience of the organization and completion of an extended project where the results and outcomes are not fully defined at the beginning
11. organize, keep and use a comprehensive log book of the work done in the project
12. comply with regulatory frameworks and practicing professional ethics relevant to physics.
13. manage time and resources to optimal effect to produce a project report to a given deadline.
14. analyze, interpret and critical evaluate research findings;
15. write a full report including a concise summary of the relevant literature, the pertinent aspects of the method and a critical discussion of the results and conclusions
16. gain experience the preparation of scientific posters and the oral reporting of results
17. demonstrate an understanding of the close relationship between scientific research and the development of new knowledge in a global context;

Feedback methods

Students are expected to meet with their Supervisor on a weekly basis to work on their research project. Feedback will be offered by supervisors at each stage of the work, but especially about two weeks prior to submission, when students should discuss the structure and broad content of students' project report with their supervisor, who will offer oral feedback. Students must demonstrate satisfactory progress at the end of the fourth year of study to be allowed to submit their project report. A project report is submitted at the end of the senior year of study. The students are required to meet with their Supervisor on a weekly basis and provide them with an update of their research work.

Guidelines

The project takes place during the senior year of undergraduate study. It is expected that students will spend 1/2 days per week working on the project. It must be completed and handed in at the end of the senior year. Students are assigned at the start of senior year a project selected from their list of choices which is timed to take place when they are free from their coursework's and lab works. The supervisor will outline possible approaches and offer guidance and advice during the course of the project.

The student will carry out an individual study of a current topic in physics, which should show evidence of original thinking and may take the form of a design element. The focus of the project should be clearly on the physics, broadly construed; students unsure whether their planned approach meets this criterion should discuss the issue with their supervisor. The student will write a report or essay along the lines of a scientific article. The length of the report will be notified by the coordinator. At the end of the project students give a timed presentation followed by a question and answer session. Penalty for late submission will be decided by the Senior Honors Project Coordinator.

The students should follow the guidelines for doing project at the beginning of this handbook. Some of the important rules are as follows:

1. Project work should be done as an extension of topics in the syllabus.
2. Project can be experimental / theoretical or done in the department of Physics or in collaboration (association) with a recognized national research laboratory or organizations.

The student's first carryout a literature survey which will provide the background information necessary for the investigations during the research phase of the project. The various steps in project works are the following:-

1. Wide review of a topic.
2. Investigation on an area of Physics in systematic way using appropriate techniques.
3. Systematic recording of the work.
4. Reporting the results with interpretation in written and oral forms.

Assessment

Assessment is based on a written report and an interview with relative weights 30 and 20 respectively. The marking is carried out by the supervisor and an independent assessor. A mark of 40% or more in this course is required in order to obtain an honors BSc degree.

Honors Colloquium

Students will participate in an honors colloquium in which each will give a presentation of their research project. Students will also be required to attend an oral examination in which they demonstrate their competency in the research project. This is formative, will happen at the end of the senior year and carries 40% mark of the course.

Research Report

The research report will provide students with an opportunity to communicate with a literate but non-specialist physics audience and give them practice in writing and presenting a scientific report. The report should include an introduction to the research project, showing where it fits within the overall picture of physics and the nature and aims of the project, including a succinct description of the particular problems to solve. The report should be prepared in full consultation with the Supervisor.

Late Submission

If an extension is not applied for, or not granted then a penalty for late submission will apply. A penalty of up to a maximum of 50% of the available marks will be applied. This means that a project report that is 5 days late or more without an approved extension can only receive a maximum of 50% of the marks available for that project.

Example project titles

Power for the 21st century – alternative concepts in magnetically confined fusion
Measuring the Temperature of the Troposphere by Radio-Acoustic Sounding
A Tuning Device for a Musical Instrument
The Physics of traffic jams
The carbon crunch: living for the future
A sunlight health policy
Airships: History and Future Potential
The potential impact of LED based solid state lighting
Ultra-fast dynamics of biological molecules
SETI: the search for extra-terrestrial intelligence
Quantum Computers
Accelerator Driven Sub-Critical Reactors
Deceleration and trapping of polar molecules
Negative index of refraction
Helioseismology: a look inside the Sun
Why is water essential for life?
Recent neutron scattering technology development and its application in bio-research

PHY-411: Physics Lab - IV	**Lab: 20 Sessions**	**Credit: 4**
Physics Core Practicals	**Contact Hours: 120**	**Full Marks: 100**
	Practical: 1 sessions/week,	**6 hour/session**

Aims and objectives

To teach basic laboratory skills and illustrate physics topics such as basic principles of electric circuit analysis, damping and resonance in electric circuits, optics, solid state physics and nuclear physics, astrophysics, biomedical physics, renewable energy, geophysics and computational physics illustrated by experiment. They are designed to teach specific experimental skills and techniques e.g., experimental data collection and analysis, ethical standards in a scientific investigation through individual experiments drawn from various topics in physics.

The objectives of physics practical labs are as follows:

1. to introduce and develop group-working skills and enhance writing and written presentation skills
2. to develop the appropriate skills and confidence to use computers for the tasks required in laboratory work
3. to introduce the basic concepts and methods required for laboratory data analysis.
4. to develop sound judgement in interpreting experimental results and uncertainties.
5. to develop the skills required for good scientific communication.
6. to ensure that students can competently use an oscilloscope and to foster an understanding of the way electrical signals are shaped by passive circuit elements.
7. to understand how simple optical instruments work.

Learning outcomes

On completion successful students will be able to:

1. Link the experimental findings to underlying physics in lecture courses, textbooks and scientific journals and apply their physics knowledge and problem-solving skills to model problems in science
2. recognize a wide range of measurement instrumentation, develop and extend prescribed experimental procedures
3. use and measure with common instrumentation and handle sophisticated apparatus with confidence
4. work independently and also co-operatively with colleagues
5. keep professional quality systematic records of laboratory work in a log book while demonstrating high ethical standards during a scientific investigation
6. critically evaluate the results of an experiment, assess the significance of the experimental results compared to expected outcomes and draw valid conclusions
7. appreciate the importance of uncertainties in experimental measurements and be able to apply them in an appropriate manner
8. estimate the precision of experimental results, from an understanding of the experimental procedure and from a statistical analysis of repeated measurements
9. describe the sources of random and systematic error, calculate their effects on the results and evaluate ways of reducing the dominant error
10. use specific computer applications to manipulate and present experimental data in the form of graphs and tables and to describe experiments in coherent, structured formal written reports based on their experiments

Feedback methods

Feedback will be offered orally by demonstrators in lab sessions, orally by demonstrators when they mark each experiment and in writing for all lab reports.

Lab: Laboratory group will be allocated, and supported by, a demonstrator who will monitor progress and provide continuous feedback. A demonstrator is assigned to each group of students for the duration of each experiment. The demonstrator gives guidance and instruction and may be consulted at any time during the laboratory hours. Each laboratory has attendant/technicians who maintain the equipment and have a pool of special items (such as stopwatches) for loan.

During discussions, advice on how to improve the measurement, analysis and presentation of results will be given orally and also written on the assessment sheets, copies of which will be given to the student.

In written reports, detailed comments on how the report might be improved are written on the reports. More general comments are written on the marked sheets, copies of which are returned to the students along with the marked reports. Students are strongly encouraged to collect their marked reports from the markers, when any written comments can be elaborated upon.

Organization

The fourth year teaching laboratories are located on the second floor and hosts experiments on electricity and magnetism, electronics, solid state physics, nuclear physics, astrophysics, geophysics, renewable energy, biomedical physics and computational physics. The laboratory unit includes packages on wave optics Circuits PHY-103, PHY-202, Basic Electronics PHY-205, Solid State Physics PHY-305, Nulcear Physics PHY-306 and PHY-402, 407, 408, 409.

Assessment

The demonstrator assesses each group of students during the course of the experiment by considering physics understanding, experimental results, quality of data analysis, innovation, quality of notes in laboratory book and a short interview at the end. During the year students are required to submit written reports on all of the experiments undertaken. The total laboratory mark for the year is based on the experiments and the written reports. Failure to submit such a report will constitute a failure to satisfy the work and attendance requirements and hence the student will not be allowed to proceed to the final term exam.

(**A student will be required to perform two experiments in the final examination taking one from each group**).

Part A: LIST OF EXPERMIMENTS

1. (a) (i) To construct stabilized power supply and observe the effect of variation of input voltage on output voltage.
   (ii) To plot a graph of input vs. output voltage and hence to calculate the percentage of regulation.
   (b) To construct a square wave generator using the constructed stabilized power supply and to demonstrate its operation.

2. To construct and test a phase shift oscillator using a transistor and observe the following:
   (a) measure the frequency of oscillation,
   (b) compare the measured value of frequency with that of the calculated value,
   (c) observe the effect of using two RC sections instead of three.
3. To study the JFET Characteristics.
4. To design, construct and analyze inverting and noninverting high gain operational amplifier using 741 Linear IC and hence:
   (a) measure the input resistance of the inverting voltage gain amplifier,
   (b) measure the output resistance of the non-inverting voltage gain amplifier.
5. To design, construct and test a high-pass Active Filter using LM324 linear integrated circuit and observe the following:
   (a) determine the frequency range where filtering occurs,
   (b) plot a voltage gain versus frequency graph.
6. (a) To demonstrate the operation and characteristics of a TTL Logic gate and to show how it can be used to perform different Logic functions.
   (b) To demonstrate the operation and characteristics of a CMOS logics gate and to show how it can be used to perform different logic functions.
7. To study the UJT Characteristics.
8. (a) To design, construct and test an Astable Multivibrator and hence determine:
   (i) frequency of oscillation,
   (ii) time period of oscillation by different combination of resistor and capacitor.
   (b) To design, construct and test an Monostable Multivibrator using Timer 555 IC and hence determine the triggering network, and find
   (i) Minimum triggering voltage.
   (ii) Maximum triggering frequency.

Part B: LIST OF EXPERMIMENTS

1. To construct an Audio frequency Amplifier and hence
   (a) To observe distortion,
   (b) measure the output and input impedance,
   (c) measure the power gain,
   (d) plot its frequency response curve.
2. To study the SCR Characteristics.
3. (a) To demonstrate the operation and characteristics of set –reset (latch) Flip-flop.
   (b) To demonstrate the operation and characteristics of a D-type Flip-flop and a storage register.
4. To design, construct and test a low pass active filter using LM324 linear integrated circuit and
   (a) determine the low frequency range where filtering occurs,
   (b) plot a graph of voltage gain versus frequency graph.
5. (a) To design, Test and evaluate an IC Amplifier operated as a square-wave (Free-running square wave) oscillator and
   (i) measure the output voltage,
   (ii) determine the frequency by adjusting R between its limits,
   (iii) determine the frequency oscillation where it is dependent on the supply voltage for oscillation.
   (b) To design, construct and evaluate sine wave oscillator using linear IC and
   (i) record the output wave shape of the maximum undistorted peak output voltage,
   (ii) calculate the frequency of oscillation,
   (iii) calculate the output impedance.
6. (a) To determine the operation and characteristics of diode AND & OR gate (Using discrete components)

(b) To determine the operation and characteristics of a typical discrete component transistor logic gate.

7. To verify Stefan's law and hence to determine Stefan's constant.
8. To demonstrate the operation and characteristics of exclusive OR and exclusive NOR gates.

N.B.: In addition to the above experiments the Department may include/exclude some experiments.

Recommended Books

Each experiment is described in a laboratory script which is provided for the student. References to relevant text-books for background reading are given in the script.

The following is the recommended book for a discussion of general experimental techniques:

- Taylor, John Robert. An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements. University Science Books, 1997.
- Bevington, Philip R., and D. Keith Robinson. Data Reduction and Error Analysis for the Physical Sciences. McGraw-Hill, 2003.
- Squires, G.L. Practical Physics, 4th edition (Cambridge, 2001).
- Melissinos, Adrian Constantin, and Jim Napolitano. Experiments in Modern Physics. Academic Press, 2003.
- Preston, Daryl, and Eric Dietz. The Art of Experimental Physics. John Wiley & Sons, 1991.
- Paul B. Zbar and Albert Paul Malvino, Basic Electronics: A Text-Lab Manual
- Thomas C. Hayes, Paul Horowitz; Learning the Art of Electronics: A Hands-On Lab Course, CUP.
- Millman, J and Taub, H; Pulse, Digital and Switching Waveforms: Devices and Circuits for Their Generation and Processing, McGraw-Hill.
- Gregory, Philip Christopher. Bayesian Logical Data Analysis for the Physical Sciences: A Comparative Approach with Mathematica® Support. Cambridge University Press, 2006.
- George H. Stout and Lyle H. Jensen, Practical Structure Determination X-Ray Structure Determination: A Practical Guide, 2nd Edition, Wiley-Interscience.
- Ahmed, G and Uddin, MS, Practical Physics
- H D Young, R A Freedman, University Physics with Modern Physics, Pearson, 14th Ed., 2015

APPENDIX A

জাহাঙ্গীরনগর বিশ্ববিদ্যালয়	**Department of Physics** **Jahangirnagar University** Savar, Dhaka 1342, Bangladesh.

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APPENDIX B

Important Examination Regulations for the Four-Year Bachelor (Honours) Degree according to *Ordinance 2003, JU*

Section 10: Improvement of grade

(i) If a student obtains a grade between D and A in one or more courses in a particular Part, but obtains more than 2.25 GPA in that Part, the student will not be allowed to repeat any course for the purpose of grade improvement.

(ii) Students securing only F grades are eligible for improvement examination subject to the condition that if a student obtains an ‘F’ grade in maximum two courses in any Part. Other than Part IV examination, and also obtains at least a GPA of 2.00 in the relevant Part, the student will be allowed to appear for improvement examination for the maximum of two courses of that Part along with the examinations of the next academic session. The transcript will have no reference regarding the improvement.

(Amended by Syndicate on 23.08.2009)

Section 11: Qualifying GPA for Promotion

A student securing at least GPA of 2.00 in a particular part of study and at least D grade in all courses at the end of the academic year, the student will be deemed to have qualified in that part of study.

Section 12: Promotion to Higher Class

(i) A student must secure the minimum qualifying grade in Part I final examination as per provision of section 11 of this ordinance in order to be promoted to the 2nd year class (Part II).

A Student who fails to satisfy the requirements of section 11 will be deemed to have failed in the Part I examination. Such a student will, however, be able to repeat the courses in Part I as per provisions of section 14 of this Ordinance. The same rule will be followed in Part II examination for promotion to Part III class, and in Part III examination for promotion to Part IV class, subject to the provisions of section 1.2 relating to 6 year maximum time limit for course completion.

(ii) If a student fails to appear at one course at the Part-end final examinations due to serious illness or accident (which should be reported before the commencement of the examination), but qualifies for promotion the student may be provisionally promoted to the next higher Part and will be allowed to sit for examination of that course in the course-end examination in the next academic session This opportunity will be given to a student only once in the 4-year program of study, either in Part I, Part II, Part III or Part IV.

(iii) ১ম পর্ব হতে ৩য় পর্ব পর্যন্ত সকল পরীক্ষায় উত্তীর্ণ (F গ্রেডসহ) ছাত্র-ছাত্রীরাই কেবল ৪র্থ পর্বের চূড়ান্ত পরীক্ষায় অংশ গ্রহণের সুযোগ পাবে। সেমিস্টার পদ্ধতির ক্ষেত্রে ১ম হতে ৭ম সেমিস্টার পরীক্ষায় উত্তীর্ণ (F গ্রেডসহ) ছাত্র-ছাত্রীরাই শুধু ৮ম সেমিস্টার পরীক্ষায় অংশ গ্রহণের সুযোগ পাবে। (২৭৪ তম সিন্ডিকেট : ২৩.০৮.২০০৯)

Section 13: Irregular Students

(i) A student who appears at the Part IV examination but fails to secure a minimum of 2.25 CGPA will cease to be a regular student of the University.

(ii) Such a student, however, with the approval of the Chairperson of the Department concerned and after fulfilling the specific requirements of the Department (if any) may be allowed to sit for examination in the following year as an irregular candidate.

(iii) An irregular candidate will appear in all courses of the Part and in the *viva-voce* examination. The course- end examination will be conducted normally according to the syllabus of the Academic session in which the student applies for examination. However, if major changes in the syllabus of the course or courses occurs in the meantime, the relevant Examination Committee of the Department may arrange for holding the examination for the student according to the old syllabus. Any extra cost incurred in the process may have to be borne by the candidate as determined by the University. Marks that had been obtained by the student in the tutorial tests and class attendance in the courses of Part IV will, however, be credited to the student in the examination.

(iv) ৪র্থ পর্ব স্নাতক সম্মান চূড়ান্ত পরীক্ষায় সিজিপিএ ২.২৫ সহ সর্বাধিক ২টি কোর্সে **F** গ্রেড প্রাপ্ত ছাত্র-ছাত্রীরা পরবর্তী শিক্ষাবর্ষের সাথে অনিয়মিত পরীক্ষার্থী হিসাবে **F** গ্রেড প্রাপ্ত কোর্সগুলোতে পরীক্ষায় অংশগ্রহণ করতে পারবে (অবশ্যই ৬ষ্ঠ শিক্ষাবর্ষের আওতায়)। দুই এর অধিক কোর্সে অকৃতকার্য ছাত্র-ছাত্রীদেরকে অনিয়মিত পরীক্ষার্থী হিসেবে পরবর্তী শিক্ষাবর্ষের সাথে সকল কোর্সের পরীক্ষায় অংশগ্রহণ করতে হবে। ৪র্থ পর্বের চূড়ান্ত পরীক্ষায় অকৃতকার্য ছাত্র-ছাত্রীদের স্নাতকোত্তর শ্রেণীতে সাময়িক ভর্তি বাতিল বলে গণ্য হবে। (২৭৪ তম সিন্ডিকেট : ২৩.০৮.২০০৯)

Section 14: Repetition of Courses for Improvement

(a) A student who (i) is debarred from appearing at the examination due to inadequate class attendance or (ii) fails in Part I examination as per rules of section 11 or (iii) fails to appear in the course-end examinations for some reasons acceptable to the Department may be, on the recommendation of the Chairperson of the Department concerned, allowed by the Vice-Chancellor to continue for one more year in Part I class and repeat all the courses of Part I. The same rule will also apply to students who fail in Part II and Part III.

(b) If a student of Part IV class is not allowed to appear at Part IV examination because of unsatisfactory class attendance, the student may be, on the recommendation of the Chairperson of the Department concerned, allowed by the Vice-Chancellor to continue for one more year in Part IV and repeat all the courses of Part IV.

Section 15: Time Limit for Bachelor/Bachelor (Honours) degree Program

No student will be permitted to continue Bachelor/Bachelor (Honours) Degree program beyond the end of the sixth consecutive academic year after admission into the Bachelor/Bachelor (Honours) Degree program.

APPENDIX C

Important Rules Pertaining to Discipline and Examination Offences as per *Ordinance 2003, JU*

SECTION B. DISCIPLINE IN THE EXAMINATION

1. Candidates for different examinations shall strictly follow the following instructions:

i) Candidates are strictly forbidden to write their names on the cover or in any part of the answer book. If any candidate does so, his answer book may not be assessed.

ii) Each candidate must write legibly on the cover his/her examination Roll Number. If any candidate omits to write his/her examination Roll Number and the University Registration Number on the cover of his/her answer book, the paper may not be assessed.

iii) When more than one answer book is used, each additional book should be stitched to the first book immediately it is supplied and the Examination Roll Number and the University Registration Number should also be written by the candidate on the cover of the additional book or books immediately.

iv) No loose paper will be provided for scribbling and no paper is to be brought in for this purpose. All works must be done in the book provided and pages must not be torn out. The book provided must be submitted; it cannot be replaced by another, but if necessary, an additional book will be given. All works intended for assessment by the examination should be written on both sides of the paper.

v) Candidates are forbidden to write anything what so ever on the question paper or on other papers.

vi) Candidates must get their answer books signed by the invigilator in the examination hall.

vii) In any matter not specifically mentioned in these rules candidates are required to abide by the decision of the chief invigilator in the examination hall.

viii) No candidate will be allowed to leave the examination hall within 60 minutes from the time when the question papers are given out.

SECTION C. EXAMINATION OFFENCES AND DISCIPLINARY ACTION

1. The followings will be considered examination offences:

a) Communication with one another.

b) Smoking inside the examination hall.

c) Possession of incriminating documents.

d) Copying from incrimination documents or from another’s script.

e) Using abusive language or holding out threats to the invigilator.

f) Creating disturbance or obstruction inside the examination hall.

g) Assault or attempt to assault the chief invigilator or the invigilator or anyone in the examination hall.

h) Such other acts on the part of a candidate as in the opinion of an invigilator/chief invigilator may constitute an offence.

2. Disciplinary action against candidates for committing offences described above shall be taken by the Syndicate on the recommendation of the Disciplinary Board. The Controller of Examinations Office will communicate the decision of the Syndicate/Vice-Chancellor to the student concerned before the publication of the relevant result.

3. The following procedure shall be adopted in dealing with the cases of examination offences and breach of discipline in University examination:

a) The invigilator shall submit separate report for each case stating clearly the nature and circumstances of the offence supported by all connected documents to the Chairperson of the Department. The report of the invigilator should be countersigned by the chief invigilator.

b) On receipt of such report, the Chairperson of the Department will call for explanation from the candidate concerned asking him why necessary action should not be taken against him for the offence committed. The candidate must be given at least seven days' time to submit his/her explanation.

c) The Chairperson of the Department will then place all relevant documents of the case together with the explanation of the candidate to the Secretary. Board of Health, Residence and Discipline through the Controller of Examinations Office within three days of the receipt of the explanation from the offender.

4. In making recommendations for disciplinary action, the Discipline Board shall follow the principles mentioned below:

a) Candidates who are detected in the act of communication with one another or found smoking within the examination hall shall be fined according to the gravity of offence.

b) Candidates who are found with incrimination documents in their possession shall have the examination on the course concerned cancelled.

c) Candidates who are detected in copying from incriminating documents or from another's script or found creating obstruction or disturbance inside the examination hall shall be debarred from appearing at one or more examinations in addition to the cancellation of the examination concerned.

d) Candidates who use abusive language or hold out threats to the invigilator or any other persons in the precincts of the examination hall shall be debarred form appearing at two or more examinations in addition to cancellation of the examination concerned.

e) Candidates who assault the invigilator or commit such other serious offences would be liable to maximum punishment up to debarment from all subsequent examinations of the University in addition to cancellation of the examination concerned.

5. Candidates committing any of the examination offences mentioned in section (1) above except sub-clause (a), (b) and (c) shall not be allowed to continue with the examination in that course as well as in the examination on subsequent courses and their scripts shall not be sent for evaluation till appropriate action is taken on their cases.

Scripts of the candidates committing offences under section 1 sub-clause (a), (b) and (c) shall be sent for evaluation but separately from the scripts of the other candidates. Such candidates may be allowed to continue the examination on subsequent courses.

6. Offences Detected During Script Evaluation

Serious examination offences that are detected during evaluation of scripts will be addressed according to the following procedure for disciplinary action.

a) If an examiner finds during examination of the script sufficient reasons to suspect that the candidate may have resorted to serious wrongdoing in the matter of the examination the examiner will immediately bring it to the notice of the Chairperson of the Examination Committee with an explanatory note clearly giving/substantiating the reasons for such suspicion and suggesting specific nature of the offence. The Chairperson of the Examination Committee will arrange review of the case with other members of the Committee within 7 days and come to a definite decision as to whether the case warrants further action, in which case the matter will be referred to the Controller of Examinations Office with specific recommendation as to minimum punishment deemed appropriate.

b) Review of such cases involving post-examination detection of offences that defy the spirit and purpose of examination will be completed by the Disciplinary Board within 15 days of receipt of the case from the Controller of Examinations Office following which the candidate will be served with a notice about the allegations and an opportunity for defense to the candidate, which should be responded by the candidate within 7 days of receipt of the notice. The Board will arrive at a clear award within 7 days after the candidate’s response to the charges. The Board thus must announce a clear verdict on the case within a maximum of 30 days after the case is referred to the Board by the Controller of Examinations Office.

Relevant clauses of section (1) will apply in dealing with the case as deemed appropriate by the Disciplinary Board.

7. The Syndicate will take disciplinary action against candidates for committing offences described above on the recommendation of the Disciplinary Board. The Controller of the Examinations Office will communicate the decision of the Syndicate/Vice-Chancellor to the student concerned before publication of the relevant result.

APPENDIX D

Policy on Academic Malpractice including Plagiarism

Definition of academic malpractice

Academic malpractice is any activity – intentional or otherwise – that is likely to undermine the integrity essential to scholarship or research. It includes plagiarism, collusion, fabrication or falsification of results, and anything else that could result in unearned or undeserved credit for those committing it. Academic malpractice can result from a deliberate act of cheating or may be committed unintentionally. Whether intended or not, all incidents of academic malpractice will be treated seriously by the University.

Introduction

1. As a student you are expected to cooperate in the learning process throughout your programme of study by completing assignments of various kinds that are the product of your own study or research. You must ensure that you are familiar with, and comply with, the University's regulations and conventions: ignorance of the University regulations and conventions cannot be used as a defence for plagiarism or some other form of academic malpractice

2. This guidance is designed to help you understand what we regard as academic malpractice and hence to help you to avoid committing it. You should read it carefully, because academic malpractice is regarded as a serious offence and students found to have committed it will be penalized. A range of penalties may be applied including the capping of marks, being awarded zero (with or without loss of credits), failing the whole unit, being demoted to a lower class of degree, or being excluded from the programme.

3. In addition to the advice that follows, your department will give you advice on how to avoid academic malpractice in the context of your discipline. It will also design assessments so as to help you avoid the temptation to commit academic malpractice. Finally, you should take note that work you submit may be screened electronically to check against other material on the web and in other submitted work.

Plagiarism

Plagiarism is presenting the ideas, work or words of other people without proper, clear and unambiguous acknowledgement. It also includes 'self-plagiarism' (which occurs where, for example, you submit work that you have presented for assessment on a previous occasion), and the submission of material from 'essay banks' (even if the authors of such material appear to be giving you permission to use it in this way). Obviously, the most blatant example of plagiarism would be to copy another student's work.

Hence it is essential to make clear in your assignments the distinction between:

The ideas and work of other people that you may have quite legitimately exploited and developed, and
The ideas or material that you have personally contributed.

To assist you, here are a few important **do's** and **don'ts**:

Do get lots of background information on subjects you are writing about to help you form your own view of the subject. The information could be from electronic journals, technical reports, unpublished dissertations, etc. Make a note of the source of every piece of information at the time you record it, even if it is just one sentence.

Don't construct a piece of work by cutting and pasting or copying material written by other people, or by you for any other purpose, into something you are submitting as your own work. Sometimes you may need to quote someone else's exact form of words in order to analyze or criticize them, in which case the quotation must be enclosed in quotation marks to show that it is a direct quote, and it must have the source properly acknowledged at that point. Any omissions from a quotation must be indicated by an ellipsis (…) and any additions for clarity must be enclosed in square brackets, e.g. "[These] results suggest… that the hypothesis is correct." It may also be appropriate to reproduce a diagram from someone else's work, but again the source must be explicitly and fully acknowledged there. However, constructing large chunks of documents from a string of quotes, even if they are acknowledged, is another form of plagiarism.

Do attribute all ideas to their original authors. Written 'ideas' are the product that authors produce. You would not appreciate it if other people passed off your ideas as their own, and that is what plagiarism rules are intended to prevent. A good rule of thumb is that each idea or statement that you write should be attributed to a source unless it is your personal idea or it is common knowledge. (If you are unsure if something is common knowledge, ask other students: if they don't know what you are talking about, then it is not common knowledge!)

As you can see, it is most important that you understand what is expected of you when you prepare and produce assignments and that you always observe proper academic conventions for referencing and acknowledgement, whether working by yourself or as part of a team. In practice, there are a number of acceptable styles of referencing depending, for example, on the particular discipline you are studying, so if you are not certain what is appropriate, ask your tutor or the course unit coordinator for advice! This should ensure that you do not lay yourself open to a charge of plagiarism inadvertently, or through ignorance of what is expected. It is also important to remember that you do not absolve yourself from a charge of plagiarism simply by including a reference to a source in a bibliography that you have included with your assignment; you should always be scrupulous about indicating precisely where and to what extent you have made use of such a source.

So far, plagiarism has been described as using the words or work of someone else (without proper attribution), but it could also include a close paraphrase of their words, or a minimally adapted version of a computer program, a diagram, a graph, an illustration, etc. taken from a variety of sources without proper acknowledgement. These could be lectures, printed material, the Internet or other electronic/AV sources.

Remember: no matter what pressure you may be under to complete an assignment, you should never succumb to the temptation to take a 'short cut' and use someone else's material inappropriately. No amount of mitigating circumstances will get you off the hook, and if you persuade other students to let you copy their work, they risk being disciplined as well (see below).

Collusion

Collusion is when a student or students collaborate with another student or students, as an individual or group to gain a mark or grade to which they are not entitled. Students who allow another student to copy their work are also committing collusion and both the copier and the provider of the work are liable to be penalized. Where it is proved, collusion will be subject to penalties similar to those for plagiarism.

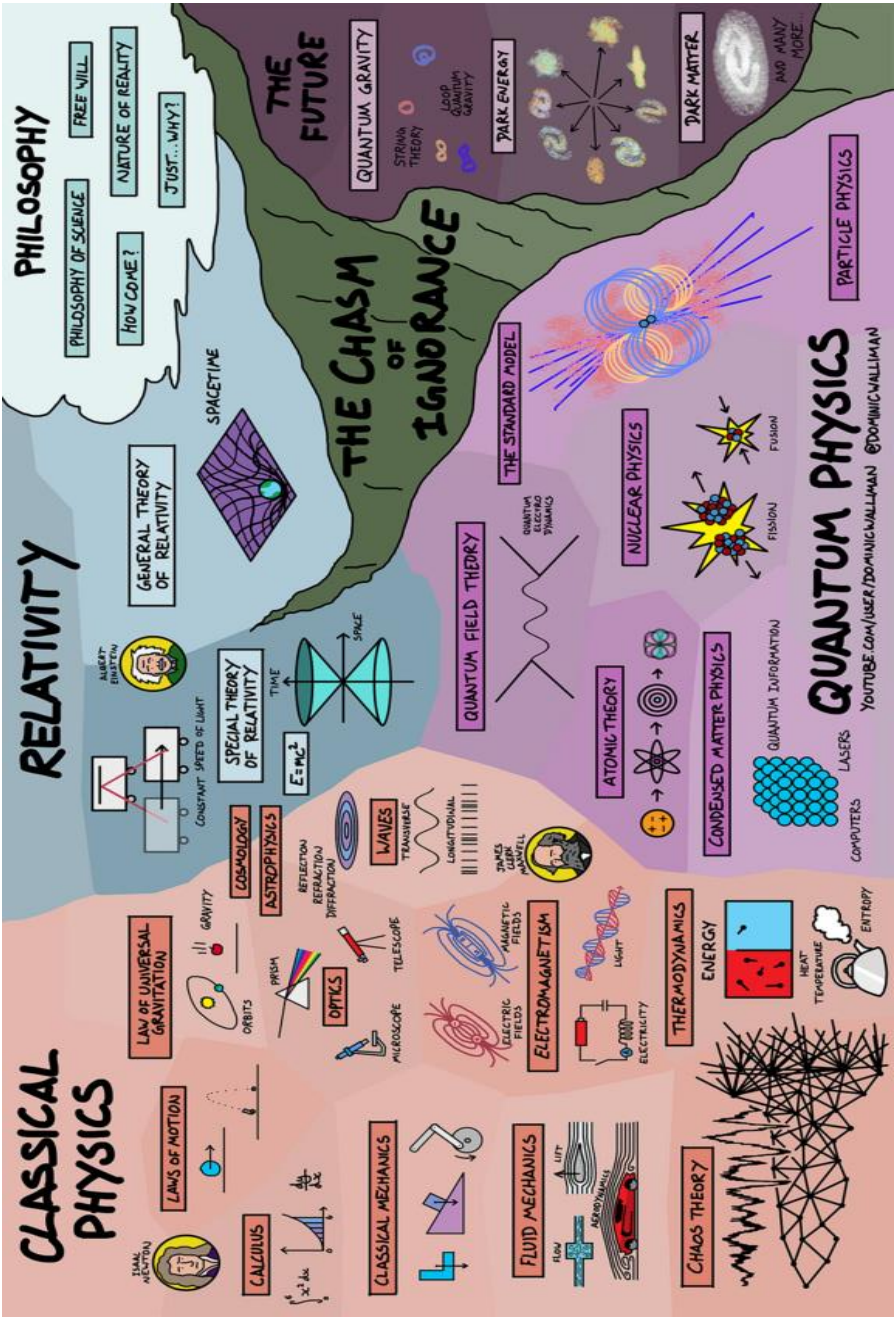
On the other hand, collaboration is a perfectly legitimate academic activity in which students are required to work in groups as part of their programme of research or in the preparation of projects and similar assignments. If you are asked to carry out such group work and to collaborate in specified activities, it will always be made clear how your individual input to the joint work is to be assessed and graded. Sometimes, for example, all members of a team may receive the same mark for a joint piece of work, whereas on other occasion's team members will receive individual marks that reflect their individual input. If it is not clear on what basis your work is to be assessed, to avoid any risk of unwitting collusion you should always ask for clarification before submitting any assignment.

Fabrication or falsification of data or results

For many students, a major part of their studies involves laboratory or other forms of practical work, and they often find themselves undertaking such activity without close academic supervision. If you are in this situation, you are expected to behave in a responsible manner, as in other aspects of your academic life, and to show proper integrity in the reporting of results or other data. Hence you should ensure that you always document clearly and fully any research programme or survey that you undertake, whether working by yourself or as part of a group. Results or data that you or your group submit must be capable of verification, so that those assessing the work can follow the processes by which you obtained them. Under no circumstances should you seek to present results or data that were not properly obtained and documented as part of your practical learning experience. Otherwise, you lay yourself open to the charge of fabrication or falsification of results.

Finally…

If you commit any form of academic malpractice, teaching staff will not be able to assess your individual abilities objectively or accurately. Any short-term gain you might have hoped to achieve will be cancelled out by the loss of proper feedback you might have received, and in the long run such behavior is likely to damage your overall intellectual development, to say nothing of your self-esteem. You are the one who loses.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LAWS OF MOTION
LAW OF UNIVERSAL GRAVITATION
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FLUID MECHANICS
FLOW
LIFT
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ELECTROMAGNETISM
ELECTRIC FIELDS
MAGNETIC FIELDS
ELECTRICITY
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SPECIAL THEORY OF RELATIVITY
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FREE WILL
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STRING THEORY
LOOP QUANTUM GRAVITY
DARK ENERGY
DARK MATTER
AND MANY MORE...
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QUANTUM ELECTRO DYNAMICS
THE STANDARD MODEL
NUCLEAR PHYSICS
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