Graduate
Course Handbook

Curriculum and Syllabus
for the MS Degree in Physics
(For students admitted in session: 2018-2019 to 2021-2022)

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

Contents

Guideline to use this handbook

MS student should read the sections in details for various offered courses. 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 Graduate Curriculum

Master of Science (MS) program in Physics consists of **two groups**, namely general group and thesis group. The program contains 36 credits with one year duration for general group and 42 credits with one and half year duration for thesis group. Courses for the program are offered with the approval of departmental academic committee. Dissertations are also offered for the top students of B. Sc. (Honors) merit list by the departmental academic committee. Course registration has to be done within fifteen days after the completion of B.Sc. (Honors) fourth part examination with the course coordinator appointed by the departmental academic committee. The registration must be approved by the Chairman of the Department.

1.5-year MS Program (Thesis Group)

Students in this group have to take seven theoretical courses (26 credits) from the offered courses. Out of seven courses, one course must be related to the thesis work. Thesis students will have a chance to change one course to make it thesis related after choosing the topic of the thesis. In each course, 70% marks is earmarked for course-end final theory examination, 20% for tutorial, and 10% for class attendance. The thesis carries 12 credits and the viva-voce on the dissertation carries 2 credits. Two credits are earmarked for general viva-voce on theoretical courses.

Distribution of Credits for the Thesis Group

COURSE	UNIT	CREDITS PER UNIT	TOTAL CREDITS	GRAND TOTAL
Theoretical courses	6.5	4	26	42
Thesis	3	4	12	
Thesis presentation and viva voce	1/2	4	2	
General viva	1/2	4	2	

N.B. Each student will have to submit their thesis within **SIX (06) months** after the successful completion of their theoretical course's exam.

1-year MS Program (General Group)

Students of this group have to take six theoretical courses (24 credits) from the offered courses and one and half unit laboratory courses (6 credits) and a half unit project (2 credit). Each 4 credit course carries 100 marks of which 70 marks is earmarked for course-end final theory examination, 20 marks for tutorial, and 10 marks for class attendance. Each 2 credit course carries 50 marks of which 35 marks is earmarked for course-end examination, 10 marks for tutorial on experiments, and 5 marks for class attendance. The project carries 02 credits and the viva-voce on the project carries 2 credits. Two (02) credits are earmarked for general viva-voce on theoretical courses.

Distribution of Credits for the General Group

Course	Unit	Credits per Unit	Total Credits	Grand Total
Theoretical courses	6	4	24	36
Laboratory work	1.5	4	6	
Project	1/2	4	2	
Project Viva	1/2	4	2	
General Viva	1/2	4	2	

Courses of studies for MS Examination

The courses PHY-501, PHY-502, PHY-503 and PHY-504 are compulsory for both the thesis and general group students. All the MS students have to take at least two of the compulsory courses and four other offered courses. In addition, for thesis group the PHY-517 course is mandatory. MS program comprises of the courses (units) listed below.

Course Code	Course Title	Credits
PHY-501	Advanced Quantum Mechanics	4
PHY-502	Advanced Solid State Physics	4
PHY-503	Electronics and Electronic Communication	4
PHY-504	Advanced Nuclear Physics	4
PHY-505	Advanced Material Science	4
PHY-506	Nano-Physics and Nano-Electronics	4
PHY-507	Advanced Plasma Physics	4
PHY-508	Advanced Geophysics	4
PHY-509	Advanced Reactor Physics	4
PHY-510	Health and Radiation Physics	4
PHY-511	Biophysics and Medical Physics	4
PHY-512	Atmospheric Physics	4
PHY-513	Photonics & Non-Linear Optics	4
PHY-514	Biomaterials	4
PHY-515	Computational Physics	4
PHY-516	Non-Linear Wave Dynamics	4
PHY-517	Research Methodology & Scientific Writings	2
PHY-518	Oceanography	4
PHY-519	Laser Physics	4
PHY-520	Theory of Relativity	4
PHY-521	MS Physics Lab	4
	Thesis/Project	12/2
	Thesis/Project (Viva Voce)	2
	Viva Voce	2

Teaching and learning methods

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.

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 MS exams 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 presentations 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.

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.

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 N 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 MS Degree

A student who has

a) secured at least GPA of 2.00 for theoretical and practical courses as well as viva voce in MS examinations,

b) secured at the end of MS a CGPA of 2.25 will be deemed to have qualified for the MS Degree in the subject offered.

Award of MS Degree

a) A successful candidate who has secured a minimum of 2.25 will be awarded a Degree of Masters of Science [cited as MS in Physics] in the Faculties of Mathematical and Physical Sciences.

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

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 Masters Degree.

Syllabuses for MS Courses of Studies

PHY- 501: Advanced Quantum Mechanics **Credit: 4** **Full Marks: 100**
Contact Hours: 70 **Lectures: 3 (1 hour) sessions/week** **Theory: ~ 70 Lectures**

Aims and objectives

This course is graduate level course, and will introduce several advanced topics in quantum physics, including semiclassical approximation, path integral, scattering theory, and relativistic quantum mechanics. Introduction to the path integral formulation of quantum mechanics. Derivation of the perturbation expansion of Green's functions in terms of Feynman diagrams. Several applications will be presented, including non-perturbative effects, such as tunneling and instantons. At the end of the course we will introduce relativistic quantum field theory as the conceptual and mathematical framework describing fundamental interactions.

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. Formulate a quantum mechanical problem in terms of a Path integral and Compute gaussian path integral as determinants
10. Express physical quantities in terms of the Green function
11. Translate a Feynman diagram into a mathematical expression and carry out practical calculations based on Feynman diagrams.
12. Compute tunneling rates in simple quantum potentials and Formulate the quantum theory of a particle interacting with an external electromagnetic field
13. Expound the relativistic quantum field theory and its phenomenological consequences
14. Demonstrate an understanding of field quantization and the expansion of the scattering matrix

Course Contents

1. **Fundamental concepts**: Kets, bras, and operators; Measurements, observables, and uncertainty relations; Change of basis; Position, momentum; Transition from quantum physics to classical mechanics: the coherent states and the Ehrenfest theorem;

2. **Quantum dynamics and Path Integral:** Schrödinger and Heisenberg pictures, Schrödinger equation and elementary solutions; Path integral formulation: Introduction, Propagators and Green's functions; Fluctuation determinants; Quantum mechanics in imaginary time and statistical mechanics; Path integral representation of quantum mechanics: Schrodinger equation from path integral, physical interpretation of the path integral and the principle of minimal action, Euclidean path integral and statistical physics, Non perturbative effects - "instanton" and "bounce"; Interaction with external magnetic field: gauge invariance in quantum mechanics, Landau levels, Aharonov-Bohm effect, Dirac's magnetic monopole and charge quantization.

3. **Composite systems:** Tensor product states; quantum entanglement; Density matrices; Quantum information; Concept of Quantum Computer.

4. **Symmetry in Quantum Mechanics and Identical Particles:** Symmetry Groups in QM; Continuous symmetries and conservation laws; Discrete symmetries: Parity and Time Reversal; Lattice Translation as a Discrete Symmetry - Bloch's Theorem; Tight-binding Approximation; Basic Band Theory.

   Identical Particles (2 Particles) - Permutations; Spin Statistics; Pauli Exclusion; Helium; Central Field Approximation; Hartree Equations; N > 2 Identical Particles and the Symmetric Group - Permutation Group SN; Representation Theory of SN; Young Diagrams and Tableaux with Applications to Representation Theory of SU(N), SN; Applications: Quarks, Multi-electron Atoms;

   Angular momentum: Angular momentum algebra, SO(3) vs SU(2), Irreducible representations of SU(2) and SO(3), Addition of angular momentum: Total angular momentum in quantum mechanics; Addition of two spin ½'s; Addition of arbitrary angular momentum; Angular momentum matrices; Clebsch-Gordon coefficients; Wigner - Eckart theorem.

5. **Perturbation theory:** Green's functions: definition and general properties; Functional methods; perturbation theory by Feynman diagrams; Time-dependent Perturbation Theory and Applications to Radiation; Time-dependent Potentials: Exactly Soluble 2-State Problem, Time-dependent Perturbation Theory, First Order Perturbation Theory - Fermi's Golden Rule, Coupling to Radiation Field, Absorption Cross-section, Photoelectric Effect, Quantization of Transverse EM Field, E1 Spontaneous Emission, Higher Multipole Transitions, Planck's Radiation Law, Damping and Natural Line Width, Adiabatic Theorem and Berry's Phase.

6. **Semiclassical approximation:** The semiclassical limit: Semiclassical approximation in quantum mechanics: general form of the semiclassical wave function and matching conditions at turning points; One-dimensional problems in semiclassical approximation: Bohr-Somerfield quantization condition and the Planck formula, tunneling probability through a potential barrier, lifetime of a metastable state, splitting of the energy levels in a double-well potential.

7. **Scattering theory:** General Framework for Scattering Theory; cross-section; Moller operators and S-matrix, Green's functions and the scattering amplitude, the T-matrix and the Lippmann-Schwinger formula; The Born approximation; Condition for validity of the Born approximation; Applications of the Born approximation; Perturbation theory for amplitudes and the Born approximation, scattering amplitude via stationary scattering states; Optical Theorem; Spherical Waves; Partial Wave Scattering; Low-energy Scattering, Bound States, Resonances; Coulomb Scattering.

8. **Relativistic Quantum Mechanics:** Importance of the theory of relativity in quantum mechanics; Basics of Special Relativity; Schrödinger's relativistic equation; Probability and current densities; Klein-Gordon Equation; Dirac Equation and its non-relativistic limit - the Pauli equation; Relativistic Particles and Group Theory; Solutions to Dirac: Free Particle, Relativistic Hydrogen Atom; Negative energy states and hole theory; Fundamental motivations for quantum field theory; Overview of the Standard Model of particle physics.

9. **Second Quantization:** An introduction to second quantization; Occupation number formalism; Creation and annihilation operators in quantum mechanics; Applications of second quantization: single spin ½ operator, local density operator, free electron, free electrons in magnetic field, Coulomb interaction.

Recommended Books

1. Sakurai, J. J. Modern Quantum Mechanics. Revised Edition. Addison-Wesley publishers
2. Cohen-Tannoudji, C., et al. Quantum Mechanics. Vols. 1 and 2. Wiley-Interscience publishers
3. L. D. Landau and E. M. Lifshitz; Quantum Mechanics
4. R. Shankar*;* Principle of Quantum Mechanics
5. R. P. Feynman, A. R. Hibbs, Quantum Mechanics and Path Integrals
6. J. R. Taylor, Scattering Theory: The Quantum Theory of Nonrelativistic Collisions
7. J. D. Bjorken, S. D. Drell, Relativistic Quantum Mechanics
8. Crewther, R., Lecture Notes: Relativistic Quantum Mechanics (2003)
9. A. Messiah; Quantum Mechanics
10. D. Griffith; Introduction to Quantum Mechanics
11. L.S. Schulman,Techniques and applications of Path Integration, John Wiley & Sons Inc., 1981.
12. S. Coleman, Aspects of Symmetry, Cambridge University Press, 1985.
13. E. Merzbacher; Quantum Mechanics
14. P. T. Matthews; Introduction to Quantum Mechanics
15. Peskin, M.E. and D.V. Schroeder, An Introduction to Quantum Field Theory, Addison-Wesley 1995, Ch. 1-5.
16. Mandl, F. and G. Shaw, Quantum Field Theory, Wiley 1984.
17. Itzykson, C. and J.-B. Zuber, Quantum Field Theory (1980)

PHY- 502: Advanced Solid State Physics **Credit: 4** **Full Marks: 100**

Contact Hours: 70 **Lectures: 3 (1 hour) sessions/week** **Theory: ~ 70 Lectures**

Aims and objectives

Advanced Solid State Physics provides a materials and experimental technique oriented introduction to electronic and magnetic properties of condensed matter systems. The aim is to give a firm grounding in these core concepts. Two thirds of the course will be focused on providing a basic understanding of the electrical, optical, thermal and mechanical properties of solids and condensed matter. This course will provide an introduction to the theory of a few remarkable phenomena of condensed matter physics including many electron interactions.

Learning outcomes

Upon successful completion of this course it is intended that a student will be able to:

1. demonstrate an understanding of the crystal lattice and how the main lattice types are described;
2. discuss the elastic properties of solids and the physics of phonons;
3. appreciate the different material types in solids like alloys;
4. appreciate electronic band structure of metals and be able to apply the relevant theory to simple metals;
5. discuss the mechanism for electrical conductance in metals;
6. demonstrate an understanding of the phases and phase transitions in condensed matter;

The following are some intended learning outcomes for each topics covered in this course:

Elastic Properties of Solids:

- In this chapter students will learn about the stress and strain components of solids and their applications.
- Students will be able to calculate the longitudinal and transverse wave velocities along (100), (110) and (111) directions of a cubic crystals.

Alloys:

- In this chapter students will learn the mechanism of alloys formation, Hume-Rothery rules.
- How the phase change of alloys occurs with temperatures.

Characterization of Crystals:

- In this chapter students will learn about the crystal growth, origin of X-ray, Bragg's X-ray diffraction (XRD), modification of Bragg's law.
- Students will be able solve the crystal structure using XRD
- Students will get familiarization with EXAFS and XFS techniques and their applications.

Electron States and Energy Bands in Solids:

- In this chapter students will learn about the origin of energy band gaps, differences between the free electron model and tight binding model.
- Students will be able to calculate the energy bands for S.C, B.C.C, and F.C.C crystals.

Plasmons, Polaritons and Polarons:

- In this chapter students will get the idea of the 4^{th} state of the matter.
- Students will be able to calculate the wave vector and frequency dependent plasma frequency
- Students will learn electro-static screening and metal-insulator transition.

Magnetic resonance:

- In this chapter students will learn about the origin of NMR NQR, FMR, AFMR and other NMR techniques.
- Students will understand the concept of Spin-spin and Spin-lattice relaxation time.
- Students will be able to solve the structure of organic compounds/other samples by NMR (using the facilities of Wazed Miah Science Research Center).

Course Contents

1. **Elastic Properties of Solids:** Elastic constants and modulii of elasticity; Analysis of elastic strains; Stress components, dilation of a cubic crystal, Elastic compliance and stiffness constants; Elastic longitudinal and transverse waves in [100], [110], [111] directions of a cubic crystals.

2. **Alloys:** General considerations, Substitutional solid solutions and Hume Rothery rules; Order-disorder transformation; Elementary theory of order; Phase diagrams; Phase changes in Cu-Zn alloy systems; Transition metal alloys; Kondo effect.

3. **Characterization of Crystals:** Bragg's law for X-ray diffraction, structure determination, characterization of Crystals by X-ray; Modified Braggs law, Monochromators, design of a monolithic monochromator; Lattice parameter measurements; Bonds methods, EXAFS (Extended X-ray Absorption Fine Structures); XFH (X-ray Fluorescence Holography) in crystals; Dynamical theory of X-ray diffractions and its applications.

4. **Electron States and Energy Bands in Solids:** Energy bands, The nearly free electron model; Origin of the energy gap, The tight binding method; Energy calculation for SC, BCC and FCC crystals using tight binding model, Cellular method; Muffin-Tin potentials; Augmented plane wave (APW) method; Orthogonalized plane wave (OPW); Pseudo-potential theory; Hartee and Hartee- Fock approximation.

5. **Plasmons, Polaritons and Polarons:** Dielectric function of the electron gas; Plasma optics; Dispersion relation for electromagnetic waves; Transverse optical modes in a plasma; Longitudinal plasma oscillations; Plasmons; Electrostatic screening; Mott metal-insulator transition; Screening and phonons in metals; Polaritons; Electron-electron interactions; Polaron and electron phonon interaction; Peierls instability of linear metals.

6. **Magnetic Resonance:** Fundamentals of Nuclear magnetic resonance (NMR) and Bloch equation; Relaxation mechanisms; Spin-lattice relaxation; Spin-spin relaxation; Line width; Hyperfine splitting; Knight shift; Nuclear quadrupole resonance (NQR); Ferromagnetic resonance (FM) resonance, frequency determination for FM and shape effects; Spin wave resonance (SWR); AFM resonance, Applications of NMR.

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. Blakemore, J. S.; Solid State Physics.
6. Kittel, C.; Quantum Theory of Solids.
7. Hall, H. E.; Solid State Physics.
8. James D. Patterson; Introduction to the Theory of Solid State Physics.
9. Mysers, H.P.; Introductory Solid State Physics.
10. Stephen Blundell, Magnetism in Condensed Matter (Oxford Master Series in Physics)

PHY- 503: Electronics and Electronic Communication **Credit: 4** **Full Marks: 100**

Contact Hours: 70 **Lectures: 3 (1 hour) sessions/week** **Theory: ~ 70 Lectures**

Aims and objectives

The objectives of this course are to provide students a thorough understanding of the elementary as well as advance concepts of operational amplifier (OP-Amp) and its applications in designing different electronic circuit including amplifier, subtractor, voltage follower, temperature indicator, lux meter, etc.; microprocessor and microcomputer; optoelectronics and its applications; optical and computer communication system. It will also provide basic idea of formation and characteristics of photo multiplier tube, photo diode, phototransistor, solar cells and different types of optoelectronic couplers. This also enriches the knowledge about the fundamental properties and applications of various electronic circuits in modern technology.

Learning outcomes

On completion successful students will be able to:

1. define and explain the operation and characteristics of operational amplifier (OP-Amp).
2. define and explain the operation and characteristics of different feedback amplifier, such as inverting, non-inverting and differential amplifier.
3. apply OP-Amps to design various feedback amplifiers circuits.
4. apply OP-Amps to design voltage follower, current to voltage converter, inverter, subtractor circuits.
5. apply OP-Amps to design different instrumentation amplifier circuits.
6. calculate the gain, input resistance, output resistance, bandwidth, total output off set voltage of various feedback amplifiers circuits.
7. define, construction, operation, characteristics and applications of different optoelectronic devices, like photomultiplier tube, solar cells, couplers, LED, LCD.
8. calculate different optoelectronic parameters for different optoelectronic devices.
9. define and explain microprocessor and microcomputer.
10. define and explain the fundamentals of optical and computer communication systems.
11. calculate different parameters relating to optical and computer communication systems.

Course Contents

1. **Introduction to Operational Amplifiers:** Introduction; The Operational amplifier; Block diagram representation of a typical OP-Amp; The ideal OP-Amp; Equivalent circuit of an Op-Amp; Ideal voltage transfer curve; Open loop Op-Amp configurations.

2. **An Operational Amplifier with Negative Feedback:** Introduction; Block diagram representation of feedback configurations; Voltage series feedback amplifier; Voltage follower; Voltage shunt feedback amplifier; Current to voltage converter; inverter; Differential Amplifier with one op-amp; Differential Amplifier with two Op-Amps.

3. **Frequency Response of an Op-Amp:** Introduction; Frequency response; Compensating networks; Frequency response of internally compensated op-amps; Frequency response of non-compensated op-amps; High frequency op-amps equivalent circuit; Open-loop voltage gain as a function of frequency; Closed loop frequency response; Circuit stability; Slew rate; Causes of slew rate; Slew rate equation; Effect of slew rate in applications.

4. **General Linear Applications:** Introduction; DC & AC amplifiers; AC amplifiers with a single supply voltage; The peaking amplifiers; Summing, scaling, and averaging amplifiers; Instrumentation amplifiers.

5. **Opto-Electronics:** Photodetectors and their types and characteristics; Photomultiplier tube; Photoresistor; Photoconductive cell; Photodiodes; Phototransistor; photodarlington; Photovoltaic cell; Light emiting diods; Liquid crystal displays; Optoelectronic coupler; Laser diodes.

6. **Microprocessor & Micro Computer:** Basic computer system organization; Basic μC Elements; computer words; Instruction words; Executing a machine language program; Typical μC structure; Read and write operations.

7. **Communication Fundamentals:** Communication; Block diagram of a communication system; Modulation; Transmission impairments and their types; Data; Signal and it's types; Bit interval; Bit rate; Fibre optics in communications.

8. **Computer Communication Systems:** Introduction; Computer communication network; Structure of a computer communication network; Types of networks; Examples of computer communication networks; Design features of a computer communication networks; Packet radio network; Time Division Multiple Access; Frequency Division Multiple Access; ALOHA; Carrier Sense Multiple Access; Protocols and their layers.

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, CUP; 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. Johnson, D. E., and V. Jayakumar. Operational Amplifier Circuits. Prentice Hall
10. Agarwal, Anant, Jeffrey H. Lang. Foundations of Analog & Digital Electronic Circuits. Elsevier.
11. Katz, R. H., Contemporary Logic Design, Benjamin.
12. Cahill, S. J., Digital and Microprocessor Engineering, Ellis-Horwood.
13. Peatman, J. B., Design of Digital Systems.
14. Pappas, N. L., Digital Design.
15. Charles Platt, Make: More Electronics: Journey Deep Into the World of Logic Chips, Amplifiers, Sensors, and Randomicity, Maker Media, Inc.
16. Jacob Millman and Arvin Grabel; Microelectronics; McGraw-Hill Company Limited.
17. Robert L. Boyelstad, Louis Nashelsky; Electronic Devices and Circuit Theory.
18. Agarwal, Anant, and Jeffrey H. Lang. Foundations of Analog and Digital Electronic Circuits
19. Horowitz P., Hill W., The Art of Electronics (3th ed., 2015), Cambridge University Press.
20. Paul Scherz, Simon Monk; Practical Electronics for Inventors, Fourth Edition, McGraw-Hill.
21. S.M. Sze and K. Ng, Physics of Semiconductor Devices, Wiley, 2006.
22. B. Streetman and S. Banerjee, Solid State Electronic Devices, Prentice Hall, 2005.
23. David A. Bell; Operational Amplifiers and Linear ICS.
24. Deboo, G. and Burrons; Integrated Circuits of Semiconductor Devices.
25. Taub. Schilling; Principles of Communication System.

PHY- 504: Advanced Nuclear Physics **Credit: 4** **Full Marks: 100**
Contact Hours: 70 **Lectures: 3 (1 hour) sessions/week** **Theory: ~ 70 Lectures**

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.

Learning objectives of this course are to

1. Understand the resonance scattering and the compound nucleus model
2. Describe the direct reaction processes and their kinematics
3. Explain the fundamental models and approximations to describe the nuclear reactions at different energy conditions
4. Explain the interactions of nuclei with electromagnetic radiation
5. Understand the basic nuclear analytical techniques and their applications
6. Understand nuclear interactions, standard model and ideas of unification

Learning outcomes

Upon completion of this course students will be able to

1. Understand the ideas of formation of compound nucleus and relative calculations of resonance scattering
2. Describe the kinematics of direct reaction and Born approximation
3. Explain the optical model and Nilsson's distorted potential model to describe nuclear reactions
4. Explain the multipole radiation and selection rules for gamma transitions
5. Understand the neutron activation analysis, PIXE, PIGE, neutron radiography and their applications
6. Identify nuclear interactions, standard model and ideas of unification

Course Contents

1. **Compound Nucleus:** Breit-Wigner dispersion formula for an s-state; Bohr hypothesis of compound nucleus; Resonance scattering of nuclei, formation of compound nucleus cross sections; The continuum theory of nuclear reaction; Statistical theory of nuclear reaction; Evaporation probabilities and pre-equilibrium reactions; Heavy ion reaction.

2. **Direct Reactions:** Kinematics of stripping and pick-up reactions; Semi-classical approach; Born Approximation; Distorted Wave Born Approximation (DWBA).

3. **Nuclear Models:** Optical Model (general form of optical model potential); Kapur-Peierls dispersion formula; Butler's theories; Giant resonances; Nilsson's distorted potential model; Nuclear surface deformations; Collective vibrations and collective rotations.

4. **Electromagnetic Interaction with Nuclei:** Multiple expansion; Sources of multiple radiation; Angular distribution of multiple radiation; Selection rules; Transition probabilities; Gamma-gamma angular distribution and angular correlations.

5. **Nuclear Analytical Techniques:** Neutron activation analysis, neutron radiography, PIXE, PIGE, Accelerator mass spectrometry.

6. **Elementary Particles:** Spectrum and interactions of known particles; Conservation or violation of Isospin; Strangeness and Charm in particle interactions; Hadrons spectroscopy and resonances; SU (3) Flavor classification of the lightest Hadrons; Introduction to the standard Model and ideas of Unification; Neutrino masses.

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).
14. Preston, M. A. and R. Bhaduri; Structure of the Nucleus.
15. Bohr, A. and. Mottelson, B.R; Nucleus Structure.
16. Tobocman, W.; Theory of Direct Nuclear Reactions.
17. Sctchler, G. R.; Introduction to Direct Nuclear Reactions.
18. Greiner, W. and Maruhn, J. A.; Nuclear Models.

PHY- 505: Advanced Materials Science **Credit: 4** **Full Marks: 100**
Contact Hours: 70 **Lectures: 3 (1 hour) sessions/week** **Theory: ~ 70 Lectures**

Aims and objectives

This course focuses on the fundamentals of structure, energetics, and bonding that underpin materials science. This course illustrates some selected chapters of materials physics needed to understand the mechanical and structural properties of solids. This course deals in particular with the physics of different classes of materials.

Learning outcomes

On completion successful students will be able to:

1. Sketch a phase diagram and its thermodynamic basis
2. Understand different classes of materials and their properties
3. Describe different characterization techniques of these materials

Course Contents

1. **Introduction to Materials:** Selected characteristics; Types of materials; Structure and properties; Mechanical and electrical behaviors; Thermal characteristics.
2. **Phase and Equilibrium Diagrams:** Phase rule; Solid solution; Grain boundaries; Diffusion; Alloys; Binary alloys; Chemical composition of phases; Phases of iron carbon system; The Fe-Fe_3C phase diagram; Microstructures.
3. **Organic Materials:** Wood, coal, organic polymers; Three dimensional polymers; Deformation of polymers; Electrical properties of polymers; Stability of polymers.
4. **Ceramic Materials:** Ceramic phases; Ceramic crystal; Multiphase compounds; Silicate structure; Glasses; Mechanical and electrical behaviors of ceramics.
5. **Magnetic Materials:** Magnetic materials and theoretical models for their magnetic properties; Application of magnetic materials; Ferrites and garnets.
6. **Methods for Characterization of Materials:** Diffraction methods: X-ray, electron and neutron diffraction methods; Electron microscopy.
7. **Composite Materials:** Classification; Fibrous composites; Matrix materials; Reinforcement materials; Matrix dependent classification.
8. **Superconductor:** BCS Theory, Flux Quantization, Transverse response: Landau diamagnetism, Microscopic derivation of London equation, Effect of disorder, Quasiparticles and coherence factors, Ginzburg-Landau theory, Vortices and type II superconductors, Tunneling and Josephson effect.

Recommended Books

1. W. D. Callister Jr. and D. G. Rethwisch; Material Science and Engineering, John Wiley & Sons.
2. Van-Vlack, L.H.; Elements of Materials Science and Engineering.
3. Marder, Michael P. Condensed Matter Physics. Wiley, 2000.
4. Starfield, M. J. and Shvager A. M.; Introductory Materials Science.
5. O'Handley, Robert C.; Modern Magnetic Materials: Principles and Applications. Wiley
6. D.C. Jiles; Introduction to Magnetism and Magnetic Materials, Springer.
7. B. D. Cullity, C. D. Graham; Introduction to Magnetic Materials.

PHY- 506: **Nano-Physics and Nano-Electronics**	**Credit: 4**	**Full Marks: 100**
Contact Hours: 70	**Lectures: 3 (1 hour) sessions/week**	**Theory: ~ 70 Lectures**

Aims and objectives

This course is for graduate level students and the goal is to understand the relevant experimental and theoretical concepts of the nanoscale science. The course move from basic concepts like quantum size effects to recent research trends such as spin transport for data storage applications (spintronics), carbon electronics, or nanocatalysis.

Learning outcomes

On completion successful students will be able to:

1. Explain the differences between nanoscopic and macroscopic scale
2. Analyze the results of a scientific experiment
3. Design a scientific experiment
4. Integrate the notions of critical reading of articles
5. Assess / Evaluate scientific articles, their quality and defaults
6. Interpret knowledge of several specific experimental methods

Course Contents

1. **Basic Properties of Nanoparticle:** Particle size; Top down and bottom up ideas, Particles shape; Size effect and properties of nanoparticles; Particle density; Melting point; Surface tension; Wettability; Specific surface area and pore; Composite structure; Crystal structure; Surface characteristics; Mechanical properties; Electrical properties; Magnetic properties; Optical properties; Applications of vacuum technology.

2. **Quantum Phenomena:** One dimensional quantum or electron leak; Quantized electron energy; Time dependent perturbation theory; Transition to continuum (Fermi's Golden rule); Density of states (DOS); Spin effects (Kondo resonance, Zeeman splitting) spectroscopy.

3. **Scanning Tunneling Microscopy (STM):** Fundamentals: Introduction of STM, band structure effects; Coulomb blockade and single electron tunneling; Elastic; Inelastic; Spin-polarized tunneling, Surface density of states for different dimensions, Role of tip geometry; Lithography and atomic manipulation; Information extracted: Real space images with atomic resolution of conducting nanomaterials, spectroscopy at the nanoscale, Electronic surface density of states; Basic Operation: Constant current and constant voltage modes.

4. **Atomic Force Microscopy (AFM):** Fundamentals: Attractive or repulsive tip-sample interactions, Van der Waals force; Electrostatic force; Magnetic force; Force spectroscopy; Nanotribology. Information extracted: Real-space morphological images with nearly atomic resolution of conducting and non-conducting nano-materials, Charge distribution in polymer surfaces; Basic operation: Tapping, non-contact and contact modes.

5. **Nanostructure Electronic and Chemical Characterization:** X-ray Photoelectron Spectroscopy (XPS): Fundamentals: Photoelectric effect, binding energy and chemical shift, spin-orbit splitting, initial and final state effects, charge compensation in insulators, inelastic mean free path and sampling depth; Information extracted: Surface composition and chemical state of surface species; Ultraviolet Photoelectron Spectroscopy (UPS): Information extracted: Band structure, occupied band states of clean solid surfaces as well as bonding orbital states of adsorbed molecules; Fundamentals of Fourier transform infrared radiation (FTIR) and Raman spectroscopy.

6. **Nano Systems:** An artificial and tunable atom (quantum dot); Quantum wire; Quantum Hall effect; Carbon nano-tube; Tunnel diode; Molecular transistor; Single electron transistor; Spin polarized transistor; Thin films; Self assembly.

Recommended Books

1. Roland Wiesendanger; Scanning Probe Microscopy and Spectroscopy – Methods and Applications; Publisher: Cambidge University Press (1994).
2. Joel I. Gersten, Frederick W. Smith; The Physics and Chemistry of Materials; Publisher: John Willey and Sons, Inc. (2001)
3. B. Bhushan, H. Fuchs, M.Tomitori; Applied Scanning Probe Methods IX Characterization (NanoScience and Technology); Publisher: Springer (2008).
4. John C. Vickerman; Surface Analysis (The principal Techniques); Publisher: John Wiley and Sons (2003).
5. Wolf, E.; Nanophysics and Nanotechnology, Wiley-VCH, (2006).
6. Briggs, D., Seah, M.P.; Practical Surface Analysis-Auger and X-ray Photoelectron Spectroscopy, Wiley Interscience 1990 (2nd ed.)
7. Sergei N. Magonov, Myung-Hwan Whangbo; Surface Analysis with STM and AFM: Experimental and Theoretical Aspects of Image Analysis, VCH Publishers (1996).
8. Bandyapadya, A.K.; Introduction to Nanotechnology.

PHY- 507: Advanced Plasma Physics **Credit: 4** **Full Marks: 100**
Contact Hours: 70 **Lectures: 3 (1 hour) sessions/week** **Theory: ~ 70 Lectures**

Aims and objectives

Following an introduction of the main plasma properties, the fundamental concepts of the fluid and kinetic theory of plasmas are introduced. Applications concerning laboratory, space, and astrophysical plasmas are discussed throughout the course.

Learning outcomes

On completion successful students will be able to:

1. Manipulate the fundamental elements of the plasma fluid and kinetic theory
2. Describe various applications of plasma physics
3. Describe the main scientific issues in space and astrophysical plasmas
4. Describe the main scientific issues in plasma applications

Course Contents

1. **Review of Waves in Plasmas:** Ion-acoustic waves: Basic concept, Derivation of dispersion relation, Physical interpretation; Lower hybrid waves: Basic concept, Derivation of lower-hybrid frequency, Physical interpretation; Upper-hybrid waves: Basic concept, Derivation of upper-hybrid frequency, Physical interpretation; Shear Alfvén waves: Basic concept, Derivation of dispersion relation, Physical interpretation; Compressional Alfvén waves: Basic concept, Derivation of dispersion relation, Physical interpretation.

2. **Nonlinear Waves in Plasmas:** Solitary waves; Shock waves; Ion-acoustic solitary waves: Derivation of Korteweg-de Vries (K-dV) equation, Stationary solitary wave solution of K-dV equation, Physical interpretation; Ion-acoustic shock waves: Derivation of Burgers equation, Stationary shock wave solution of Burgers equation, Physical interpretation.

3. **Concept of Dusty Plasma Physics:** Definition of dusty plasmas; Characteristics of dusty plasmas; Differences between electron-ion plasma and dusty plasma; Occurrence of dusty plasmas; Typical dusty plasma parameters in space and laboratory devices; Aspects of dusty plasma physics.

4. **Linear Waves in Dusty Plasmas:** Dust-ion-acoustic waves: Basic concept, Derivation of dispersion relation, Physical interpretation; Dust-acoustic waves: Basic concept, Derivation of dispersion relation, Physical interpretation; Dust-lower-hybrid waves: Basic concept, Derivation of dust-lower-hybrid frequency, Physical interpretation; Dust cyclotron waves: Basic concept, Derivation of dust-cyclotron frequency, Physical interpretation; Shear dust- Alfvén waves: Basic concept, Derivation of dispersion relation, Physical interpretation; Compressional dust Alfvén waves: Basic concept, Derivation of dispersion relation, Physical interpretation.

5. **Nonlinear Waves in Dusty Plasmas:** Dust-ion-acoustic solitary waves: Derivation of K-dV equation, Stationary solitary wave solution of K-dV equation, Physical interpretation;

Dust-acoustic solitary waves: Derivation of K-dV equation, Stationary solitary wave solution of K-dV equation, Physical interpretation; Dust-ion-acoustic shock waves: Derivation of Burgers equation, Stationary shock wave solution of Burgers equation, Physical interpretation.

Recommended Books

1. Chen, F. F.; Introduction to Plasma Physics and Controlled Fusion (Plenum, New York, 1984).
2. Shukla, P. K. and Mamun, A. A.; Introduction to Dusty Plasma Physics (Institute of Physics Publishing Ltd., London, 2002).

PHY- 508: Advanced Geophysics **Credit: 4** **Full Marks: 100**

Contact Hours: 70 **Lectures: 3 (1 hour) sessions/week** **Theory: ~ 70 Lectures**

Aims and objectives

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. It is split into two sections: (i) seismic methods and (ii) data processing. In each section, we start with the underlying mathematical basis and examine applications at global, exploration and environmental scales. The course also involves methods of geophysical data analysis, modelling, visualization and interpretation through a series of computer laboratories.

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. discuss advantages and limitations to various geophysical methods with respect to sensitivities and geologic conditions;
4. discuss the assumptions applied to Maxwell's equations and the conditions under which they apply that result in fundamentally different geophysical phenomena;
5. develop relationships for characteristic temporal and spatial scales from more complex mathematical relationships;
6. design an appropriate set of geophysical surveys to investigate a potential subsurface target.
7. develop their own fieldwork program;
8. undertake computer analyses and modelling geophysical phenomena;

Course Contents

A. Seismic Wave Theory

1. Seismic Theory: Theory of Elasticity; Wave equation and its solution; Body waves (P & S waves); Surface waves; Energy of waves; Partition of energy at an interface.

2. Seismic Wave Path: Seismic velocity; Reflection paths in a constant-velocity layer; Velocity gradient and ray path curvature; Geometry of refraction path; Characteristics of seismic events: Diffractions, multiples, surface waves, types of seismic noise, attenuation of noise.

3. Field Methods and Equipment: (i) Reflection field methods and field layouts; Measurement of velocity; Data reduction (ii) Refraction field methods and profiles; Comparison of reflection and refraction methods; Data reduction.

B. Digital Signal Processing

1. **Digital Signal Processing:** Fourier transformation; Convolution; Co-relation; Phase consideration; Frequency filtering; Velocity analysis; Common-midpoint stacking; Apparent velocity filtering; P-τ transformation; Migration of imaging; Measures of coherence.

2. **Interpretation:** (i) Refraction interpretation methods; Delay time methods; Wave front methods; Engineering applications; (ii) Reflection interpretation; Modeling evidence of faulting; Fold and flow structure; Hydrocarbon indicators.

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.
11. Kanasewich, E.R.; Time Sequence Analysis in Geophysics.

PHY- 509: Advanced Reactor Physics **Credit: 4** **Full Marks: 100**

Contact Hours: 70 **Lectures: 3 (1 hour) sessions/week** **Theory: ~ 70 Lectures**

Aims and objectives

In this course reactor core cooling, power limits and technological consequences due to fuel, cladding and coolant properties, main principles of reactor and power plant design including auxiliary systems are explained. It covers reactions induced by neutrons, nuclear fission, slowing down of neutrons in infinite media, diffusion theory, the few-group approximation, point kinetics, and fission-product poisoning. It emphasizes the nuclear physics bases of reactor design and its relationship to reactor engineering problems. System technology of most important thermal and fast reactor types is introduced.

Learning outcomes

On completion successful students will be able to:

1. Assess / Evaluate performance of reactor types
2. Systematize reactor system components
3. Formulate safety requirements for reactor systems

Course Contents

1. **Physics of Breeding and Fuel Cycles**: Breeding: General considerations, breeding ratio, breeding gain, doubling time, breeding reactors, fast breeders, thermal breeders, advanced breeding concepts; Nuclear Fuel Cycle: Uranium-plutonium cycle, thorium-uranium cycle, other fuel cycle, uranium enrichment.

2. **Neutron Spectrum in the Energy Region above 1 eV:** Neutron spectrum in an infinite assembly; High energy region; Slowing down region; Neutron spectra in a finite assembly; Effect of inelastic scattering on neutron spectrum.

3. **Energy Spectrum of Thermal Neutrons:** Thermal spectrum in an infinite medium; The maxwelliun spectrum; Diffusion heating and cooling; Neutron spectrum in an ideal proton gas; Solution of Wigner-Wilkins equation for a weak 1/v-type absorber; Neutron spectrum of heavy gas model; The effect of temperature model.

4. **Heterogeneous Reactors:** A qualitative discussion of lattice effects on k_∞; A unit cell; Eta; Thermal utilization; Resonance escape probability; Fast fission factor; Diffusion length.

5. **Heat Generation and Removal:** Heat generation in fuel elements; Heat removal from fuel elements; Heat transfer by conduction: Steady state case; Heat transfer by convection: Single phase flow, boiling heat transfer.

6. **Reactor Materials:** Radiation effects on materials; Structural materials; Moderation and reflector materials; Fuel materials; Production of reactor fuels; Properties of fuel element materials; Waste disposal.

7. **Radiation Shielding:** Part I- Gamma-ray shielding: Buildup factors, infinite planar and disc sources, the line sources, multilayered shields; Part-II- Nuclear reactor shielding: Principle of reactor shielding, removal cross sections; Reactor shielding design: Removal-attenuation calculations, removal diffusion method, exact methods, shielding the gamma rays, coolant activation, ducts in shields.

Recommended Books

1. Lewis, Elmer E. Fundamentals of Nuclear Reactor Physics. Academic Press, 2008.
2. Duderstadt, James J., and Louis J. Hamilton. Nuclear Reactor Analysis. Wiley.
3. Liverhant. S.E; Elementary Introduction to Nuclear Reactor Physics.
4. Glasstone. S and Edelund M.G; Elementary of Nuclear Reactor Theory.
5. Lamarsh, John R., Anthony J. Baratta. Introduction to Nuclear Engineering. Prentice Hall, 2001.
6. Glasstone S. and Sessonske; A Nuclear Reactor Engineering.
7. Beck L.K.; Nuclear Reactor for Research.
8. Bell and Glasstine: Nuclear Reactor Theory.
9. James, J. D.: Buclear Reactor Analysis.
10. Knief, R. A. Nuclear Engineering: Theory and Technology of Commercial Nuclear Power.
11. El-Wakil, M. M. Nuclear Energy Conversion. Intext Educational Publishers, 1971.

PHY- 510: Health and Radiation Physics **Credit:** **4** **Full Marks: 100**
Contact Hours: 70 **Lectures: 3 (1 hour) sessions/week** **Theory: ~ 70 Lectures**

Aims and objectives

Problems in nuclear engineering often involve applying knowledge from many disciplines simultaneously in achieving satisfactory solutions. This is an introductory course in the basic concepts of radiation detection and interactions and energy deposition by ionizing radiation in matter, radioisotope production and its applications in medicine, industry and research.

The central theme of this course is the interaction of radiation with biological material. The course is intended to provide a broad understanding of how different types of radiation deposit energy, including the creation and behavior of secondary radiations; of how radiation affects cells and why the different types of radiation have very different biological effects. The course will focus on understanding the nuclear radiation phenomena including the resulting interdependencies affecting the overall safety of the plant and regulatory oversight. The course will provide an understanding of the effects of radiation in vivo, operational health physics, radiation protection and epidemiological methods appropriate for practice as a medical or health physicist.

Learning outcomes

On completion successful students will be able to:

1. Explain the basic physics principles that underpin radiotherapy, e.g. types of radiation, atomic structure, etc.
2. Explain the interaction mechanisms of ionizing radiation at keV and MeV energies with matter.
3. Explain the principles of radiation dosimetry.
4. Explain the principles of therapeutic radiation physics including X-rays, electron beam physics, radioactive sources, use of unsealed sources and Brachytherapy.
5. Describe how to use radiotherapy equipment both for tumour localisation, planning and treatment.
6. Define quality assurance and quality control, in the context of radiotherapy and the legal requirements.
7. Explain the principles and practice of radiation protection, dose limits, screening and protection mechanisms.
8. Explain the use of radiation in industrial and research applications.

Course Contents

1. **Interaction of Radiation with Matter:** Beta Rays: Range-energy relationship; Mechanisms of energy loss (Ionization and Excitations; Bremsstrahlung); Alpha Rays: Range-energy relationship; Energy transfer; Gamma Rays: Exponential absorption; Interaction mechanisms, Neutrons: Production, classification; Interaction: Scattering, Absorption, Neutron activation.
2. **Radiation Dosimetry:** Units: Absorbed dose; Exposure; Exposure Measurement: Free air chamber; Exposure Measurement: Air wall chamber, Exposure dose relationship, Absorbed Dose Measurement: Bragg-Gray principle; Kerma; Source Strength: Specific

gamma ray emission; Internally deposited radioisotopes; Corpuscular radiation; Effective half-life; Total Dose: Dose commitment, Gamma emitters, MIRD method, Neutrons.

3. **Biological Effects of Radiation:** Dose-Response Characteristics: Direct action, Indirect action, Radiation effects: Acute effects, Delayed effects; Risk Estimates: BEIR III, Relative biological effectiveness (RBE) and quality factor (QF); Dose Equivalent: Sievert (and the Rem), High energy radiation.
4. **Radiation Protection Guides:** Organizations of Set Standards: International commission on radiological protection, International Atomic Energy Agency, International labor organization, International Commission on Radiological Units and Measurements, National Council on Radiation Protection and Measurements; Philosophy of Radiation Protection; Basic Radiation Safety Criteria: Effective dose equivalent; Exposure of individuals in the general public; Exposure of populations; Medical exposure; Allowable limit of intake (ALI); Inhaled radioactivity; Derived air concentrations (DAC); Gastrointestinal tract; Combined exposure; Basis for Radiation Safety Regulations: ICRP report; Calculation of MPC in drinking water based on dose to critical organ; Concentration in drinking water based on comparison with radium; Airborne radioactivity; Maximum permissible concentrations for non-occupational exposure.
5. **Health Physics Instrumentations:** Radiation Detectors: Particle counting instruments; Gas-filled particle counters; Ionization chamber counter; Proportional counter; Geiger counter; Quenching a Geiger counter; Resolving Time: Measurement of resolving time; Scintillation counters, nuclear spectroscopy, Cerenkov detector; Semiconductor detector; Dose-Measuring Instruments: Pocket dosimeters; Film badges; Thermoluminescent dosimeter; Ion current chamber; Neutron measurements; Detection reactions; Neutron counting with a proportional counter; Long counter; Proton recoil counter; Neutron dosimetry.
6. **External Radiation Protection:** Basic principles; Techniques of External Radiation Protection: Time, distance, shielding: X-ray shielding; Beta ray shielding; Neutron shielding.
7. **Internal Radiation Protection:** Internal radiation hazard; Principles of Control: Control of the source; Confinement, Environmental; Control of Man: Protective clothing; Respiratory protection; Surface contamination limits; Waste Management: High level liquid wastes, intermediate and low level liquid wastes.
8. **Radioactive waste Management and Radiation Protection**
   Consequences of releases of radioactivity, Storage of radioactive waste, solid waste, liquid waste, releases to the atmosphere, regulation; Applications of ionizing radiations, General principles and organization, Protection against sealed sources: diagnostic radiography, diagnostic fluoroscopy, Radiotherapy, Protection against unsealed sources, control and disposal of radioactive materials.

Recommended Books

1. James E. Martin, "Physics for Radiation Protection", Wiley-VCH (2nd edition, 2006)
2. F.M. Khan, The Physics of Radiation Therapy, 4th edition, 2010
3. G.C. Lowenthal, P.L. Airey, Practical Applications of Radioactivity and Nuclear Reactions, Cambridge University Press (2001)
4. K.H. Lieser, Nuclear and Radiochemistry, Wiley-VCH (2nd edition, 2001)
5. Herman Cember; Introduction to Health Physics; 2nd ed. McGroaw-Hill, Inc.
6. Lapp, R. E., and Andrews, H.L.; Nuclear Radiation Physics.
7. Martin, A., and Harbison, S.A.; An Introduction to Radiation Protection; 2nd Ed.
8. Liverhant, S.E.; Elementary Introduction to Nuclear Reactor Physics.
9. Knoll, G.F. ; radiation Detection and Measurement; John Wiley & Sons (New York).

PHY- 511: Advanced Biophysics

Credit: 4 | **Full Marks:** 100

Contact Hours: 70 | **Lectures:** 3 (1 hour) sessions/week | **Theory:** ~ 70 Lectures

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.

Learning outcomes

On completion successful students will be able to:

1. To introduce the topic of biophysics, 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.

Course Contents

1. **Properties and structure of macromolecules:** Atomic and Molecular forces. Types of macromolecules, Amino acids, peptide bond, Levels of protein structure, Nucleic acids, Structure of DNA, RNA, Viruses, Methods of replication, Genetic Code, Transcription, Translation; X-ray diffraction, Spectroscopy, NMR.

2. **Neurobiophysics:** Overview of the nervous system, Neural communication, Basic membrane properties, Diffusion Fick's law, selectivity of ion channels, Membrane potential, Action potential, Propagation of action potential, equivalent dipole and volume conductor fields, electrical model of a nerve fibre, conduction velocity, conduction in myelinated nerve fibres, neuromascular junction, neurotransmitter, Muscle action potential, major disorders of the neuromuscular system and their effects on conduction – nerve block, demyelination.

3. **Physics of the Senses:** Vision- Eye accommodation, light and dark adaptation, colour vision, Visual evoked potentials, vision defects and corrections; Hearing: Ear canal resonance, sound transmission and amplification through ossicles, Cochlear function, Otoacoustic Emission, Hearing threshold in terms of Sound pressure level (SPL) and Hearing threshold level (HTL), hearing defects in terms of HTL; smell, taste, touch.

4. **Lungs and Respiration:** Mechanism of breathing in terms of pressure creation by body, Pressure and Volume related functions of lungs during tidal breathing and forced manoeuvres, the same in lungs with disorders, airway resistance. (4h)

5. **Biomechanics:** Mechanical properties of biological tissues, musculoskeletal system, mechanism of muscle contraction, skeletal joints, forces and stresses in human joints, Neuromascular control, Gait; Sports, occupational and clinical biomechanics.

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. DL Bartel, DT Davy, TM Keaveny; Orthopedic Biomechanics

PHY- 512: Atmospheric Physics

Credit: 4 | **Full Marks: 100**

Contact Hours: 70 | **Lectures: 3 (1 hour) sessions/week** | **Theory: ~ 70 Lectures**

Aims and objectives

This course provides an introduction to the physics of the atmosphere, including experience with computer codes with special emphasis on the atmosphere of the Earth. It will also provide students with knowledge of the physical processes that govern weather and climate. This course also provides a review of radiation and fluid dynamics including the role of waves in planetary atmospheres and ionospheres.

Learning outcomes

On completion successful students will be able to:

1. have an understanding of the basics of atmospheres, including atmospheres in diffusive equilibrium.
2. understand the transfer of radiation through the atmosphere, including general solutions of the radiative transfer (schwartzchild) equation.
3. understand the production and loss mechanisms that lead to formation of different atmospheric regions.
4. understand radiative properties of single lines and use for remote sensing from space.
5. understand the role of atmospheric waves in transporting momentum and how this affects the state of the atmosphere.
6. understand ionization processes in planetary atmosphere and the production and loss mechanisms that influence the formation of different regions of the ionosphere
7. understand the propagation of radiowaves through weak plasmas and how this can be used to study the ionosphere.

Course Contents

1. **Some Basic Idea of the Atmosphere:** Planetary atmospheric; Equilibrium temperature; Hydrostatic equation; Adiabatic lapse rate; Sandstorm's theorem.

2. **Radiative Equilibrium Model:** Blackbody radiation; Absorption and emission; Radiative equilibrium in grey atmosphere; Radiative time constants; Greenhouse effect.

3. **Thermodynamics:** Entropy of dry air; Vertical motion of saturated air; Tephigram; Total potential energy of an air column; Available potential energy; Zonal and eddy energy.

4. **Middle and Upper Atmosphere:** Temperature structure; Diffusive separation; Escape of hydrogen; Energy balance of the thermosphere; Photo chemical processes; Breakdown of thermodynamic equilibrium.

5. **Clouds:** Cloud formation; Growth of cloud particles; Radiation properties of clouds; Radiative transfer in clouds.

6. **Dynamics:** Total and partial derivatives; Equation of motion; Geostrophic approximation; Cyclostrophic motion; Surfaces of constant pressure; Thermal wind equation.

7. **Atmospheric Waves:** Introduction; Sound waves; Gravity waves; Rossby waves; Varticity equation; Three dimensional Rossby-type waves; Turbulence.

8. **The General Circulation:** Laboratory experts; Systematric circulation; Inertial instability; Barotropic and baroclinic instability; Sloping convection; Energy transport; Transport of angular momentum; General circulation of the middle atmosphere.

9. **Meso-Scale Connective Systems:** Genesis; Thunderstorm; Squad line; Nor'westers; Tornadoes.

10. **Atmospheric Predictability & Climate Change:** Short-term predictability; Variations of climate; Atmospheric feedback processes; Different kinds of predictability; Jupiter's great red spot; Challenge of climate research.

Recommended Books

1. Andrews, D. G. (2000): An Introduction to Atmospheric Physics, CUP.
2. Andrews, D. G. J. R. Holton and C. B. Leovy (1987): Middle Atmosphere Dynamics, Academic Press.
3. Houghton, J. (1977): The Physics of Atmospheres, CUP.
4. Holton, J. R. (1980): An Introduction to Dynamic Meteorology, Academic Press.
5. Byers, H.R.; Introduction to General Meteorology.
6. Wallace, J. M. and P. V. Hobbs (2006): Atmospheric Science: An Introductory Survey, 2nd Edition, (Academic Press)
7. Rogers, R. R. and M. K. Yau (1989): A Short Course in Cloud Physics, 3rd Edition, (Pergamon Press).

PHY- 513: Photonics and Nonlinear Optics **Credit: 4** **Full Marks: 100**
Contact Hours: 70 **Lectures: 3 (1 hour) sessions/week** **Theory: ~ 70 Lectures**

Aims and objectives

This course explores the fundamentals of optical and optoelectronic phenomena and devices based on classical and quantum properties of radiation and matter culminating in lasers and applications. Fundamentals include: Maxwell's electromagnetic waves, resonators and beams, quantum theory of light, matter and its interaction, classical and quantum noise, device design principles of LEDs, lasers and laser dynamics, continuous wave and short pulse generation, light modulation; examples from integrated optics and semiconductor optoelectronics and nonlinear optics.

Learning outcomes

On completion successful students will be able to:

1. define and explain the propagation of light in conducting and non-conducting media;
2. define and explain the physics governing laser behavior and light matter interaction;
3. apply the principles of atomic physics to materials used in optics and photonics;
4. calculate the properties of various lasers and the propagation of laser beams;
5. calculate properties of and design modern optical fibers and photonic crystals;
6. use the tools, methodologies, language and conventions of physics to test and communicate ideas and explanations
7. integrate several components of the course in the context of a new situation (unique to postgraduate coursework).

Course Contents

1. **Nature of light and how it is manipulated:** photon effects .Characteristics of light, How light is produced - the LASER and LED: Einstein A and B coefficients, rate equations, gain and losses, optical feedback, laser threshold, 3 and 4 level lasers, cavity stability, cavity modes, Gaussian beams. The LED and laser diode, p-n junction, hetero junction and stripe geometries.

2. **Light detectors:** photomultiplier tubes, photodiodes. Generic system issues: sources of noise and signal-to-noise ratio, limitations on temporal response and effective bandwidth.

3. **Transmission and modulation techniques:** Delivery methods. Basics of optical fiber techniques: step index fiber; acceptance angles, single and multimode fibers, dispersion limitations, transmission characteristics. Acousto-optic and electro-optic techniques, LED switching, analogue and digital techniques using lasers, AM, FM, phase modulation techniques.

4. Introduction and Nonlinear Maxwell's Equations, Second Order Nonlinearity, Second Harmonic Generation, Phase Matching and Quasi Phase Matching, Optical Parametric

Oscillation, Third Order Nonlinearity, Nonlinear Schrodinger equation (NLS), envelope soliton, Four Wave Mixing, Optical Phase Conjugation.

5. Optical Kerr Effects, Optical Soliton, Raman Scattering, Spontaneous Raman Scattering Stimulated Raman Scattering, Coherent Anti-Stokes Raman Scattering, Brillouin Scattering Spontaneous Brillouin Scattering, Stimulated Brillouin Scattering.

6. Multi-photon processes, Absorption, coherence and Microscopy.

Recommended Books

1. Saleh, B. E. A., and M. C. Teich. Fundamentals of Photonics, John Wiley and Sons.
2. Robert W. Boyd Nonlinear Optics, 2nd or 3rd Edition
3. Amnon Yariv and Pochi Yeh, Photonics: Optical Electronics in Modern Communications, 6th Edition
4. Svelto, Orazio. Principles of Lasers. Plenum Press.
5. Govind P.Agrawal, Applications of Nonlinear Optics 5th Edition, Academic Press, 2008
6. Hecht, E., and A. Zajac. Optics. 3rd ed, Addison-Wesley.
7. Haus, H. A. Waves and Fields in Optoelectronics, Prentice Hall.
8. Liu, Jia-Ming. Photonic Devices, Cambridge University Press, 2005.
9. E. Rosencher and B. Vinter, Optoelectronics, Cambridge University Press, 2002.
10. Buck, J.A., Fundamentals of Optical Fibres, John Wiley & Son, 2004.
11. Joannopoulos, J.D. et al., Photonic Crystals: Moulding the Flow of Light, Princeton Univ. Press.

PHY- 514: Biomaterials

Credit: 4 **Full Marks: 100**

Contact Hours: 70 **Lectures: 3 (1 hour) sessions/week** **Theory: ~ 70 Lectures**

Aims and objectives

The aim of this course is to introduce students to materials that can be used in the human body. The following subjects will be covered in the module:

- Natural tissues in the human body - materials and structure: Skin and Bone
- General considerations for biomaterials - biocompatible, sterile
- Biomaterials for use in orthopedics: joint replacement, fracture fixation
- Biomaterials for use in dentistry
- General aspects of Tissue engineering

Learning outcomes

On completion successful students will be able to:

1. Understand the structure of natural tissue
2. Describe the general requirements for synthetic biomaterials
3. Select and justify appropriate biomaterials for use in orthopedic medical devices
4. Understand the concept of tissue engineering and its current limitations

Course Contents

1. **Introduction to Biomaterials:** Definition of biomaterials; Bone structure and types; Biological materials; Designed biomaterials; Basic properties of biomaterials; Methods to characterise biomaterials surfaces; Role of water in biomaterials; Tissue engineering; Properties of ideal scaffold for tissue engineering; Classification of potential scaffold materials.

2. **Physico-Chemical Properties of Biomaterials:** Mechanical (elasticity, yield stress, ductility, toughness, strength, fatigue, hardness, wear resistance); tribological (friction, wear, lubricity); morphology and texture, physical (electrical, optical, magnetic, thermal), Chemical and Biological properties.

3. **Biomedical Glasses and Glass ceramics:** Introduction to Bioactive Glass; Types of Bioactive Glass; Phase diagram; Bioactivity spectrum; Melt-derived bioactive Bioglass; Sol-gel derived bioactive; Phases of surface reactions; In vitro evaluation of bioactivity; Foam scaffolds and their Applications.

4. **Dental Glass Ionomer Cements:** Glass Design; Polyalkenoate Cements Setting Reaction; Fluorapatite Mullite Glass-Ceramics; Implanted FAP Glass; Implanted FAP Glass-Ceramic; Sr substituted aluminosilicate ionomer glass; Characterization of glasses and glass ceramics; APS and Crystallization; Schematic APS and Crystal Growth; Solid State Magic Angle Spinning Nuclear Magnetic Resonance MAS-NMR.

5. **Metals as Biomaterials:** Mechanical properties of metallic biomaterials; Advantages of metallic biomaterials; Loading of Joint Prostheses; Stainless & ASS; Alloy Design; Pitting corrosion; Intergranular corrosion; Corrosion induced fracture of ASS stem; Alloy Development; Orthopaedic Applications; Orthodontic Applications; Surgical Instrument & Devices.

6. **Polymers as Biomaterials:** Polymers; Major Biomedical Applications of Polymers; Biomedical Applications of Natural Polymers; The 2 types of polymer synthesis; Polyethylene – Addition Polymerization; Condensation Polymerization; Structural types of polymers; Structure of a semi-crystalline polymer; Thermoplastic polymers; The Reptation Model.

7. **Composites as Biomaterials:** Bone grafting; Hydroxyapatite; Methods for synthesizing HA; Wet methods- Precipitation method; Glass reinforced HA Composites; Hydroxyapatite (HA) Preparation; Glass preparation; Composite preparation ; Biological assessment of Glass reinforced HA Composites;

8. **Ceramics as Biomaterials:** Calcium phosphate ceramics; Applications of calcium phosphates; Hydroxyapatite; Bone; Ceramics according to their different levels of organization; Forms of HA graft; Calcium orthophosphate solubility; The influence of stirring of particle size; Hydroxyapatite ceramic processing; Surface modification of Si substituted apatite; Multifunctional SiHA particles; Functionalisation of SiHA; Crosslinking SiHA; tricalcium phosphate; Calcium orthophosphate cements; Calcium orthophosphate compositions; Chemistry of the cement setting reactions; Load-bearing cement.

Recommended Books

1. Mark D Miller. Review of Orthopedics. Saunders Elsevier.
2. Mark D Miller, Jennifer Hart, John MacKnight. Essential Orthopedics. Saunders Elsevier.
3. David J Warwick, Louis Solomon, Selvadurai Nayagam. Apley's system of orthopedic and fractures. 8th Edition
4. Brown B.H. and Small wood R.H, D.C Barber P V Lawford and D R Hose; Medical Physics and Biomedical Engineering.
5. Jeffrey O. Hollinger; An Introduction to Biomaterials, Second Edition, by CRC Press.

PHY- 515: Computational Physics **Credit: 4** **Full Marks: 100**

Contact Hours: 70 **Lectures: 3 (1 hour) sessions/week** **Theory: ~ 70 Lectures**

Overview

The course teaches the art of quantum mechanical calculations from both the physics and chemistry point of view. It falls somewhere between a laboratory course and a lecture course. In a laboratory course, you must learn by doing, and it is more important that you learn how to run the equipment well and how to interpret the data than that you learn how a piece of equipment is constructed and what exactly is under its cover. Similarly, in this course, you will learn how to run various quantum codes correctly and how to interpret the output of the codes, but you will not necessarily need to know how each algorithm in the 100's of 1000's of lines of code works. On the other hand, you will learn the theories behind the computer codes, so that you will be able to interpret the output of the codes. You will also learn about applications of computational quantum mechanical methods, in order to understand their potential and scope. Finally, you will gain insight into the current research and development of these methods to know where the field is going and what to expect in the future.

Aims and objectives

This course provides an introduction into modeling and simulation approaches, covering continuum methods (e.g. finite element analysis), atomistic simulation (e.g. molecular dynamics) as well as quantum mechanics. Atomistic and molecular simulation methods are new tools that allow one to predict functional material properties such as Young's modulus, strength, thermal properties, color, and others directly from the chemical makeup of the material by solving Schrodinger's equation (quantum mechanics). This approach is an exciting new paradigm that allows to design materials and structures from the bottom up — to make materials greener, lighter, stronger, more energy efficient, less expensive; and to produce them from abundant building blocks. These tools play an increasingly important role in modern engineering! In this course students will get hands-on training in both the fundamentals and applications of these exciting new methods to key engineering problems.

Learning outcomes

On completion of this course a student should be able to:

1. Learn a different approach to solving scientific and engineering problems: performing quantum mechanical calculations and understanding their scope, possibilities and limitations.
2. Be able to perform calculations during your research at JU and in your future work.
3. Interpret experimental properties using a computer program
4. Gain a (partial) familiarity with the literature and be able to read it critically.
5. Identify modern computational methods and describe the capabilities and limitations of computational methods in physics;
6. Synthesize results in the form of a scientific report and understand current research directions and possibilities.

Course Contents

1. Particle and Continuum Methods

Introduction; Basic molecular dynamics; Property calculation; How to model chemical interactions; Application to modeling brittle materials; Reactive potentials and applications; Applications to biophysics and bionanomechanics.

2. Quantum Mechanical Methods

The theory of quantum mechanics; From many-body to single-particle: Quantum modeling of molecules; Application of quantum mechanics; Quantum modeling of solids: Basic properties; Advanced properties of materials; Some review and introduction to solar photovoltaics (PV).

3. Atomistic Computer Modeling of Materials

Introduction and Case Studies; Potentials, Supercells, Relaxation, Methodology; Potentials for Organic Materials and Oxides; Energetics and Structure from Empirical Potentials; First Principles Energy Methods: Hartree-Fock and DFT; Technical Aspects of Density Functional Theory; Case Studies of DFT; Advanced DFT: Success and Failure; DFT Applications and Performance; Finite Temperature: Review of StatMech and Thermodynamics; Excitations in Materials and How to Sample Them; Molecular Dynamics; First Principles Molecular Dynamics; Monte Carlo Simulations: Application to Lattice Models, Sampling Errors, Metastability; Free Energies and Physical Coarse-Graining; Model Hamiltonions; Ab-Initio Thermodynamics and Structure Prediction; Accelerated Molecular Dynamics, Kinetic Monte Carlo, and Inhomogeneous Spatial Coarse Graining; Modeling in Industry; Case Studies: High Pressure

4. Modelling and Simulation of Molecular and Extended Systems

Introduction; Electronic Spin, Spin Orbitals, Molecular Orbital Theory, Valence Bond Theory; Hartree-Fock Theory, Matrix Manipulations; Mathematical Underpinnings, Dirac Notation, G16 Calculations; Solution of Hartree-Fock Equations, Variational Principle, Mean Field Theory, Meaning of Eigenvalues, Basis Sets Introduction; Gaussian Basis Sets; Correlation, CI, MP Perturbation Theories; Density Functional Theory (DFT) – Introduction; DFT: Solution of Kohn-Sham Equations and Exchange-Correlation Functionals; Coupled-Cluster Theories, QCISD, G1, G2; The Plane-wave Pseudopotential Method (PWPP); Introduction to Classical Molecular Dynamics (MD); Car-Parrinello Molecular Dynamics – Method; Running the Car-Parrinello Code; Car-Parrinello Molecular Dynamics – Applications; Embedding, Reaction Field Methods, Solvation, Combined QM/MM; Exploring Complex Free Energy Landscapes – Reactivity; Computing Reaction Rate Constants; Design of Selective, Sulfur Resistant, Oxidation Automotive Catalysts.

Recommended Books

1. Martin, Richard M. Electronic Structure: Basic Theory and Practical Methods. Cambridge University Press, 2004.
2. Szabo, Attila, and Neil S. Ostlund; Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory. McGraw-Hill, Inc., 1989.
3. Jensen, Frank. Introduction to Computational Chemistry. John Wiley and Sons, 1998.
4. Hehre, Warren J., Leo Radom, Paul v.R. Schleyer, and J. A. Pople. Ab initio Molecular Orbital Theory. John Wiley and Sons, 1986.
5. Parr, Robert G., and Weitao Yang. Density-Functional Theory of Atoms and Molecules. Oxford University Press, 1989
6. Ercolessi, Furio. A Molecular Dynamics Primer.
7. Levine, Ira N. Quantum Chemistry. 5th ed. Prentice Hall, 1999.
8. Cohen-Tannoudji, Claude, Bernard Diu, and Franck Laloë. Quantum Mechanics. John Wiley and Sons, 1977.
9. Hill, Terrell L. An Introduction to Statistical Thermodynamics. Addison-Wesley Publishing Company, 1962.
10. McQuarrie, Donald A. Statistical Mechanics. Harper Collins Publishers, Inc., 1976.
11. Ashcroft, Neil W., and N. David Mermin. Solid-State Physics. Harcourt Brace College Publishers, 1987.

PHY- 516: Non-Linear Wave Dynamics **Credit: 4** **Full Marks: 100**

Contact Hours: 70 **Lectures: 3 (1 hour) sessions/week** **Theory: ~ 70 Lectures**

Aims and objectives

The course provides students with the tools to approach the study of nonlinear systems and chaotic dynamics. Emphasis is given to concrete examples and numerical applications are carried out during the exercise sessions.

Learning outcomes

On completion successful students will be able to manipulate the fundamental elements of nonlinear systems and chaotic dynamics

Course Contents

1. **Introduction and general overview**
    - Wave motion, linear and nonlinear dispersive waves, non-dispersive waves, shocks, canonical linear and nonlinear wave equations, integrability and inverse scattering transform (IST), asymptotic and perturbation methods.
2. **Dispersive wave models: derivation techniques and basic properties**
    - Korteweg-de Vries (KdV) and related equations.
    - Nonlinear Schrödinger (NLS) equation, and generalizations with applications to modulational instability of periodic wavetrains.
    - Resonant interactions of waves (general three-wave and four-wave interactions, second harmonic generation, long-short wave resonance; phase-plane analysis, description in elliptic functions).
    - Second order models: Boussinesq and sine-Gordon equations (Fermi-Pasta-Ulam problem, Zabusky-Kruskal model, solitons; Frenkel-Kontorova model, Bäcklund transformations, kinks and breathers).
3. **Inverse scattering transform and solitons**
    - KdV equation (conservation laws, Miura transformation, Lax pair, discrete and continuous spectrum of the time-independent Schrödinger operator, direct and inverse scattering problems, initial-value problem by the inverse scattering transform. Reflectionless potentials and N-soliton solutions. Hamiltonian structures).
    - NLS equation (symmetries, focusing and defocusing, bright and dark solitons, breathers, AKNS scheme, linear problem, inverse scattering transform for the focusing NLS equation, N-soliton solutions).
    - Perturbed and higher-order KdV equations (effects of inhomogeneity, asymptotic integrability, Gardner equation).
4. **Nonlinear hyperbolic waves and classical shocks**
    - Kinematic waves, solution via characteristics, hodograph transformation, Riemann invariants, gradient catastrophe.

- Hyperbolic conservation laws, weak solutions and shock waves. Rankine-Hugoniot conditions. Lax entropy condition.
- Structure of the viscous shock wave, Burgers equation, Cole-Hopf transformation, Taylor's shock profile, N-wave.

5. **Whitham modulation theory and dispersive shock waves**

- Whitham's method of slow modulations (nonlinear WKB, averaging of conservation laws, Lagrangian formalism).
- Generalised hodograph transform and integrability of the Whitham equations. Connection with the inverse scattering transform.
- Formation of a dispersive shock wave. Decay of an initial discontinuity for the KdV equation. Gurevich-Pitaevskii problem.

Recommended Books

1. Whitham, G.B. 1974 *Linear and Nonlinear Waves*, Wiley, New York.
2. Ablowitz, M.J. & Segur, H. 1981 *Solitons and the Inverse Scattering Transform*, SIAM.
3. Dodd, R.K., Eilbeck, J.C., Gibbon, J.D. & Morris, H.C. 1982 *Solitons and Nonlinear Waves Equations*, Academic Press, Inc.
4. Novikov, S.P., Manakov, S.V., Pitaevskii, L.P. & Zakharov, V.E. 1984 *The Theory of Solitons: The Inverse Scattering Method*, Consultants, New York.
5. Newell, A.C. 1985 *Solitons in Mathematics and Physics*, SIAM.
6. Drazin, P.G. & Johnson R.S. 1989 *Solitons: an Introduction*, Cambridge University Press, London.
7. Scott, A. 1999 *Nonlinear Science: Emergence and Dynamics of Coherent Structures*, Oxford University Press Inc., New York.
8. Kamchatnov, A.M. 2000 *Nonlinear Periodic Waves and Their Modulations-An Introductory Course*, World Scientific, Singapore.

PHY- 517: Research Methodology and Art of Scientific writings | **Credit:** 4 | **Full Marks:** 100

Contact Hours: 70 | **Lectures:** 3 (1 hour) sessions/week | **Theory:** ~ 70 Lectures

Aims and objectives

This course allows students to gain experience and acquire the general research skills essential for academic and research study, whilst at the same time extending and consolidating their knowledge of physics. The material presented is designed to assist students to develop research skills. The series of seminars, delivered at the beginning of the MS thesis work, provides an appreciation of the scientific method and of ethics as well as practical aspects of physics, experimental design, research methodology, laboratory safety and control, use of computers and bibliographic databases, preparation of initial research proposal, evaluation of research papers, scientific writing and presentation of research findings. These skills are key foundations for project work later in the MS degree programme and valuable in life beyond MS study; in research, industry or business.

Learning outcomes

On completion successful students will be able to:

1. Recognize the stylistic conventions of written and oral scientific discourse and how these vary according to the requirements of the target audience.
2. Identify important information that is missing from a research article, and devise a strategy for obtaining it from other sources.
3. Use bibliographic citations and references to communicate the relationships between different pieces of research and, in conjunction with bibliographic databases, to locate papers relevant to a specific piece of research.
4. Evaluate the validity and significance of published research and use this to inform a scientific argument or overview.
5. Communicate their scientific understanding in written and oral forms in a manner that is appropriate to an audience with less, similar or more experience of physics than themselves, and following the conventions of professional scientific discourse.
6. Work as part of a collaborative team.
7. Reflect on the development of their own skills.

Course Contents

1. Concept of Research Planning, Comprehensive research plan, Hypothesis-framing of a hypothesis and importance of a hypothesis in research.

2. Objectives and Importance of research methodology, Research design, sampling design sample survey, Tools and techniques for data collection, Method of data collection, data Processing and analysis.

3. Case studies

4. Scientific writing: Writing the Scientific proposal, Report and Thesis; The Author's procedure.

5. Preparation of title: List of authors and addresses, preparation of the abstract; Introduction: Materials and methods; Result and discussion. Acknowledgement, References.

6. Design effective tables, graphs and illustration; when to use tables and graphs, arrangement of tabular material; Titles footnote and abbreviations; when to illustrate and to use graphs, preparation of graphs, symbols and legends; photographs and micrographs.

7. The review process (dealings with editors) and the publishing process (Proof dealings)

8. Writing a review paper, a conference report, a book review; present a paper orally: preparation of poster.

Recommended Books

1. Bishop, (1992) ON.19. Statistics for Biology, A practical guides for the experimental Bilogists, longman UK
2. Blalock, H.M.Jr. (1979): Social Statistics, MacGraw Hill Book Company, New Delhi.
3. Cochran, W.G. and Cox, G.M. (1957): Experimental Designs; John Wiley and sons, London.
4. Cochran, W.G. (1963). Sampling Techniques (second Edition), John wiley & Sons, NY
5. Islam, M. Nurul. (2009). An introduction to Research Methods. Mllick and Brothers, New Market, Dhaka.

PHY- 518: Oceanography **Credit: 4** **Full Marks: 100**
Contact Hours: 70 **Lectures: 3 (1 hour) sessions/week** **Theory: ~ 70 Lectures**

Aims and objectives

The aim is to help students acquire an understanding of some of the basic concepts of fluid dynamics that will be needed as a foundation for advanced courses in physical oceanography, ocean engineering, atmospheric science etc. The emphasis will be on fluid fundamentals, but with an ocean twist. This course also presents the phenomena, theory, and modeling of turbulence in the Earth's oceans. The regimes of turbulence include homogeneous isotropic three dimensional turbulence, convection, boundary layer turbulence, internal waves, two dimensional turbulence, quasi-geostrophic turbulence, and macrotrubulence in the ocean.

Learning outcomes

On completion successful students will be able to:

1. understand basic ideas of geophysical wave motion in rotating, stratified, and rotating-stratified fluids.
2. understand general wave concepts of phase and group velocity.
3. describe the dynamics and kinematics of gravity waves with a focus on dispersion, energy flux, initial value problems, etc.
4. describe topics include: resonant interactions, potential vorticity, wave-mean flow interactions, and instability.

Course Contents

1. **LINEAR WAVES**

I. Surface Gravity Waves: Governing equations. Linearization - small amplitude waves. Linear wave solution for slowly varying topography. Kinematics. Dynamics.
II. **Dispersive Waves:** Dispersion relation. Wave geometry and dynamics. Model Equations: Boussinesq, KdV, Schrodinger.

2. **NONLINEAR WAVES**

I. Examples: Stokes waves. Solitary & cnoidal waves. Shallow water waves. Bore formation. Nonbreaking waves on a beach. Three-wave interactions.
II. Weak Turbulence: Zakharov and Hasselmann Equations. Resonance. Nonlinear shoaling.
III. Large Amplitude Waves: Wave breaking. Freak (Rogue waves).

3. **APPLICATIONS:** Deep water wave forecasting. Nonlinear shoaling. Harbour resonance.

Recommended Books

1. Crapper, G.D., Introduction to Water Waves, Ellis Horwood, John Wiley & Sons, 1984.
2. Mei, C.C., M. Stiassnie, and D. K.P. Yue, Theory and Applications of Ocean Surface Waves, Advanced Series on Ocean Engineering, World Scientific, 2005.
3. Whitham, G.B., Linear and Nonlinear Waves, Pure and App. Mathematics, Wiley-Interscience.
4. Kundu, P. K., and I. M. Cohen. Fluid Mechanics. 3rd ed. Elsevier Academic Press, 2004.
5. Cushman-Roisin, B. Introduction to Geophysical Fluid Dynamics. Prentice Hall, 1994.

PHY- 519: Laser Physics **Credit: 4** **Full Marks: 100**

Contact Hours: 70 **Lectures: 3 (1 hour) sessions/week** **Theory: ~ 70 Lectures**

Aims and objectives

Lasers are essential to an incredibly large number of applications. Today, they are used in bar code readers, compact discs, medicine, communications, sensors, materials processing, computer printers, data processing, 3D-imaging, spectroscopy, navigation, non-destructive testing, chemical processing, color copiers, laser "shows", and in the military. There is hardly a field untouched by the laser. But what exactly is so unique about lasers that makes them so effective?

This course gives an introduction to Lasers by both considering fundamental principles and applications. The course starts with a review of the basic physics of optical cavities and the spontaneous/stimulated emission from materials leading to laser amplifiers and oscillators. Examples of atomic, ionic and molecular gas lasers are presented including systems for continuous wave and pulsed beam operation. The optical properties of laser cavities, and the optics of Gaussian beam are discussed. The final component of this course is a short review article on laser applications.

Learning outcomes

On completion of this course a student should be able to demonstrate understanding of and be able to solve problems on:

1. absorption and spontaneous and stimulated emission in two level system, the effects of homogeneous and inhomogeneous line broadening, and the conditions for laser amplification,
2. operations of the Fabry-Perot cavity including mode separation and line-widths, laser gain conditions, gain clamping in both homogeneous and inhomogeneous line broadened media,
3. the four-level laser system, the simple homogeneous laser and its output behaviour and optimal operating conditions,
4. spectral properties of a single longitudinal mode, mode locked laser operation, schemes for active and passive mode locking in real laser system,
5. operations and basic properties of the most common laser types, He-Ne, Argon-ion, and carbon-dioxide, ruby, titanium sapphire, neodymium YAG and glass, knowledge of other main laser types,
6. matrix optics of the laser cavity and stability conditions,
7. basics of Gaussian beam in laser cavity and optical properties of laser output, design of stable laser cavities using Gaussian beam optics, the ABCD law for Gaussian beams.

In addition each student will undertake a review article on a particular laser application.

Course Contents

1. **Introduction:** how light is generated, outline and need for the laser, scope of course.

2. **Interaction of EM Radiation with Matter:** two-level system, spectral line-shapes, finite lifetime, Doppler effects, absorption and decay processes, spontaneous and stimulated emission.

3. **Amplification Criteria:** amplification conditions, Lorentzian line-shapes, Gaussian line-shapes, simple cavity model.

4. **Fabry-Perot cavity:** optics of Fabry-Perot cavity, laser use of Fabry-Perot, laser gain conditions, laser modes, homogeneous broadening, inhomogeneous broadening, control of modes, examples of lasers.

5. **Four level laser:** four level rate equations, four level gain profile, simple homogeneous laser, output behaviour and power, optimal output conditions, inhomogeneous laser.

6. **Laser Modes and Mode Locking:** properties of a single mode, multi-mode laser, two-mode system, mode locking in multi-mode laser, mode locking of real laser, active mode locking, passive mode locking, the Kerr lens.

7. **Gas Lasers:** operation and characteristics of the He-Ne laser, argon and krypton ion lasers and the carbon-dioxide lasers. Summary of other gas lasers.

8. **Solid State Lasers:** laser media, the ruby laser and Q-switching, titanium sapphire laser, neodymium YAG and glass lasers, visible solid state lasers, other rare earth lasers, summary of other laser types.

9. **Cavity Stability:** matrix optics ray methods, matrix model of optical cavity, laser stability conditions, practical laser cavities.

10. **Gaussian Beams:** scalar potentials, plane wave solution in optical cavity, Gaussian solution, divergence angle and beam parameters, beam waist and Rayleigh region, Gaussian beams in cavities, higher order modes, transformation of Gaussian beams, ABCD law, basic optics of Gaussian beams.

11. **Applications Review:** individual review contributing to 15% of the course marks with each person reviewing a different application.

Recommended Books

1. S Hooker and C Webb; Laser Physics, OUP, 2010.
2. G Brooker; Modern Classical Optics, OUP, 2003.
3. Milonni, Eberly; Laser Physics, Wiley Interscience.
4. Saleh, B. E. A., and M. C. Teich; Fundamentals of Photonics, John Wiley and Sons.
5. Yariv, A.; Optical Electronics in Modern Communications, Oxford University Press.
6. Amnon Yariv; Quantum Electronics, Wiley.

PHY- 520: Theory of Relativity **Credit: 4** **Full Marks: 100**

Contact Hours: 70 **Lectures: 3 (1 hour) sessions/week** **Theory: ~ 70 Lectures**

Aims and objectives

This course will give students a working knowledge of analytical mechanics and relativity to the standard required for further study in physics. In the first part, this course introduces the basic ideas and equations of Einstein's Special Theory of Relativity. If you have hoped to understand the physics of Lorentz contraction, time dilation, the "twin paradox", and $E=mc^2$, you're in the right place. Later, this course introduces the students to general relativity and its classical tests. General Relativity presents one of the most interesting intellectual challenges of an undergraduate physics degree, but its study can be a daunting prospect. This course provides an outline of differential geometry with applications to General Relativity, including the Schwartzchild solutions, weak fields and gravitational waves. The classic results such as light bending and precession of the perihelion of Mercury are obtained from the Schwarzschild metric by variational means. Einstein's equations are developed, and are used to obtain the Schwarzschild metric and the Robertson-Walker metric of cosmology.

Learning outcomes

On completion successful students will be able to:

1. Explain the basic concepts of special and general relativity
2. Describe physical phenomena in different coordinate systems
3. Discuss the role of mass in Newtonian physics, and inertial forces, and state and justify the principle of equivalence; define a local inertial frame
4. Define the metric tensor (and inverse), and interpret as gravitational potentials
5. Discuss the space-time approach to relativity and four-vectors
6. Derive the geodesic equation from the principle of equivalence; derive the affine connections
7. State the Correspondence Principle and the Principle of General Covariance; calculate the special relativistic and Newtonian limits of GR equations; Derive Einstein's equations and justify them in empty space, and with matter; Discuss and justify the inclusion of a cosmological constant
8. Define a tensor; define and use appropriate tensor operations, including contraction, differentiation; Discuss the need for a covariant derivative and derive it; Define parallel transport, curvature tensor; Discuss the relation of curvature to gravity and tidal forces; derive the curvature tensor
9. Derive gravitational time dilation and redshift, precession of Mercury's perihelion, light bending, radar time delays, cosmological redshift, horizons; Discuss and apply the concept of proper times
10. Compute Christofell symbols and curvatures from a given line element
11. Solve Einstein's field equations for static spherically symmetric problems
12. Show the equivalence of the variational formulation of GR and the geodesic equation; derive the Euler-Lagrange equations; apply them to metrics such as the Schwarzschild

and Robertson-Walker, to obtain affine connections, conserved quantities and equations of motion

13. Explain the observational effects at the scale of the Solar System that cannot be described by Newtonian gravity
14. Derive and sketch effective potentials in GR and Newtonian physics; examine qualitative behavior; analyze to find features such as the minimum stable orbit
15. Write down the Schwarzschild and Robertson-Walker metrics; describe the meaning of all terms; Solve Einstein's equations to derive both metrics and the Friedman equation
16. Discuss gravitational waves; derive their wave equation
17. Discuss metric singularities (and relate to Black Holes), event horizons and infinite redshift surfaces
18. Apply the general techniques to solve unseen problems, which may include analysis of previously unseen metrics

Course Contents

Part A: Theory of Special Relativity

1. **Newton's Laws and Relativity:** Frames of reference and inertial frame, the principle of relativity, demonstration of relativity in Newton's laws.
2. **Einstein's Resolution:** Ether concept and Michelson-Morley experiment; Lorentz-Fitzgerald contraction hypothesis and ether-drag hypothesis; Postulates of Special Theory of Relativity; Galilean Transformation; Simultaneity of two events in different inertial frames of reference and its frame dependence; Lorentz Transformation; Velocity Transformation; Relative velocity with examples; Length Contraction and Time dilation with examples; Relativity of simultaneity; Summary of consequences of relativity for times and distances.
3. **Relativistic Invariants:** The invariant interval; Space time diagrams; Time like and Space Like intervals; Causality; Need to redefine Momentum; Vector and Four-Vectors; Proper time interval.
4. **Relativistic Energy and Momentum:** Relativistic momentum; Properties of relativistic momentum; Relation between symmetries and conservation laws; Relativistic energy; Mass-Energy Relationship; Relationship between new energy and momentum.

Part B: Theory of General Relativity

5. **A Brief History of Relativity and Basic Idea of General Relativity:** Special versus general relativity; Space and inertia in Newtonian physics; Newton's theory and the orbits of planets; The basic assumptions of general relativity; Inadequacy of Special Relativity; Einstein's Principle of Equivalence; Immediate Consequences of the Principle of Equivalence; The Curved Space-Time Concept; The Principle of General Covariance; Distance and Time Intervals.
6. **The equivalence principle and space-time curvature:** The concept of a manifold; Coordinates; Curves and surfaces; Coordinate transformations; Summation convention; Geometry of manifolds; Riemannian geometry; Riemann spaces; The curvature of a Riemann space; Curvilinear Coordinates; Christoffel Symbols and the Metric Tensor; Symmetry Properties of the Christoffel Symbols; Geodesics; Riemannian manifolds; Covariant differentiation; Bianchi identities: Ricci and Einstein tensors; Newtonian gravity; The equivalence principle; Gravity as spacetime curvature; Local inertial

coordinates; Observers in a curved spacetime; Weak gravitational fields and the Newtonian limit; Electromagnetism in a curved spacetime.

7. **Einstein's Field Equations and Gravitational radiation/field:** Purpose and justification of the field equations; Einstein's equations; Einstein's equations for weak gravitational fields; Newtonian gravitational fields; The field equations in the presence of matter and energy; Energy-momentum conservation; Some energy-momentum tensors; The Newtonian limit of general relativity; The propagation of gravitational waves; The detection of gravitational waves; The energy carried away by gravitational waves; Astrophysical sources of gravitational waves; Gravitational Radiation.
8. **The Schwarzschild Solutions and Black Holes:** Trajectories in the Schwarzschild spacetime; Nature of the surface $r = 2M$; The Schwarzschild Black Hole; General black holes; Real black holes in astronomy; Quantum mechanical emission of radiation by black holes: the Hawking Radiation; The Schwarzschild Metric; The Schwarzschild Solution of the Vacuum Field Equations; Schwarzschild Geodesics; Quasiuniform Gravitational Field.
9. **Experimental tests of general relativity:** Precession of planetary orbits; The bending of light; Deflection of light rays in a gravitational field; Light retardation (The Shapiro Experiment); Radar echoes; Accretion discs around compact objects; The geodesic precession of gyroscopes.

Recommended Books

1. French, A. P. Special Relativity, Norton, 1968.
2. Resnick, Robert. Introduction to Special Relativity. Wiley, 1968.
3. Rindler, W., Introduction to Special Relativity, 2nd ed., OUP 1991
4. Weinberg, Steven. Gravitation and Cosmology. Wiley, 1972.
5. Misner, Charles W., Kip S. Thorne, and John Archibald Wheeler.; Gravitation, 1973.
6. Schutz, Bernard. A First Course in General Relativity. Cambridge University Press, 1985.
7. Hartle, James. Gravity: An introduction to Einstein's general relativity. Addison-Wesley, 2002.
8. Taylor, Edwin F., and John A. Wheeler. Exploring Black Holes: Introduction to General Relativity. Addison Wesley Longman, 2000.
9. A. Einstein, Relativity: The Special and General Theory
10. Carroll, Sean. An Introduction to General Relativity: Spacetime and Geometry. Addison Wesley, 2003.
11. L. Landau, Lifshitz, The classical theory of fields.
12. MP Hobson, GP Efstathiou, AN Lasenby; General Relativity- An Introduction for Physicists
13. Wald, Robert. General relativity. University of Chicago Press, 1984.

PHY- 521: MS Physics Lab **Credit:** 4 **Full Marks:** 100

Contact Hours: ~ 120 **Lab:** 20 sessions **Practical :** 1 (6 hour) sessions /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, 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.

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 Masters Physics Lab located on the second floor and hosts experiments on electronics, solid state physics, nuclear physics, astrophysics, geophysics, renewable energy, biomedical physics and computational physics. The second part of the lab is introduction to MATLAB programming language and its application to solve physical problems.

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 one experiments from PART A and one program from PART B in the final examination**).

Part A: LIST OF EXPERMIMENTS

1.

   a. To construct and study of a voltage series feedback amplifier using µA 741 IC and hence to find following:
      i. Gain with various combination of feedback,
      ii. Input resistance with feedback,
      iii. Output resistance with feedback,
      iv. To plot a frequency response curve and hence to find the 3 dB point

b. **To construct and study of a voltage follower by using above amplifier and to see the waveform on the oscilloscope.**

2. **To construct and study of a Current series feedback amplifier using Transistor and examine the following:**

    i. Measure the voltage gain without feedback,
    ii. Measure the voltage gain with feedback,
    iii. Compare the gain with and without feedback,
    iv. Compare the theoretical and practical value of gain with feedback.
    v. Plot a frequency response curve and hence find the 3 dB point and bandwidth (B.W.) from the graph.

3. **To construct and study a voltage shunt feedback amplifier using µA 741 IC and hence to find following:**

    i. Gain with various combination of feedback,
    ii. Input resistance with feedback,
    iii. Output resistance with feedback,
    iv. To plot a frequency response curve and hence to find the 3 dB point and bandwidth (B. W.) from the graph.

4. **To construct and study of an inverter by using above amplifier and to see the waveform on the oscilloscope.**

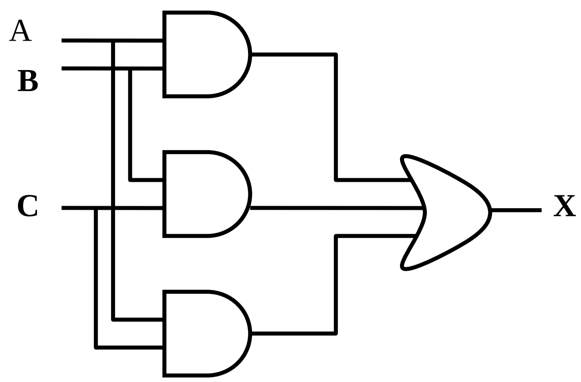
5. **To demonstrate the operation and characteristics of a typical Phototransistor and show how it can be used as a Photo diode.**

6.

    a. **To demonstrate the operation and characteristics of a typical Photoconductive cell.**
    b. **To demonstrate the operation and current-voltage characteristics of a typical LED**

7.

    a. **To verify the Associative Law, Distributive Law and De-Morgan's Law of Boolean Algebra.**
    b. **To implement the given combinational logic circuit.**



8.

a. **To study the characteristics of a half adder and a full adder in the Arithmetic circuit and construct the truth table.**
b. **To study the characteristics of a half subtractor and construct the truth table.**

9.

a. **To design, construct and demonstrate the operation of a digital Multiplexer.**
b. **To design, construct and demonstrate the operation of a Decoder.**

10.

a. **To demonstrate the operation and characteristics of a JK Flip-flop.**
b. **To demonstrate the operation and characteristics of a 4 bit binary counter.**

Part B: LIST OF PROGRAMS

1. **Using Matlab write the source code to implement the following mathematics-**

   a. Determine inverse, transpose, Eigen vector and Eigen values of the following matrix-

2. $$A = \begin{bmatrix} 9 & 7 & 11 \\ -2 & 20 & 5 \\ 2 & 0 & 1 \end{bmatrix}$$

   b. Add two given matrix and hence determine conjugate transpose (Hermitian Transposition) of the resultant matrix.

3. $$A = \begin{bmatrix} 7 & 9 & 11 \\ 2 & 15 & -6 \\ 2 & 8 & 3 \end{bmatrix} \qquad B = \begin{bmatrix} 2 & 8 & 1 \\ -2 & 10 & 5 \\ 5 & 11 & 3 \end{bmatrix}$$

4. **Using Matlab write the source code to implement the following mathematics-**

   a. Find the roots of a given function.
      i. $f(x) = 2.x^6 + 7.x^4 + 9.x^3 + 3.x + 4$
      ii. x + 2y + 4z = 8
      x + 4y + 3z = 2
      x - 2y + 4z = 3

   b. Perform the following operations-
      i. $I = \int_{0.2}^{11} Cos(\pi.x).dx$

   c. Find the Fourier transformation of function $f(x) = (Cos^3.x)$.

5. **Using Matlab write the source code**

   a. to plot a sinusoidal oscillation curve.
   b. to plot a damped oscillation curve for a the following equation-
   $$f(x) = 1.5 \times e^{(-0.3.x)} \times (0.1 \times \sin(5.\pi.x))$$

6. Using Matlab write the source code to plot an

a. exponentially rising curve.
b. exponentially decaying sinusoidal curve.

$$f(x) = 2 \times e^{(-0.6.x)} + \sin(4.\pi.x)$$

7. Using Matlab write the source code to plot

a. three sinusoidal signals with different phase.
b. three sinusoidal signals with different amplitude.
c. three sinusoidal signals with different frequency.

8. Using Matlab write the source code to plot

a. the following data on a polar co-ordinate plane-

Elevation angle in degree	Antenna gain in dB
0	2
45	2.8
90	3
135	2.3
150	3.2
180	3.5
225	3.7
270	3.5
320	3.2
350	2.5
360	2.2

b. a given equation on a polar co-ordinate plane

$$r(\theta) = e^{\sin 3.\theta} + 2.\cos(4.\theta)$$

9.

a. **Study and Implementation of Amplitude Modulation and Demodulation.**
b. **Study and Implementation of Frequency Modulation and Demodulation.**

10.

a. **Study and Implementation of Charging and Discharging Phase of a R-C Network using Matlab.**
b. **Implementation of Maximum Power Transfer Theorem.**

11.

a. **Using Matlab Analysis of Temperature Effect on Diode Characteristics.**
b. **Using Matlab Analysis of Mobility Vs Doping Concentration of carriers.**
c. **Using Matlab Analysis of Frequency response of a Low pass Filter.**

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

MS Thesis/Project **Credit: 12/2** **Full Marks: 300/50**

Supervised reading, weekly meetings with Supervisor and research work over MS years

Aims and objectives

The MS Thesis/Project aims to help students identify and cultivate the technical, personal, and presentation skills needed to work successfully in a physics-based research/development environment. During the research project, students work on their own under the supervision of their Supervisor. The function of the Supervisor is initially to define the project and then to give advice as students' work proceeds. However, it should be understood that the project must be a reflection of students own work and ideas. This research thesis/project works develop independence in the skills of experimental design and scientific project management, develop oral reporting skills, and to encourage high quality technical presentation and written summaries. This requires substantial experimental or theoretical research work on a related topic in advanced physics. This research work is student's main chance to work on their own topic of interest and to show their own initiative, theoretical and experimental skills. The MS Thesis/Project Presentation (Viva Voce) course aims to identify and develop key scientific presentation skills required to work in a physics-based research or development environment. Students will present their MS thesis/project research works to scientific peers.

In this research works, students may select any potential topics including but not limited to, depending on the nature of the thesis/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 MS Thesis/Project Coordinator and their prospective thesis/project supervisor regarding the selection of the topics as it must be unique. The research 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 work is selected at the start of the MS year following consultation with the Thesis/Project Coordinator and depends on availability of research supervisors in the department in any particular year.

The educational objectives of the MS thesis/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 research project.
3. develop such transferable skills as scientific report writing and oral presentation.
4. facilitate self-reliance and the application of scientific 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 and demonstrate initiative and intellectual independence in scientific work
5. conduct a comprehensive search of the literature relevant to a research topic and to select and summarize the crucial aspects of the relevant literature
6. use a range of primary source material including library and on-line resources
7. apply knowledge of physical science to the planning and development of a research/technical project
8. critically evaluate information and techniques when deciding upon research methodologies and analysis, using criteria that can be defended
9. gain experience of the organization and completion of an extended project where the results and outcomes are not fully defined at the beginning
10. organize, keep and use a comprehensive log book of the work done in the project
11. comply with regulatory frameworks and practicing professional ethics relevant to physics
12. manage time and resources to optimal effect to produce a project report to a given deadline
13. analyze, interpret and critical evaluate research findings
14. 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
15. gain experience the preparation of scientific posters and the oral reporting of results
16. have gained experience of working in a research group environment and interacting in a professional manner with research scientists
17. demonstrate an understanding of the close relationship between scientific research and the development of new knowledge in a global context

At the completion of the course students will have acquired the key skills to present scientific research to a variety of audiences: to scientific peers via a presentation, question and answer session.

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 three months prior to submission, when students should discuss the structure and broad content of students' thesis/project report with their supervisor, who will offer oral feedback. Students must demonstrate satisfactory progress at the end of the MS year of study to be allowed to submit their thesis/project report. A thesis/project report is submitted at the end of the MS 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.

APPENDIX A

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

Department Teaching and Learning Academic Team

Name	Designation	Research Interest	Email
Dr. S M Azharul Islam	Professor	Nuclear and Reactor Physics	azharphyd@juniv.edu
Dr. Md. Nurul Alam	Professor	Plasma Physics	alamphys@juniv.edu
Dr. Md. Abul Hossain	Professor	Condensed Matter Physics: Crystal Growth, Phase Transition, Magnetic Materials, Polymer Composites	mdabulh@juniv.edu
Dr. Md. Abdul Mannan Chowdhury	Professor	Atmospheric Physics and Advanced Electronics	marzia111@juniv.edu
Dr.Tahmina ferdous	Professor	Solid State physics, Material Science, Astrophysics	tferdous.1958@juniv.edu
Dr. M. Salahuddin	Professor	Plasma Physics; Dusty Plasma Physics; Nonlinear Waves in Plasmas	su_2960@juniv.edu
Dr. A A Mamun	Professor	Plasma Physics: Nonlinear electrostatic/electromagnetic waves and structures; Collective processes; Nonlinear effects in laser-plasma interaction processes, etc.	mamun_phys@juniv.edu
Dr. Farid Ahmed	Professor	Condensed Matter Physics: Thin Films, Solar Cells, Magnetic Materials, Polymer Composites	fahmed@juniv.edu
Mohammad Mominur Rahman	Professor	Electronics, photonics and condensed matter physics	mm_rahman@juniv.edu
Md. Abul Quasem	Professor	Condensed Matter Physics	quasem66@juniv.edu
Dr. Mohammad Obaidur Rahman	Professor	Condensed Matter Physics: Crystal Growth, Phase Transition, Magnetic Materials, Solar Cells	morahman@juniv.edu
Dr. Md. Shafiqul Islam	Professor	Fiber Laser, Photonics Devices, Applications of Non-linear Optics , Fiber based Biosensors, FSO, Fiber and Bio-Communication	shafiq1190@juniv.edu
Dr. Rubina Rahman	Professor	Health and Radiation Physics, Medical Physics	rrahman@juniv.edu
Dr. Jahirul Islam Khandaker	Professor	Nanoscience and Nanotechnology	jahir-nanophysics@juniv.edu
Dr. Md. Kabir Uddin Sikder	Associate Professor	Soft condensed matter and Biophysics, Medical Physics and Neurophysics, Physics Education	kabirsikder@juniv.edu

Dr. Sharmin Sultana	Associate Professor	Mathematical Modeling, Nonlinear Dynamics & Applications, Nonlinear Waves and Instabilities in Plasmas, Dusty Plasmas (Complex Plasmas)	ssultana@juniv.edu
Md. Moshiur Rahman	Associate Professor	Nuclear physics, Radiation Physics, Medical Physics	phy_mmr@juniv.edu
Humayun Kabir	Associate Professor	Materials Engineering (Nanomaterials, Biomaterials, Polymeric materials, Composites), Plasma Polymer Thin Films, Condensed Matter Physics, Electronics.	rumy140@juniv.edu
Dr. M. Mahbubur Rahman	Associate Professor	Materials Engineering and Surface Analysis; Magnetic Materials and Magnetism; Optical Thin Films; Photovoltaics; Photovoltaic Thermal Devices; Solar Selective Surface	mahbub235@juniv.edu
Dr. M. Arifur Rahman	Assistant Professor	Machine Learning, Gaussian Process, Data Science, Computational Biology	arif@juniv.edu
Md. Alamgir Kabir	Assistant Professor	Condensed Matter Physics, Biomaterials, Thin Film, Solar Cell.	alamgirjuphy@juniv.edu
Dr. Budrun Neher	Assistant Professor	Condensed Matter Physics	budrunneher@gmail.com
Md. Mahbubur Rahman	Assistant Professor	Condensed Matter Physics	rahmanmahbubur@ymail.com
Md. Kamal Hossain	Assistant Professor	Condensed Matter Physics: Nano-materials, Solar Cells, Materials Modelling and Simulation	khossain@juniv.edu
Md. Sahadat Alam	Assistant Professor	Plasma Physics; Dusty Plasma Physics; Nonlinear Waves in Plasmas; Computational Plasma Physics, Nonlinear Optics.	soyon@juniv.edu
Dr. Abdul Mannan	Assistant Professor	Nonlinear dynamics, Numerical analysis of PDE, Simulation, Turbulence, Water Waves, Rogue Waves, Beam-Plasma based acceleration, Quantum methodologies, Coastal Hydrodynamics, Modulational Instability, Nonlinear Phenomena in Plasma Physics, etc.	abdulmannan@juniv.edu
Mst. Shamima Khanom	Lecturer	Condensed Matter Physics, Thin Films, Polymer Composites, etc.	skhanom@juniv.edu
Shariful Islam	Lecturer	Solar Energy (Thin films), Nanotechnology (Energy related), Semiconductor Physics and Solid State Electronics Devices.	s_islam@juniv.edu
Kazi Golam Martuza	Lecturer	Electronics, Photonics.	mp39@juniv.edu
Sujan Kumar Das	Lecturer	Condensed Matter Physics, Electronic and Magnetic Materials, Thin Film, Renewable energy and Solar Cell	skdas@juniv.edu

APPENDIX B

Important Examination Regulations according to *Master's Degree Ordinance 2005, JU*

Clause **Regulations**

6.1 A student who fails to appear at the Master's Degree examination or does not pass in the Master,s degree examination shall cease to be a regular student of this University and shall not be admitted again to the Master's Degree course in another session. He/she may, however, with the approval of the Chairperson of the Department concerned, be allowed to sit for the Master's Degree examination within two years as an irregular candidate provided that he/she has fulfilled the requirements of the class attendance and other specific requirements, if any, of the department concerned and provided further that he/she will get only one such chance.

6.2 An irregular candidate shall appear in all the courses and the viva-voce examination at a subsequent Master's Degree examination. The course-end examinations will be conducted normally according to the syllabus in force in the session in which candidate appears at such examination.

If however, there are major changes in the syllabus of the course or courses, the relevant Examination Committee, may arrange for holding his/her examination according to the old syllabus.

Marks obtained in the tutorial in any course for Master's Degree shall hold good for the subsequent examination in that course. An irregular examinee may opt for the conversion of 80 marks in the theoretical and practical courses to 100 marks in lieu of tutorial marks.

6.3 স্নাতকোত্তর নিয়মিত পরীক্ষায় অংশগ্রহণ করে যদি কেউ অকৃতকার্য হয়, তবে সে অনিয়মিতভাবে শুধু একবার সকল কোর্সে স্নাতকোত্তর পরীক্ষায় অংশ গ্রহণের সুযোগ পাবে। গ্রেডিং পদ্ধতির ক্ষেত্রে সর্বাধিক ২'টি কোর্সে **F** গ্রেড প্রাপ্ত কোর্স দুটিতে অনিয়মিত পরীক্ষার্থী হিসাবে পরীক্ষায় অংশগ্রহণের সুযোগ পাবে। তবে এ ক্ষেত্রে তার প্রাপ্ত **GPA** ২.০০ থাকতে হবে। **GPA** ২.০০ এর কম পেলে সকল কোর্সে অনিয়মিতভাবে পরীক্ষায় অংশগ্রহণ করতে হবে।

6.4 Irregular students who intend to appear at a subsequent Master's Degree examination must apply to the Office of the Controller of Examinations through the Chairperson of the Department concerned in the prescribed form together with the fee for the examination at least six months before the commencement of the examination.

Irregular students who intend to appear at a subsequent Master's Degree examination involving Practical examination, may be required to attend practical classes on payment of fees to be determined by the department concerned before they qualify for appearing at the subsequent Master's Degree examination.

6.5 The results of the irregular candidates will be published separately. Successful candidates will be placed in classes as per provisions of the clause 5.3, but without indicating any position within the class obtained.

7.0 Time limit for the Master's Degree

স্নাতকোত্তর শ্রেণীতে ভর্তিকৃত ছাত্র-ছাত্রীরা সর্বাধিক দুইট শিক্ষাবর্ষেও মধ্যে তাদের স্নাতকোত্তর ডিগ্রী লাভ করতে পারবে। স্নাতকোত্তর নিয়মিত পরীক্ষায় অংশগ্রহণ করে যদি কেউ অকৃতকার্য হয়, তবে সে অনিয়মিতভাবে শুধু একবার সকল কোর্সে স্নাতকোত্তর পরীক্ষায় অংশ গ্রহণের সুযোগ পাবে। (সিন্ডিকেট : ২৩-০৮-২০০৯)

7.1 Improvement Examination

A candidate who has passed the Master's Degree examination in the 3rd class or D grade (2.00) in GPA system may be permitted to re-appear as irregular candidate at the same examination in order to improve his/her qualifications without further attending classes, under the following conditions:

a) Not more than one chance shall be given to such a candidate.
b) There shall be a time limit of two years for reappearing at the examination.
c) A candidate willing to re-appear at the Master's Degree examination in a subject having laboratory/field work courses shall have to attend Practical class/Field work etc. for at least three months before he/she can be permitted to re-appear at the examination.
d) A candidate willing to re-appear at the Master's degree examination for improvement shall appear in all the courses and the viva-voce. The course-end examinations will be conducted normally according to the Syllabus in force in the session in which the candidate appears at the improvement examination. If, however, there are major changes in the syllabus of the course or courses the relevant Examination Committee may arrange for holding the examination according to the old syllabus.
e) Marks obtained in the tutorial examination in any course for the Master's degree shall hold good for the Improvement examination for that course or the candidate may opt for conversion of the theoretical and practical course from 80 to 100 in lieu of tutorial marks..
f) The results of the improvement examination will be published separately. Successful candidates will be placed in classes as per provisions of the clause 5.3, but without indicating any position within the class obtained.
g) The certificate to be awarded to such candidates shall be in the usual form, without any reference to previous results. No word '**Improvement'** will not be mentioned in the official certificates.

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.

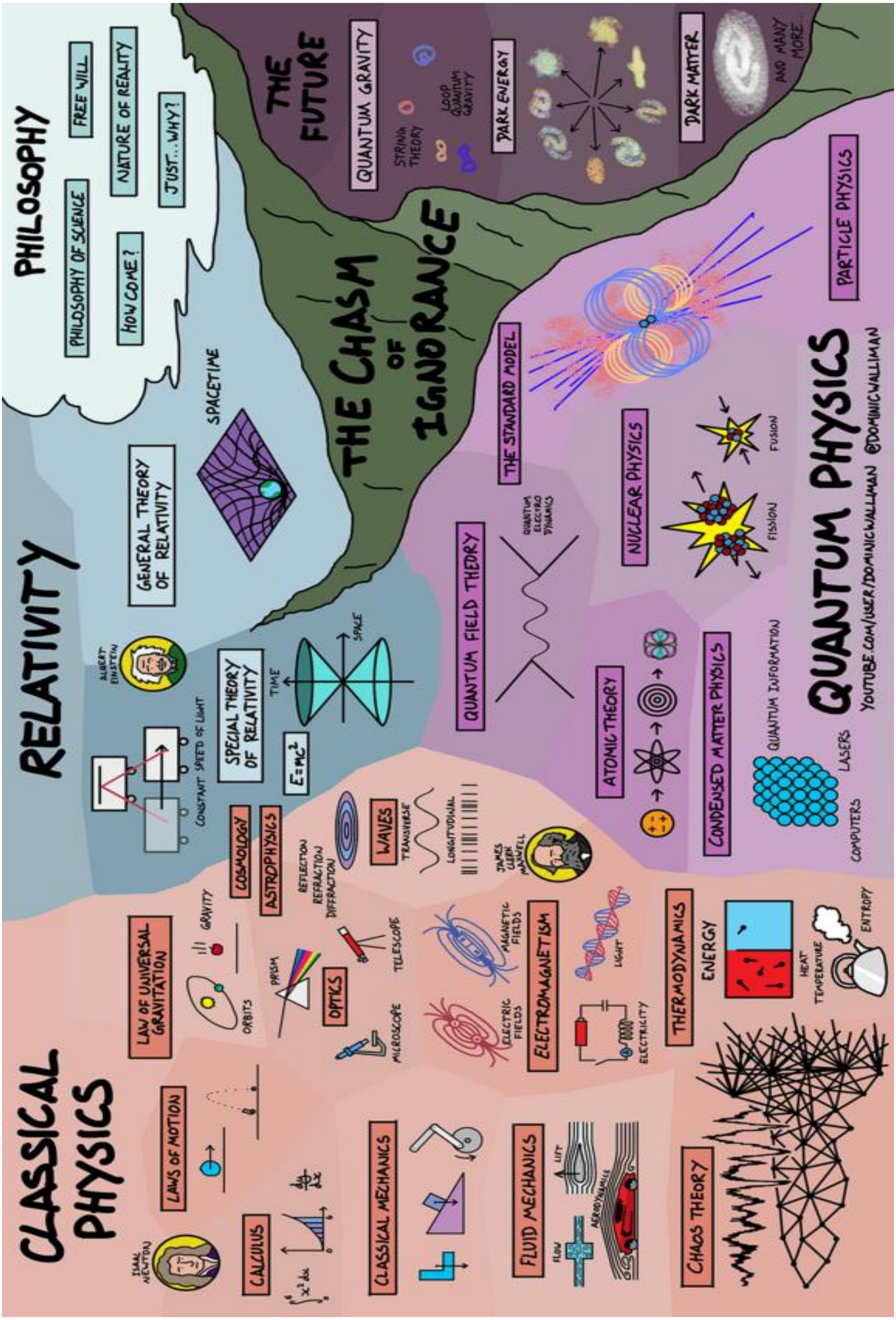
On the other hand, collaboration is a perfectly legitimate academic activity in which students are required to work in groups as part of their programme of research or in the preparation of projects and similar assignments. If you are asked to carry out such group work and to collaborate in specified 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.


PHILOSOPHY
PHILOSOPHY OF SCIENCE
FREE WILL
NATURE OF REALITY
HOW COME?
JUST...WHY?
RELATIVITY
GENERAL THEORY OF RELATIVITY
SPACETIME
SPECIAL THEORY OF RELATIVITY
CONSTANT SPEED OF LIGHT
TIME
SPACE
E=mc²
THE CHASM OF IGNORANCE
THE FUTURE
QUANTUM GRAVITY
STRING THEORY
LOOP QUANTUM GRAVITY
DARK ENERGY
DARK MATTER
AND MANY MORE...
CLASSICAL PHYSICS
CALCULUS
LAWS OF MOTION
LAW OF UNIVERSAL GRAVITATION
ORBITS
GRAVITY
COSMOLOGY
ASTROPHYSICS
OPTICS
PRISM
MICROSCOPE
TELESCOPE
REFLECTION
REFRACTION
DIFFRACTION
WAVES
TRANSVERSE
LONGITUDINAL
CLASSICAL MECHANICS
FLUID MECHANICS
FLOW
LIFT
AERODYNAMICS
ELECTROMAGNETISM
ELECTRIC FIELDS
MAGNETIC FIELDS
ELECTRICITY
LIGHT
THERMODYNAMICS
ENERGY
HEAT
TEMPERATURE
ENTROPY
CHAOS THEORY
QUANTUM PHYSICS
QUANTUM FIELD THEORY
QUANTUM ELECTRODYNAMICS
THE STANDARD MODEL
PARTICLE PHYSICS
NUCLEAR PHYSICS
FISSION
FUSION
ATOMIC THEORY
CONDENSED MATTER PHYSICS
QUANTUM INFORMATION
LASERS
COMPUTERS
YOUTUBE.COM/USER/DOMINICWALLIMAN @DOMINICWALLIMAN

2018

Department of Physics

Handy guide to the Master of Science Degree

Graduate Booklet

To find out more about the Department of Physics visit following website: www.juniv.edu/department/phy

This brochure has been drafted in advance of the academic year to which it applies. Every effort has been made to ensure that the information contained in this brochure is accurate at the time of publishing, but changes (for example to course content) are likely to occur given the interval between publication and commencement of the course. It is therefore very important to check our website for any updates before you apply for the course by following **www.juniv.edu/department/phy**. Where there is a difference between the contents of this brochure and our website, the contents of the website take precedence.

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