Physics is concerned with those aspects of nature which can be understood in a fundamental way in terms of elementary principles and laws. In the opinion of a non-physicist (J Moliere, French playwright), "Physics explains the properties of natural bodies and properties of matter; it discourses on the nature of elements, minerals, plants, rocks and animals, and teaches us the causes of all the meteors, rainbow, aurora borealis, comets, lightening, thunderbolts, rains, snows, hails and whirl winds". In course of time, various specialized sciences broke away from physics to form autonomous fields of investigation. In this process physics retained its original aim of understanding the structure of the natural world and explaining natural phenomenon. Physicists think about what exists and how it works; they also seek to understand reality from possible infinite vastness of the universe down to the infinitesimal particles that form the structure of an atom.

**History**

The Department of Physics, Rajshahi University, started functioning in March 1958 and its academic activity started in July 1958 in its own building in the university campus, under the leadership of Late Dr Ahmad Husain with a batch of 15 post-graduate students and three teaching staff members. The teaching was started in December, 1958. A three-year B.Sc. (Honours) course was introduced in 1962. Over the years, the department has grown in every sphere and now assumes the structure of a large department in the university.

The department has been offering a four-year B.Sc. (Honours) course since 1998. At present, there are 26 members of teaching staff and 26 supporting technical and office staff catering the needs of over 500 students including a number of research scholars.

**Location**

The Department of Physics is located in the first science building, which is surrounded by the scenic beauty of the university. It has a beautiful flower garden inside.

**Research Activities**

The department has a long tradition of research in various areas of physics under M.Sc., M.Phil. and Ph.D. programmes. The faculty members along with their research students pursue research in diverse fields which has resulted in a large number of research publications in various journals of international repute, like Nature, Physical Review Letters, Physical Review, Nuclear Physics, Physica C, Journal of Superconductivity, Superconductor Science and Technology, Solid State Communications, Physics Letters, Journal of Materials Science, Journal of Non-Crystalline Solids, Physica Status Solidi, Journal of Physics and Chemistry of Solids, Journal of High Energy Physics, Physics and Chemistry of Glasses, Nuovo Cimento, Annals of Physics, etc. The department is also working under different international collaboration programmes with UK, USA, Japan, South Africa, Germany, India, Turkey etc. The current research areas are:

- Nuclear Physics: Nuclear Reaction &Nuclear Structure
- Radiation Physics and Medical Physics
- Atomic Physics
- Condensed Matter Physics:
  - Perfect and Defect Crystals- Computer Simulation studies (theoretical).
  - Solid State Reaction (experimental)
- Superconductivity
- Semiconductors: Thin Film Deposition and Characterization
- Structural properties of Glass and Glass Ceramics
- Solar Energy
- High Energy Physics: Lattice QCD.

**Teaching Activities**

The department is at present involved in teaching the following courses:

- Four-year B.Sc. (Honours) degree course (started from the session 1997-98).
- One-year M.Sc. course in General and Thesis group.

**Mission and Objectives of the Department**

Since its inception in 1958, the mission of the Department of Physics, University of Rajshahi has been to advance the knowledge in various branches of Physics via teaching-learning and research. The academic program is focused on the creation, translation, and dissemination of knowledge on the subject matter. The strategic goals of the Department are to:

- Support the aims and objectives of the University within the capacity of our Departmental program.
- Advance the academic, research, scholarship and service priorities, consistent with a top tier university, and continue to promote growth and national prominence in these areas.
- Train and produce high-quality graduates to meet up national and international requirements in scientific sectors of the job market.
- Enhance the teaching-learning and research capacities of the Department by retaining and recruiting outstanding faculty and staff.
- Enhance the Department's learning environment by attracting and retaining students of high intellectual ability and aptitude.

**M.Sc. Program Learning Outcomes (PLOs)**

The M.Sc. Degree programs offered by the Department cover the advanced topics of Physics. It also provides a selection of recent topics and develops experimental, mathematical, computational, and other transferable skills. On successful completion of these programs a student should have-

1. Knowledge and understanding of advanced physical laws, principles and phenomena and competence in the application of these to diverse branches of Physics.
2. An ability to solve problems in Physics using appropriate mathematical tools.
3. An ability to execute and analyze the results of an experimental investigation or theoretical modeling and to draw valid conclusions with an estimate of the uncertainty in the result. An ability to compare experimental results with the predictions of relevant theories.
4. A knowledge of the principles and applications of some advanced areas of Physics at the forefront of contemporary research.
5. An ability to use IT packages and a competence of the usage of analytical software in problem solving.
6. An ability to communicate scientific information verbally and in the form of clear and accurate scientific reports.
7. An ability to make appropriate use information and communication technologies in regard to problem solving in different sectors of Physics.

Knowledge and understanding of areas 1 – 2, and 4 – 7 are acquired through lectures, tutorials, problem classes and guided independent study. The practically oriented knowledge of area 3 is acquired in practical classes, both experimental and computing, and in thesis work.

An M.Sc. student, after completion of his/her degree from the Department is expected to have the following mental and moral attributes:

8. An understanding and appreciation of current issues and debates in various branches of Physics.
9. An understanding and appreciation of the philosophical bases, mathematical structure, methodologies, characteristics of scientific scholarship, research, and creative work.
10. An ability to work independently and in collaboration with others.
11. Personal and professional integrity and an awareness of the requirements of ethical behavior.

The graduates are also expected to have the following skills:

12. Competence in using various computer software and programming languages.
13. Competence in troubleshooting and solving basic problems in electronic equipments and circuits.
14. An ability to prepare multimedia presentations for conveying scientific facts and findings to audience with diverse backgrounds.

## Mapping of Programme Learning Outcomes (PLOs) with Course Learning Outcomes (CLOs) of the M.Sc. Programme in Physics at the University of Rajshahi

| Domain | Prog.Learning Outcomes (PLOs) | PH501 | PH502 | PH503 | PH504 | PH505 | PH506 | PH507 | PH508 | PH509 | PH510 | PH511 | PH512 | PH513 | PH521 | PH522 | PH523 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cognitive** | **PLO1** | X | X | | X | X | X | X | X | X | X | X | X | X | | | |
| | **PLO2** | | | | | | | | | | | | | | | | X |
| | **PLO3** | | | | | | | | | | | | | | | | X |
| | **PLO4** | | | | | | | | | | | | | | | | X |
| | **PLO5** | | | | | | | | | | | | | | | | X |
| | **PLO6** | | | | | | | | | | | | | | X | | X |
| | **PLO7** | | | X | | | | | | | | | | | | | X |
| | | | | | | | | | | | | | | | | | |
| **Affective** | **PLO8** | | | | | | | X | | | X | | | | | | |
| | **PLO9** | | | | | | | | | X | | | X | | | | |
| | **PLO10** | | | | | | | | | | | | | | | X | X |
| | **PLO11** | | | | | | | | | | | | | | | | X |
| | | | | | | | | | | | | | | | | | |
| **Psycho-motor** | **PLO12** | | | | | | | | | | | | | | | | X |
| | **PLO13** | | | X | | | | | | | | X | | X | | | |
| | **PLO14** | | | | | | | | | | | | | | | | X |

**Resources**

The department has 28 members of teaching staff consisting of Professors, Associate Professors, Assistant Professors and Lecturers, who cater the needs of nearly 500 undergraduates, post-graduates and research students. A list of members of academic staff (at time of start of physical classes) is given below:

| Name | Specialization |
|---|---|
| **Professor Emeritus** | |
| Dr Arun Kumar Basak<br>*MSc(Raj), PhD(Birmingham), FInstP (London), CPhys* | Nuclear Physics, Atomic Physics |
| **Professors** | |
| Dr M Mozibur Rahman<br>*MSc(Raj), PhD(Dnipropetrovsk, Ukraine)* | Condensed Matter Physics (Expt.), Electronics, Metallurgy |
| Dr M Khalilur Rahman Khan<br>*MSc(Raj), PhD(Yamanashi, Japan)* | Cond. Matter Physics, Mat. Science (Expt.), Thin films, Superconductivity |
| Dr Irine Banu Lucy<br>*MSc(Raj), PhD(Brunel,UK)* | Condensed Matter Physics (Expt.) |
| Dr M Rafiqul Ahsan<br>*MSc(Raj, PhD(Raj)* | Cond. Matter Physics, Glass and Glass Ceramics, X-ray Crystallography |
| Dr F Nazrul Islam<br>*MSc(Raj), PhD(Raj)* | Cond. Matter Physics (Comp. simulation), Superconductivity, Nuclear Physics |
| Dr Saleh Hasan Naqib<br>*MSc(Raj), PhD(Cambridge)* | Superconductivity, Computational Condensed Matter Physics |
| Dr Abul Kalam Fazlul Haque<br>*MSc(Raj), PhD(Raj)* | Atomic and Molecular Physics, Nuclear Physics |
| Dr Abdullah Shams Bin Tariq<br>*MSc(Raj), PhD(Southampton)* | Particle Physics, Nuclear Physics |
| Dr Raihana Shams Islam<br>*M Phil(Cambridge), PhD(Cambridge)* | Superconductivity |
| Dr Fahmida Parvin<br>*MSc(Raj), PhD(Raj)* | Superconductivity, Computational Condensed Matter Physics |
| Dr M A Razzaque Sarker<br>*MSc(Raj),PhD(Yamanashi, Japan)* | Materials Science |
| Dr M Atiqur Rahman Patoary<br>*MSc(Raj), MSc(Ryukyus, Japan), PhD(Ryukyus, Japan)* | Nuclear Physics, Condensed Matter Physics (Theory) |

| | |
|---|---|
| **Professors(cont.)** | |
| Dr M Samiul Islam Sarker<br>*MSc(Raj), MSc(Adelaide, Australia), PhD(Tohoku, Japan)* | Nuclear Physics, Fibre-laser, Materials Science |
| Dr M Monirul Haque<br>*MSc(Raj),<br>PhD (Ritsumeikan, Japan)* | Medical Physics, Radiation and Health Physics |
| **Associate Professors** | |
| Dr M Rezaur Rahim<br>*MSc(Raj), PhD(Brunel,UK)* | Condensed Matter Physics (Expt.), Electronics |
| Dr M Saiful Islam<br>*MSc(Raj), PhD(Kyushu, Japan)* | Condensed Matter Physics (Theory and Expt.) |
| Dr Monira Jannatul Kobra<br>*MSc(Raj), PGD(ICTP, Italy),<br>PhD (Kyushu, Japan)* | Nuclear Physics |
| Dr M Ismail Hossain<br>*MSc(Raj), PhD(Saitama, Japan)* | Theoretical Atomic Physics |
| **Assistant Professors** | |
| Mr M Masum Billah<br>*MSc( Raj)* | Atomic and Molecular Physics, Nuclear Physics |
| Mr K M Mahmudul Hasan*<br>*MSc(Raj)* | Atomic and Molecular Physics, Nuclear Physics, |
| Mr M Leaket Ali<br>*MSc(Raj)* | Condensed Matter Physics |
| Dr M Alamgir Hossain<br>*MSc(Raj), PhD(Kyushu, Japan)* | Medical Physics |
| **Lecturers** | |
| Mr M Saifur Rahman<br>*MSc( Raj)* | Materials Science |
| Mr Riju Khandaker*<br>*MSc(Raj)* | Materials Science |
| Mr M Abdur Rashid*<br>*MSc(Raj)* | Materials Science |

** on Study Leave*

**Seminar Library**

The department may boast to have the biggest seminar library in the university with text and reference books. It also has some international journals, such as Physical Review, Physical Review Letters, Reviews of Modern Physics, which the department had been receiving as a joint contribution from the Abdus Salam International Centre for Theoretical Physics, Italy and American Physical Society. The library is constantly being updated with reference books and other reading materials. There is a rental library for students. Groups of students are able to borrow important textbooks through this service. Besides, a significant number of e-books and a very large number of e-journals are accessible online through the University Central Library.

**Computer Facilities**

The department has established a computer lab with internet facilities for students and teachers. Recently a Computer Lab based on an N-Computing (thin client) system has been established for students. Research students also have access to computers and internet in their research labs.

**Workshop**

A mechanical workshop was established in the department from the beginning of the department. The students can get training in the workshop on some instrumentation, as a part of their laboratory experiments. It also serves as a centre for minor repairs of laboratory equipment.

From the inception, the department of physics is known to be one of the most disciplined departments in the university, both in administration and in academic activities. Academic members are very particular in completing their courses, conducting examinations and publishing results according to the calendar published by the department at the beginning of every academic year. It is the tradition of the department to publish the examination results within the quickest possible time and thus it has become possible for the department to avoid the academic backlog in the university. The department constantly reviews its curriculum and takes steps to enhance facilities to match the present day need and thus prepares the students to face the challenges of the future.

**Co- and Extra- Curricular Activities**

**Physics Club**

Physics Club was established in 2011. Since then Physics Club has been providing the students and the faculty members with an open platform to discuss various topics in physics outside the class hour. It has also been regularly organising the Regional Round of the Bangladesh Physics Olympiad for the last few years. This club is open to all the students of Department of Physics, University of Rajshahi (RU).

**English Club**

English Club has been functioning since 2010. This club was established with the aim to develop speaking, reading, and writing skills of the students of this department. Only the members of the English Club are permitted to participate in various club activities.

**Study tour**

The department arranges study tour within Bangladesh (and/or abroad) for the M.Sc. Students each year. The tour is partly financed by the University.

**Picnic**

Every year the Physics Society organize annual picnic in cooperation with the academic and non-academic staff.

**Physics Society**

There is a society in the department called Physics Society. All students and teachers of the department are the members of the Society. This society regularly organizes farewell for the outgoing M.Sc. students and welcome reception for the fresher's admitted in the B.Sc. course. Besides, the Society arranges various cultural and sports related activities, e.g. indoor games, management of department sports' teams etc.

**Physics Alumni Association**

Department of Physics has an active Alumni Association. The objectives of this association are to build active communication network among all the present and ex-students of the Department of Physics through various programs and to contribute in the academic development of the department and the economic development of the country.

**Sports and Culture**

Students of Department of Physics participate in all inter-department games organized by the RU. The department has achieved notable success in sports by winning matches in cricket, football, badminton, table tennis etc. The students of the department have also participated in various cultural events with distinction.

UNIVERSITY OF RAJSHAHI

FACULTY OF SCIENCE

DEPARTMENT OF PHYSICS

Curriculum for M.Sc.in Physics

Session: **2019 - 20** Examination: **2021**

The M.Sc. Examination in Physics is divided into two groups:

- General Group
- Thesis Group

All students will have to take six theoretical courses including at least one course from PH501 and PH502 (subject to the approval of the Chairman of the Department). Additionally, the students of the General group will have to take the Practical course, while the students of Thesis group will have to take a Thesis on a research topic approved by the Department.

**A full-unit** course shall carry 100 marks and a **half-unit** course 50 marks out of which 80% is for the Final Exam, 15% is for Class Test and 5% is for Class Attendance.

The M.Sc. curriculum in Physics shall consist of:

| | | | |
|---|---|---|---|
| i) Theory courses (6 units) | 100 ×6 | = 600 marks | = 24 Credits |
| ii) Practical / Thesis (2units) | | = 200 marks | = 08 Credits |
| iii) General Viva-voce (1 unit) | | = 100 marks | = 04 Credits |
| Total (10 course units) | | = 900 marks | = 36 Credits |

Mode of Examination: Written test 80% at the end of the year and two tutorial written examinations will be held for 15% within the classes. The remaining 5% will be from class attendance. The final examination script is examined by two examiners and the average taken. In case of a discrepancy of 20% or more the script is examined by a third examiner and average of the closest two taken.

**Award of Degree**

The degree of M.Sc. shall be awarded on the basis of the Grade Point Average (GPA) obtained by a candidate in his/her M.Sc. examination. In order to qualify for the degree, a candidate must obtain (within three academic years from the date of first admission):

i) A minimum GPA of 2.50,

ii)A minimum Grade point (GP) of 2.00 in Practical/Thesis, and

iii) A minimum total Credit points (TCP) of 32.

**Total GPA Round off**

Total GPA shall be round off up to 2 (two) digits after decimal. For instance GPA=2.114 shall be round off as GPA=2.11 and GPA =2.115 shall be round off as GPA =2.12.

**Result Improvement**

A student obtaining GPA less than 3.00 shall be allowed to improve his/her courses up to 12 credits including 'F' Grade only once within 3 academic years. Here, it is noted that GP of courses, which he/she wants to improve should be less than 3.00.

**Gradation of the Results**:

| Numerical Grade (NG) | Letter Grade (LG) | GP (Grade Point) |
|---|---|---|
| 80% or above | A+ (A plus) | 4.00 |
| 75% or above | A (A regular) | 3.75 |
| 70% or above | A- (A minus) | 3.50 |
| 65% or above | B+ (B plus) | 3.25 |
| 60% or above | B (B regular) | 3.00 |
| 55% or above | B- (B minus) | 2.75 |
| 50% or above | C+ (C plus) | 2.50 |
| 45% or above | C (C regular) | 2.25 |
| 40% or above | D | 2.00 |
| Less than 40% | F | 0.00 |
| Incomplete | I | 0.00 |

**Eligibility for the M.Sc. examination**

Class attendance (both in theory and practical classes):

Students with ≥ 75% class attendance are eligible to sit for the final examination.

Below 75% are considered as Non-collegiate who will have to pay Tk 500 as fine to sit for the final examination.

Below 60% are considered as discollegiate who will not be allowed to sit for the final examination.

## The Detailed Distribution of Courses

| Course no. | Title Marks | Exam | duration | Credit Point |
|---|---|---|---|---|
| **PH501** | Advanced Nuclear Physics | 100 | 4 Hours | 04 |
| **PH502** | Advanced Solid State Physics | 100 | 4 Hours | 04 |
| **PH503** | Electronic Communications | 100 | 4 Hours | 04 |
| **PH504** | Advanced Medical Physics | 100 | 4 Hours | 04 |
| **PH505** | Materials Science | 100 | 4 Hours | 04 |
| **PH506** | Superconductivity | 100 | 4 Hours | 04 |
| **PH507** | Physics of Environment | 100 | 4 Hours | 04 |
| **PH508** | Crystallography and Spectroscopy | 100 | 4 Hours | 04 |
| **PH509** | Particle Physics and Cosmology | 100 | 4 Hours | 04 |
| **PH510** | Advanced Reactor Physics | 100 | 4 Hours | 04 |
| **PH511** | Biomedical Instrumentation and Imaging System | 100 | 4 Hours | 04 |
| **PH512** | Quantum Field Theory | 100 | 4 Hours | 04 |
| **PH513** | Optical Fiber Physics | 100 | 4 Hours | 04 |
| **PH521** | General Viva-voce | 100 | | 04 |
| **PH522** | Study Tour - Industrial Scientific exposure | | | (Non Credit)* |
| **PH523** | Practical (Compulsory for General Group) | 200 | | 08 |
| | *a) Continuous Assessment* | *60* | | |
| | *b) Annual Examination (28×4)* | *112* | *(Four days)* | |
| | *c) Defense on Experiments* | *28* | *(One day)* | |
| - OR - | Thesis (Compulsory for Thesis Group) | 200 | | 08 |
| | *a) Thesis evaluation* | *150* | | |
| | *b) Defense on Thesis* | *50* | | |

***N.B.** Submission of Report on industrial trip is compulsory for all participants. Students unable to go outside Rajshahi may visit local industries to have their experience. They also have to submit report on their visit.*

## PH501 ADVANCED NUCLEAR PHYSICS (~*75 lectures*)

*Full Marks:* ***100*** (*Examination 80, Tutorial/Terminal 15, and Attendance 5*)

(*5 questions to be answered*) *Examination duration:* ***4*** *hours*

**Prerequisite Knowledge:** PH301, PH303, PH306, PH401, PH403

1. **Direct Nuclear Reactions:** Reaction kinematics: non-relativistic and relativistic; Theory of transfer reactions; Selection rules in a transfer reaction; Theory of inelastic scattering; Importance of direct reactions.

   **Intended learning outcomes:** Enables successful students to:
   - **(i)** Identify direct reactions.
   - **(ii)** Obtain expressions for transition amplitudes for transfer and inelastic processes.
   - **(iii)** Verify shell model predictions from direct reaction observables.

2. **Nuclear Shell Models:** Single particle shell model; Isospin formalism; Two-particle system; Shell model Hamiltonian; Perturbation theory and configuration mixing, Allowed states; Anti-symmetric wave functions, More than two particles in one orbit; Coefficient of fractional parentage; Spectroscopic factors; Spectroscopic factors for mixed configurations; Sum rules for single particle transfer reactions.

   **Intended learning outcomes:** Enables successful students to:
   - **(i)** Understand advanced models to identify basic nuclear structure and outline their theoretical descriptions.
   - **(ii)** Calculate isospin and third component of isospin for nuclei.
   - **(iii)** Represent a wave function diagrammatically or pictorially.
   - **(iv)** Calculate coefficient of fractional percentage and spectroscopic factor for transfer reactions.

3. **Collective Models:** Shortcomings of the shell model and the nuclear collective models; Nuclear rotational motion; Rotational energy spectra and nuclear wave functions for even and odd A nuclei; Nuclear deformation; Collective oscillation; Quadrupole deformation; Electromagnetic properties.

   **Intended learning outcomes:** Enables successful students to:
   - **(i)** Describe various models of collective nuclear excitation.
   - **(ii)** Compare rotational and vibrational energy spectra.

4. **Electromagnetic Interactions with Nuclei:** Infinitesimal rotations in vector fields; Intrinsic angular momentum of vector fields; Total angular momentum of vector fields and vector spherical harmonics; Multipole fields; Sources of multipole fields; Transition probability of a multipolar radiation; Multipole moments; Selection rules in a gamma transition; Angular distribution of a gamma transition; Angular correlations; Relative strengths

of different multipolar radiations in a transition between two low-lying states of an excited nucleus.

**Intended learning outcomes:** Enables successful students to:

- **(i)** Describe the significance of nuclear charge and current distributions in regard to nuclear structure and decays.
- **(ii)** Discuss sources of multipole fields and selection rules in gamma transition.
- **(iii)** Calculate relative transition probabilities of different multipolar radiations.

5. **Nuclear Astrophysics:** Primordial nucleosynthesis; pp chain and CNO cycle; Stellar synthesis of light elements; Synthesis of heavy elements; Stellar evolution and different stages of burning; White dwarfs and neutron stars, Supernova explosions.

**Intended learning outcomes:** Enables successful students to:

- **(i)** Recognize the importance of stars as the factory of nuclides, including red super-giants and supernova.
- **(ii)** Describe the importance of the Hoyle resonance and similar resonance states in explaining the creation and survival of carbon and oxygen.

6. **Rare or Exceptional Nuclei:** Driplines and nuclei far from stability; Exceptional light nuclei: Halo nuclei; Borromean nuclei; Transuranic nuclei.

**Intended learning outcomes:** Enables successful students to:

- **(i)** Describe key properties of rare nuclei and analyze issues related to their synthesis and stability

Books recommended

Text Books


| | |
|---|---|
| Satchler, GR | Direct Nuclear Reactions |
| Brussaard, PJ and Glaudemans, PW | Shell Model Applications in Nuclear Spectroscopy |
| Roy, RR and Nigam, BP | Nuclear Physics |
| Blatt, JM and Weiskopff, VF | Theoretical Nuclear Physics |
| Bertulani, DA | Nuclear Physics in a Nutshell |


Reference Books


| | |
|---|---|
| *Glendenning, NK* | Direct Nuclear Reactions |
| *Thompson, IJ and Nunes, FM* | Nuclear Reactions for Astrophysics |
| *Lawson, RD* | Theory of the Nuclear Shell Model |
| *Pal, MK* | Theory of Nuclear Structure |
| *Sen Gupta, HM* | Nucleo Padarthavidya (in Bangla) |
| *Greiner, W and Maruhn, JA* | Nuclear Models |
| *Bertulani, DA and Danielewicz, P* | Nuclear Reactions |
| *Iliadis, C* | Nuclear Physics of Stars |
| *Krane, K* | Nuclear Physics |
| *Ghoshal, SN* | Nuclear Physics |

## PH502 ADVANCED SOLID STATE PHYSICS (~ *75 lectures*)

*Full Marks:* ***100*** (*Examination 80, Tutorial/Terminal 15, and Attendance 5*)

(*5 questions to be answered*) *Examination duration:* ***4*** *hours*

**Prerequisite Knowledge:** PH304, PH404

1. **Periodic Structure:** Symmetry operations; Groups; Function spaces; Bravais lattice; Periodic functions; Bloch's theorem; Brillouin zones and crystal symmetry; Fermi surface construction; Experimental method: de-Hass-van Alphen oscillation.

   **Intended learning outcomes:** Enables successful students to:
   - **(i)** Locate an atom in a crystal with different symmetry.
   - **(ii)** Understand the origin of periodic potential.
   - **(iii)** Understand the use of Bloch function.
   - **(iv)** Calculate the zone boundary of Brillouin zones and draw them in reciprocal space.
   - **(v)** Show the impact of zone boundary on the solution of Schrodinger equation.
   - **(vi)** Construct the Fermi surface.

2. **Electron States and Energy Bands in Solids:** The nearly free electron model; Tight binding method; Cellular method; Muffin-Tin potentials; Orthogonalized plane wave method; Pseudopotentials; Wannier function and its uses.

   **Intended learning outcomes:** Enables successful students to:
   - **(i)** Know the origin of energy bands
   - **(ii)** Differentiate between energy bands obtained from the free electron model and nearly free electron model.
   - **(iii)** Discuss the origin of approximations used in various methods.
   - **(iv)** Calculate the free electron energy bands using different models.
   - **(v)** Show the distinct nature of energy bands due to use of different approximation methods.
   - **(vi)** Relate the Wannier function with Hartree-Fock equation.
   - **(vii)** Demonstrate the orthogonality properties of Wannier function.

3. **Energy Band beyond the Independent Electron Approximation:** Hartree equation; Hartree-Fock equation: Hartree-Fock theory of free electrons; Density functional theory for band structure calculations; Screening; Dielectric function; Thomas-Fermi theory of screening; Lindhard theory of screening.

**Intended learning outcomes:** Enables successful students to:

**(i)** Differentiate between Hartree and Hartree-Fock (H-F) equations.
**(ii)** Solve the equations for free electron case.
**(iii)** Demonstrate the utility of the presence of the exchange term in the H-F equations.
**(iv)** Demonstrate the effect of exchange term on free electron graphically.
**(v)** Calculate the effect of screening and demonstrate how the effect changes the potential with the consideration of various models.

4. **Theory of Electronic Processes in Semiconductors:** Carrier effective mass and band structure; Effects of temperature and pressure on band gap; Carrier scattering phenomena; Semiconductor statistics: Energy distribution function; Density of states; Density of carriers in intrinsic and extrinsic semiconductors; Compensation of carriers; Charge neutrality condition; Consequences of heavy doping; Conduction processes in intrinsic and extrinsic semiconductors.

**Intended learning outcomes:** Enables successful students to:

**(i)** Link the electronic band structure to carrier effective mass.
**(ii)** Demonstrate the variation of effective mass, group velocity, momentum with wave vector.
**(iii)** Explain the temperature and pressure induced changes in the bandgap.
**(iv)** Obtain expressions for the energy density of states for carriers in the conduction and valence bands.
**(v)** Calculate carrier density for intrinsic and extrinsic semiconductors.
**(vi)** Calculate the shift in Fermi energy with doping.
**(vii)** Understand the changes in the electronic structure due to heavy doping.
**(viii)** Calculate the total current density for intrinsic and extrinsic semiconductors.

5. **Theory of Optical Processes:** Reflectivity at an interface; Absorption of radiation; Kramers-Kronig relations; Determination of optical constants; Free carrier absorption: Experimental results for metals and semiconductors; Interband transition: Fundamental absorption near band gap; Theory of vertical and non-vertical transition; Optical processes in amorphous materials; Measurement of absorption and luminescence spectra.

**Intended learning outcomes:** Enables successful students to:

**(i)** Explain various optical transitions in semiconductors and metals.
**(ii)** Obtain the Kramers-Kroing (KK) relations.
**(iii)** Apply the KK relations to obtain all the frequency dependent optical constants.

**(iv)** Understand optical processes in amorphous semiconductors.
**(v)** Describe experimental arrangements for obtaining optical absorption and photoluminescence spectra.

6. **Junction Theory:** Mathematical derivation of contact potential and space charge in p-n junction; Built-in voltage; Physical mechanisms of breakdown in p-n junction; Schottky barrier and Ohmic contacts; Metal-Semiconductor junction; Semiconductor heterojunction; I-V and C-V relationships.

**Intended learning outcomes:** Enables successful students to:
**(i)** Calculate contact potential from doping.
**(ii)** Draw the electric field and potential profile across the junction.
**(iii)** Obtain the expression for junction capacitance and understand its effect in practical uses.
**(iv)** Obtain the diode equation that can be related to rectification process and other diode applications.
**(v)** Draw the band-bending features of homo- and hetero-junctions.
**(vi)** Explain the function of Schottky barrier and their applications.
**(vii)** Understand various junction breakdown mechanisms.

Books Recommended

Text Books


| | |
|---|---|
| *Ashcroft, NW and Mermin, ND* | Solid State Physics |
| *Bhattacharya, P* | Semiconductor Optoelectronic Devices |
| *Kittel, C* | Quantum Theory of Solids |
| *Clark, H* | Solid State Physics: an Introduction to Its Theory |
| *Fraser, DA* | The Physics of Semiconductor Devices |
| | Reference Books |
| *Ziman, JM* | Principles of the Theory of Solids |
| *McKelveym, JPM* | Solid State and Semiconductor Physics |
| *Mario, PT- edited* | Crystalline Semiconducting Materials and Devices |
| *Omar, A* | Solid State Physics |

## PH503 ELECTRONIC COMMUNICATIONS (*~75 lectures*)

*Full Marks:* ***100*** (*Examination 80, Tutorial/Terminal 15, and Attendance 5*)

(*5 questions to be answered*) *Examination duration:* ***4*** *hours*

**Prerequisite Knowledge:** PH305, PH402

1. **Communications Fundamentals:** Communications model; Frequency allocations; Types of signals; Analogue and Digital data transmissions; Transmission impairments; Noises: Types and measurements of noises.

   **Intended learning outcomes:** Enables successful students to:
   - **(i)** Describe the electrical and logical characteristics of analogue and digital data transmission and transmission impairments.
   - **(ii)** Know the meaning and origin of noise and its impact on signal.

2. **Modulation and Demodulation:** Principles; Modulations: Amplitude, Frequency, Phase, Pulse modulations; Demodulations: FM discrimination, Demodulation of PM waves.

   **Intended learning outcomes:** Enables successful students to:
   - **(i)** Get familiar with pulse-based communication, different pulse modulation schemes, applicability of these different design scenarios in telecommunications.

3. **Digital Communications**: Transmission modes: Asynchronous and Synchronous; Data transmission circuits; Digital codes; Matched filter; Digital carrier system; Differential Phase Shift Keying (DPSK); Baseband & Broadband communications: Channels, ISDN; Multiplexing: FDM, TDM and STDM.

   **Intended learning outcomes:** Enables successful students to:
   - **(i)** Comprehend the underlying technology of fiber-optic communication system.

4. **Transmission Media and Antennas:** Guided transmission media: Open-wire, Coaxial, Optical fibers; Wireless transmission media: Radio and Microwave; Antennas: VHF, UHF and Microwave antennas.

   **Intended learning outcomes:** Enables successful students to:
   - **(i)** Analyze components associated with digital and analog communication in guided and wireless communication systems.

5. **Optical and Satellite Communications:** Optical communication: Principles, Transmission and losses, Dispersion, Light sources and Photodetectors; Satellite communications: Orbits and inclinations, Types of satellites, Satellite construction, Satellite links.

   **Intended learning outcomes:** Enables successful students to:

**(i)** Explain the various ways in which satellites systems are classified, including the standard communication satellite system.

6. **Modern Communication Systems:** Television Fundamentals: Beam scanning, Blanking and sync pulses; TV system: Transmitter and Receiver; Mobile cellular telephony: Concept of cellular technology, Operations of cellular systems; Cellular systems: GSM and CDMA; Radar: Types and uses, Radar Range, Pulse and CW Radars; Navigation: Global positioning system (GPS), Air traffic control: ILS and GCA.

   **Intended learning outcomes:** Enables successful students to:
   
   **(i)** Identify the technology features which enable cell phone communication.
   
   **(ii)** Describe the basic function, principles of operation, and interrelationships of the basic units of a radar system.
   
   **(iii)** Comprehend the concept of modern navigation systems, like the global positioning system (GPS), ILS and GCA in air traffic controls, and their uses.
   
   **(iv)** Get conceptual and implementation aspects of computer networking applications.
   
   **(v)** Find problem solving solutions using the information gained through the component manuals and manufacturer web sites.

7. **Computer Networking and Internet:** Computer networking: Categories, Types and Topologies; Internetworking; The Internet; World Wide Web (WWW).

   **Intended learning outcomes:** Enables successful students to:
   
   **(i)** Calculate contact potential from doping.

Books Recommended

Text Books



| | |
|---|---|
| *Frenzel, LE* | Communication Electronics: Principles & Applications |
| *Roddy, D and Coolen, J* | Electronic Communications |
| *Roden, SR* | Digital and Data Communications |
| *Singh, A* | Principles of Communication Engineering |
| *Martin, J* | Communication Satellite System |
| *Chellis, J, Perkins, C and Tanenbaum, AS* | Computer Networks |



Reference Books



| | |
|---|---|
| *Stallings, W* | Data and Computer Communications |
| *Streb, M* | MCSE: Networking Essentials |
| *Pfaffenberger, B* | Mastering Internet World Wide Web |

## PH504 ADVANCED MEDICAL PHYSICS (*~75 lectures*)

*Full Marks:* ***100*** (*Examination 80, Tutorial/Terminal 15, and Attendance 5*)

(*5 questions to be answered*) *Examination duration:* ***4*** *hours*

**Prerequisite Knowledge:** PH405

1. **Medical Internal Radiation Dosimetry (MIRD):** Internal radiation dosimetry; Radiation dose: quantities and units; Calculation of radiation dose: absorbed fraction method; Cumulated activity $\bar{A}$; Equilibrium absorbed dose constant $\Delta$; Absorbed fraction $\phi$ and the dose reciprocity theorem; Mean dose per cumulated activity.

   **Intended learning outcomes:** Enables successful students to:
   - **(i)** Calculate radiation dose absorbed in patient at various biological conditions.

2. **Cancer Biology and Treatment:** What is cancer; Mutation of cells; Genes involved in cancer development; Tumor formation; Risk factors; Metastasis; Overview of methods of treatment; Radiation therapy- Teletherapy, Brachytherapy, Systematic radiation therapy; How radiation cures cancer; Fascination of radiation therapy.

   **Intended learning outcomes:** Enables successful students to:
   - **(i)** Understand the formation, development and cure of cancer and the basic techniques of cancer treatment.

3. **Clinical Radiation Generators:** Kilo-voltage units; Linac: X-ray and electron beam, Target and flattening filter, Beam collimation and monitoring, Gantry; Multi leaf collimator (MLC); Co-60 unit: Source housing; Beam collimation and penumbra.

   **Intended learning outcomes:** Enables successful students to:
   - **(i)** Design teletherapy beam (x- and $\gamma$-ray) line, develop idea regarding beam collimation and intensity modulation.

4. **Dose Distribution and Scatter Analysis:** Phantoms; Depth dose distribution; Percentage depth dose; Tissue-air ratio; Backscatter factor; Scatter-air ratio; Dose calculation parameters; Collimator scatter factor; Phantom scatter factor; Tissue-Phantom and Tissue-Maximum ratios; Properties of TMR; Scatter-Phantom and Scatter-Maximum ratios; Practical applications.

   **Intended learning outcomes:** Enables successful students to:
   - **(i)** Calculate dose in clinical situation.

5. **Isodose Distribution:** Isodose chart; Measurement of isodose curves; Parameters of isodose curves; Wedge filters; Combination of radiation fields; Isocentric techniques; Wedge field technique; Tumor dose specification.

**Intended learning outcomes:** Enables successful students to:

**(i)** Characterize the dose distribution for a radiation beam in a 3D-volume.

6. **Patient Data, Corrections and Setup:** Acquisition of patient data; Treatment simulation; Treatment verification; Corrections for contour irregularities; Corrections for tissue inhomogeneities; Tissue compensation; Patient positioning.

**Intended learning outcomes:** Enables successful students to:

**(i)** Acquire sufficient knowledge for treatment planning and simulation.

7. **Modern Radiation Therapy:** Introduction to 3-D conformal radiation therapy (3-D CRT); Intensity-modulated radiation therapy (IMRT); Image-Guided radiation therapy (IGRT), Stereotactic radiotherapy; Proton beam therapy; Volumetric modulated art therapy.

**Intended learning outcomes:** Enables successful students to:

**(i)** Realize the advantages of 3-D teletherapy over 2-D technique.
**(ii)** Demonstrate the differences between 3-D CRT, IMRT, IGRT and SRT.
**(iii)** Explain the advantages of proton beam therapy.

8. **Brachytherapy:** Radioactive sources; Calibration of brachytherapy sources; Calculation of dose distribution; Systems of implant dosimetry; Computer dosimetry; Implantation techniques; Remote after loading units; High dose rate brachytherapy.

**Intended learning outcomes:** Enables successful students to:

**(i)** Name brachytherapy sources and their characteristics.
**(ii)** Understand source implant techniques and dosimetry.

Books Recommended

Text Books

*Khan, FM & Gibbons, JP* — The Physics of Radiation Therapy (5th Ed)
*Podgorsak, EB* — Radiation Oncology Physics - A Handbook for Teachers and Students

Reference Books

*Waston, EE* — MIRD primer
*Mayles, P, Nahum, A and Rosenwald, JC* — Handbook of Radiotherapy Physics, Theory and Practice*Levitt, SH, Purdy, JA and*
*Perez, CA* — Technical Basis of Radiation Therapy
*Godden, TJ* — Physical Aspects of Brachytherapy
*Johns, HE and Cunningham, JR* — The Physics of Radiology (4th Edition)
*Sorenson, JA and Phelps, ME* — Physics In Nuclear Medicine (2nd Edition)
*Dyson, NA* — An Introduction to Nuclear Physics with Applications in Medicine and Biology

## PH505 MATERIALS SCIENCE (*~75 lectures*)

*Full Marks:* ***100*** (*Examination 80, Tutorial/Terminal 15, and Attendance 5*)

(*5 questions to be answered*) *Examination duration:* ***4*** *hours*

**Prerequisite Knowledge:** PH304, PH404

1. **Microstructure Examination (brief review):** Experimental methods for the physical examination of materials; Metallurgical microscope; Microscopy of surfaces; TEM (Transmission Electron Microscopy); SEM (Scanning Electron Microscopy); STM (Scanning Tunneling Microscopy) and AFM (Atomic Force Microscopy); Thermal analysis – DTA, TGA, DSC (Differential Thermal Analysis, Thermogravimetric Analysis, Differential Scanning Calorimeter).

   **Intended learning outcomes:** Enables successful students to:
   - **(i)** Demonstrate the principle of photography.
   - **(ii)** Know the difference between SEM and TEM sample preparation.
   - **(iii)** Predict the micrographs of SEM and TEM.
   - **(iv)** Know how to do qualitative analysis of the elements in a material.
   - **(v)** Explain the process of STM and AFM.
   - **(vi)** Predict the STM and AFM data for practical purposes.
   - **(vii)** Differentiate among DTA, TGA and DSC and predict the meaning of the traces obtained from these experiments.
   - **(viii)** Calculate thermodynamic variable and determine glass transitions, crystallographic and metallic temperature.

2. **Solidification:** Homogeneous and heterogeneous nucleations; Theory of liquid-solid phase transformation; Crystal growth technique; Sintering of materials; Glassy phase; Experimental facts regarding glass transition; V-T diagram; Non-equilibrium and thermodynamic views of glass transition; Free volume theory.

   **Intended learning outcomes:** Enables successful students to:
   - **(i)** Differentiate between homogeneous and heterogeneous nucleations.
   - **(ii)** Differentiate between solid and liquid phase.
   - **(iii)** Use V-T diagram to explain glass and crystal transition.
   - **(iv)** Know how the crystals grow.
   - **(v)** Know how the difference in cooling process changes the structure of materials.
   - **(vi)** Know the necessity of sintering as well as controlled heat treatment.

3. **Equilibrium Phase Diagrams:** Solid solution of two-component system; Simple eutectic diagram; Hume-Rothery electron compounds; Order-disorder phase transformation; Long-range and short-range order theories.

   **Intended learning outcomes:** Enables successful students to:
   - **(i)** Know what solid solution means.

**(ii)** Demonstrate the homogeneous solid mix needed to form a joint super lattice.
**(iii)** Describe the properties of Hume-Rothery compounds.
**(iv)** Explain order-disorder phase transformation.

4. **Diffusion:** Fick's laws for isothermal diffusion; Atomic mechanisms of diffusion; Hydrogen diffusion; Thermodynamics of diffusion of Pd-H system; Effect of lattice defects.

**Intended learning outcomes:** Enables successful students to:

**(i)** Derive Flick's first and second law of diffusion and know the physical significance of these equations.
**(ii)** Demonstrate the mechanism of diffusion by solving Flick's equations.
**(iii)** Demonstrate the pressure and temperature effect on diffusion.

5. **Engineering Alloys:** Ferrous and non-ferrous alloys; Production of steel; The iron-carbon phase diagram; The structure and classification of plain carbon steel; Heat treatment of steel; Alloy, Steel, Stainless steel; Cast-iron and malleable iron; Tool steels.

**Intended learning outcomes:** Enables successful students to:

**(i)** Differentiate between ferrous and non-ferrous alloys.
**(ii)** Know the purification process of ferrous ores.
**(iii)** Know how the binary or ternary phase diagrams help to calculate the amounts of components and particular temperature needed to prepare a specific phase of a material.
**(iv)** Know the necessity of heat treatment of steel.
**(v)** Calculate the amount of components needed to prepare alloy, steel and stainless steel.
**(vi)** Know the distinctive characteristics of different steels.

6. **Optoelectronic Materials and Devices:** Optical materials for LED, LASER and Photo detectors and their preparation and characterization; Physical processes in these materials.

**Intended learning outcomes:** Enables successful students to:

**(i)** Know the preparation and characterization process for materials needed to LED, LASER and photo-detector.
**(ii)** Know the necessity of optoelectronic materials.

7. **Composite Materials:** Fibers for reinforced plastic; Composite materials; Formation of composites; Open-mold and closed-mold process of preparation; Metal matrix and ceramic-matrix composites; Elastic properties of composites; Strength and toughness of fiber reinforced composites.

**Intended learning outcomes:** Enables successful students to:

**(i)** Know the necessity of reinforcement in plastics and other materials.

**(ii)** Predict the cause of change of physical, chemical and electrical properties of composite materials.
**(iii)** Demonstrate the preparation techniques for composite materials.
**(iv)** Explain the cause of formation of various matrix in composite materials.
**(v)** Know the measurement process of elastic properties, strength and toughness of ordinary and fiber reinforced composites.

8. **Corrosion:** Definition, Electrochemical considerations; Electrode potentials and EMF series; Nernst equations; Polarization; Evan's diagram; Forms of corrosion; Corrosion rate; Mechanism of oxidation; Corrosion prevention methods; Corrosion testing.

**Intended learning outcomes:** Enables successful students to:

**(i)** Know the meaning of corrosion in material science.
**(ii)** Calculate the rate of corrosion.
**(iii)** Understand the mechanisms for prevention of corrosion, e.g., anodic/cathodic process, which is used for protection of gas and oil pipeline, should be known to the students.
**(iv)** Prevent and test corrosion in physical systems.

Books Recommended

Text Books

| | |
|---|---|
| *Smith, NF* | Principles of Material Science and Engineering |
| *Heyer, RH* | Engineering Physical Metallurgy |
| *Compbell, JS* | Principles of Manufacturing Materials & Processes |
| *CallisterJr, WD* | Mater. Science and Engineering- an Introduction |
| *Pascoe, KJ* | Intro. to the Properties of Engineering Materials |
| *Fontana, Mars G* | Corrosion Engineering |
| *Askelend, Donald R* | The Science and Engineering of Materials |

Reference Books

| | |
|---|---|
| *Hench, LL and Gould, RW* | Characterization of Ceramics |
| *Verron, J* | Introduction of Engineering Materials |
| *McMillan, PW* | Glass-Ceramics |
| *Haasen, P* | Physical Metallurgy |
| *Uhlig, HH, Revie, R* | Corrosion and Corrosion Control |
| *Bhattacharya, P* | Semiconductor Optoelectronic Devices |
| *Robert, S,Norman, HM and Mario, PT- edited* | Amorphous Solids and the Liquid State |
| *Norman, HM, Butcher, PN and Mario, PT-edited* | Crystalline Semiconducting Materials and Devices |
| *Owen, FD* | Topics in Metallurgical Thermodynamics |

## PH506 SUPERCONDUCTIVITY (~ *75 lectures*)

*Full Marks:* ***100*** (*Examination 80, Tutorial/Terminal 15, and Attendance 5*)

(*5 questions to be answered*) *Examination duration:* ***4*** *hours*

**Prerequisite Knowledge:** PH304, PH404

1. **Phenomenological Theory:** London model; Thermodynamics of the superconducting state; Ginzburg-Landau (G-L) theory of phase transition: G-L free energy; G-L equation and its applications; Penetration depth; Coherence length; Type-I and type-II superconductors; Critical fields.

   **Intended learning outcomes:** Enables successful students to:

   **(i)** Relate current with electromagnetic field and explain Meissner effect.
   **(ii)** Interpret microscopic properties of superconductivity.
   **(iii)** Demonstrate the second order phase transition using G-L theory.
   **(iv)** Calculate penetration depth, coherence length.
   **(v)** Differentiate between type-I and type-II superconductor in terms of critical field.

2. **Microscopic BCS Theory:** BCS Theory: Cooper pairs; BCS ground state; Excitations in the BCS model; Energy gap equation; Critical temperature; Isotope effect; Specific heat and coherence effects; BCS theory and G-L theory.

   **Intended learning outcomes:** Enables successful students to:

   **(i)** Demonstrate the variation of critical magnetic field with temperature.
   **(ii)** Explain the condition and process of formation of cooper pairs.
   **(iii)** Demonstrate the superconducting band gap at the Fermi level.
   **(iv)** Demonstrate the isotope effect on critical temperature.
   **(v)** Demonstrate the change in heat capacity near the critical temperature for some superconductors.
   **(vi)** Compare the BCS and G-L theory.

3. **Vortex Behaviour and Critical Current:** Mixed states; Interaction between vortices; The Abrikosov lattice; Flux dynamics: Flux flow; Flux glass; Flux creep; Magnetic hysteresis (M-H) loop; The Bean Model; Pinning of vortices.

   **Intended learning outcomes:** Enables successful students to:

   **(i)** Explain the formation of vortex in type-II superconductor.
   **(ii)** Demonstrate the formation of Abrikosov vortex of supercurrent in type-II superconductor.
   **(iii)** Explain the pinning of superconductor in space above a magnet.
   **(iv)** Explain the irreversible magnetization behavior of hard type-II superconductor.

4. **High-$T_c$ Superconductors:** Introduction to high-$T_c$ superconductors: Cuprate, Organic, Diboride; Fe-based superconductors; Metallic hydrides; Cuprates: Structure, Physical properties, Anisotropy, Electronic and Magnetic phase diagrams; Diborides: Structure and Physical properties; Applications of high-$T_c$ superconductors.

   **Intended learning outcomes:** Enables successful students to:

   **(i)** Have working knowledge on various high-$T_c$ superconductors.
   **(ii)** Have detailed knowledge on diboride superconductors.
   **(iii)** Acquire detailed knowledge on the structure, properties and phase diagrams of Cuprate systems and use this knowledge for application purposes.

5. **Heavy Fermion Systems:** Heavy fermion superconductors: Structure and physical properties of heavy fermion systems; Magnetically mediated pairing; Electronic phase diagram of heavy fermion superconductors.

   **Intended learning outcomes:** Enables successful students to:

   **(i)** Have detailed knowledge on heavy fermion superconductors.

6. **Josephson Effect:** The tunnel effect: Metal-Insulator-Superconductor (MIS); Superconductor-Insulator-Superconductor (SIS) junctions; dc and ac Josephson effects; Josephson effect and Ginzburg-Landau equation; Josephson Junction in a circuit: The Resistance-Capacitance-Shunted Junction (RCSJ) model; Pendulum analog; Weak links: The Aslamazov-Larkin scenario; SQUIDS and their applications.

   **Intended learning outcomes:** Enables successful students to:

   **(i)** Explain the functioning of Josephson junctions in detail.
   **(ii)** Acquire considerable knowledge on SQUID magnetometry.
   **(iii)** Calculate junction current under different conditions.

7. **Fluctuation Effects in Superconductors:** TDGL equation, Paraconductivity and Fluctuation diamagnetism, Fluctuation heat capacity.

   **Intended learning outcomes:** Enables successful students to:

   **(i)** Explain the basic features of order parameter fluctuations in superconductors.
   **(ii)** Calculate fluctuation effects in superconductors.

Books Recommended

Text Books

| | |
|---|---|
| *Waldram, JR* | Superconductivity of Metals and Cuprates |
| *Cyrot, M and Pavuna, D* | Intro. to Superconducting and High-$T_c$ Materials |

| | |
|---|---|
| *Poole,CP, Farach,HA, Creswick, RJ and Prozorov, R* | Superconductivity (2nd Edn.) |

Reference Books

| | |
|---|---|
| *Ketterson, JB and Song, SN* | Superconductivity |
| *Burns, G* | High Temperature Superconductivity: An Intro. |
| *Tinkham, M* | Introduction to Superconductivity |

## PH507 PHYSICS OF ENVIRONMENT (~*75 lectures*)

*Full Marks:* ***100*** (*Examination 80, Tutorial/Terminal 15, and Attendance 5*)

(*5 questions to be answered*) *Examination duration:* ***4*** *hours*

**Prerequisite Knowledge:** PH202, PH407

1. **The Essentials of Environmental Physics:** The environment; The impact of human upon environment and vice versa; Global temperature; Greenhouse effect; Climate models; The Energy Balance: A zero dimensional greenhouse model; Radiative forcing; Global warming; Greenhouse effect enhancement; Elements of weather and climate; Climate variations; Impact of Covid-19 pandemic upon environment.

   **Intended learning outcomes:** Enables successful students to:

   **(i)** Explain global warming.
   **(ii)** Demonstrate greenhouse effect.
   **(iii)** Analyze temperature, pressure, wind, humidity and precipitation to study weather and climate.
   **(iv)** Determine the effective earth emissivity of long wave radiation emitted to space.

2. **Mass and Energy Transfer:** Units of measurement of pollutants, Materials balance: Conservative and non-conservative systems of pollutants; Step function response.

   **Intended learning outcomes:** Enables successful students to:

   **(i)** Convert pollutant concentrations from weight to volume or vice versa and in mixed units.
   **(ii)** Quantitively track pollutants as they disperse in the environment.
   **(iii)** Model pollution over a city for conservative and non-conservative system.
   **(iv)** Calculate the concentration of pollutants when there is a sudden change of pollution entering the system.

3. **Air Pollution:** General consideration; Comparison of polluted and unpolluted air; Types of air pollutants- formation and sources; Effects of air pollutants on plants and human body; Acceptable limits of air pollutants; Control of air pollutants.

   **Intended learning outcomes:** Enables successful students to:

   **(i)** Understand the adverse and undesired effects of air pollutants.
   **(ii)** Learn about formation and sources of air pollutants.
   **(iii)** Realize the effects of air pollution on plants, animals, materials and human body.
   **(iv)** Demonstrate how to control air contaminants at source
   **(v)** Construct models to control air pollution.

4. **Water Pollution:** Water pollutants; Surface water quality: Rivers and streams, Effects of oxygen demanding waste in rivers, Ground water; Arsenic in drinking water: Source, Effects, Measurements, Prevention and control, Arsenic pollution in Bangladesh; Water purification process: in natural systems, physical process, chemical process, Bio-chemical process.

   **Intended learning outcomes:** Enables successful students to:

   **(i)** Learn about what causes water pollution and how to be environmentally aware.
   **(ii)** Assess the quality of surface water.
   **(iii)** Calculate the critical time and distance downstream at which the oxygen deficit is maximum.
   **(iv)** Know the causes, mechanism and effects of arsenic contamination in ground water.
   **(v)** Increase the awareness among the people in our country about arsenic pollution.

5. **Noise Pollution and Control:** Sources of Noise pollution; Noise intensity; Human perception and noise criteria; Effect of noise on people; Factors affecting threshold shift; Noise pollution control.

   **Intended learning outcome:** Enables successful students to:

   **(i)** Identify the sources of noise pollution.
   **(ii)** Grasp the various adverse impacts of noise pollution.
   **(iii)** Control the noise pollution.

6. **Mechanism of Pollutants Transport:** Diffusion and its application in practical purposes; Flow in rivers: One dimensional approach, the influence of turbulence, a continuous point emission; Ground water flow: Vertical flow in the unsaturated zone, Conservation of mass, Stationary flow, Vertical flow.

**Intended learning outcome:** Enables successful students to:

- **(i)** Calculate diffusion equation.
- **(ii)** Learn about Darcy's law and how water moves through an aquifer.
- **(iii)** Determine the hydraulic conductivity of aquifer material.
- **(iv)** Explain how quicksand is formed.

7. **Nuclear Waste and the Environment:** Power plant emissions: Radioactive gases and effluents; Radioactive waste, High-level waste; Impact of reactor accidents on the environment; Radioactive waste management; Decommissioning.

**Intended learning outcomes:** Enables successful students to:

- **(i)** Learn about the radioactive wastes and their effects on the environment.
- **(ii)** Know about the impact of reactor accidents on the environment.
- **(iii)** Acquire knowledge about nuclear decommissioning.

Books Recommended

Text Books

| | |
|---|---|
| *Masters, GM* | Introduction to Environment Engineering and Science |
| *Boecker, E and van Grondelle, R* | Environmental Physics |
| *Bhatia, HS* | A Textbook on Environmental Pollution and Control |
| *Peavy, HS and Rowe, DR* | Environmental Engineering |
| *Botkin, DB and Keller, EA* | Environmental Science: Earth as a Living Planet |

Reference Books

| | |
|---|---|
| *Revenscroft, P, Brammer, H and Richards, K* | Arsenic Pollution |
| *McGuffie, K and Henderson-Sellers, A* | A Climate Modelling Primer |
| *Manahan, SE* | Environmental Science & Technology |
| *Stoker, HS and Scott, SLS* | Environmental Chemistry |
| *Monteith, JL and Unsworth, M* | Principles of Environmental Physics |
| *Nevers, ND* | Air Pollution Control Engineering |

## PH508 CRYSTALLOGRAPHY & SPECTROSCOPY (~*75 lectures*)

*Full Marks:* ***100*** (*Examination 80, Tutorial/Terminal 15, and Attendance 5*)

(5 *questions to be answered*) *Examination duration:* ***4*** *hours*

**Prerequisite Knowledge:** PH304, PH404, PH406

***Symmetry Elements:*** *Point groups; uniaxial point groups; sub- and super- group of the point groups and space groups; their formation, general equivalent points, plane groups and their uses.*

**Intended learning outcomes:** Enables successful students to:

- **(i)** Demonstrate different symmetry elements.
- **(ii)** Differentiate between point group and space group.

1. **Fourier Transform:** Fourier series; Diffraction and Fourier transform; Convolution; Diffraction by a periodic distribution; Electron density equation.

**Intended learning outcomes:** Enables successful students to:

- **(i)** Know the applicability of Fourier transform.
- **(ii)** Use Fourier transform to derive diffraction equation in reciprocal space.
- **(iii)** Calculate the inequality to show the condition of diffraction.
- **(iv)** Distinguish between diffractions from periodic and a periodic distribution of atoms.
- **(v)** Explain the effect of convolution and deconvolution.
- **(vi)** Calculate electron density.

2. **Factors Affecting X-ray Intensities:** Diffraction from a rotating crystal; Absorption of X-rays; Absorption correction; Temperature factor; Lorentz and polarization factors.

**Intended learning outcomes:** Enables successful students to:

- **(i)** Know the mechanism of production of x-rays from atomic shell.
- **(ii)** Demonstrate the effect of crystal rotation on diffraction.
- **(iii)** Calculate the degree to which the electron density is spread out either for an atom or for a group of atoms.

3. **Determination of Crystal Structure:** Patterson function; Sharpened Patterson function; Harker line and section; Heavy atom method; Inequality relationship; Least Square Refinement; Fourier Refinement, Rietveld analysis.

**Intended learning outcomes:** Enables successful students to:

- **(i)** Calculate the coordinates of atoms and $hkl/uvw$ values of the planes.
- **(ii)** Predict the differences among the various relationships.
- **(iii)** Demonstrate the way of calculating $\mathcal{X}^2$ value.
- **(iv)** Know the process of refining the crystal structure.

4. **Infrared Spectroscopy:** Introduction to IR spectroscopy; Energy of diatomic molecule; Simple harmonic oscillator; Anharmonic oscillator; Molecular vibration; IR spectrum; Scanning of IR spectrum; Sampling Technique; Qualitative and quantitative interpretation of the IR spectra.

   **Intended learning outcomes:** Enables successful students to:

   **(i)** Know the range of IR radiation.
   **(ii)** Differentiate between harmonic and an-harmonic oscillator.
   **(iii)** Calculate the energy associated with various bonds.
   **(iv)** Vibrational mechanisms of various chemical bonds in a crystal and amorphous material.
   **(v)** Calculate the amounts of various components needed to prepare sample.
   **(vi)** Know the mechanism for preparation of sample and collection of IR spectrum.
   **(vii)** Predict the various chemical bonds and calculate their amounts.

5. **Nuclear Magnetic Resonance Spectroscopy:** Nuclei in a magnetic field; Larmor precession; Bloch equation; Free induction decay; Nuclear interaction: Chemical shifts; Dipolar interaction; Quadrupolar interaction; Relaxation process: Spin-Spin and Spin-lattice relaxation time; Magic angle spinning (MAS); A basic NMR Spectrometer; Interpretation of NMR spectra.

   **Intended learning outcomes:** Enables successful students to:

   **(i)** Know the effect of static magnetic field upon nuclei.
   **(ii)** Explain what NMR signal is and how it is detected.
   **(iii)** Demonstrate the effect of various interactions on static line shapes and how do the adverse effects can be removed.
   **(iv)** Know the effect of $T_1$ and $T_2$ times on the collection of NMR signal (FID).
   **(v)** Know the reason of plotting chemical shift in terms of ppm instead of frequency.
   **(vi)** Know the necessity of Fourier transform on NMR spectrum.
   **(vii)** Draw block diagram for NMR spectrometer.
   **(viii)** Assign various peaks with different chemical environments of the investigated nuclei.

6. **Neutron Scattering Theory and Application:** Basic properties of neutrons; Advantages of using neutron as an experimental probe; Basics of neutron diffraction; Neutron scattering – elastic and inelastic scattering; Small angle neutron scattering; Scattering by magnons and determination of magnetic order; Scattering by phonons – relevance to structure of materials and lattice dynamics.

**Intended learning outcomes:** Enables successful students to:

- **(i)** Demonstrate the mechanism of Neutron diffraction.
- **(ii)** Differentiate between elastic and inelastic scattering.
- **(iii)** Predict the structure of materials from neutron diffraction pattern.

Books Recommended

Text Books

| | |
|---|---|
| *Woolfson, MM* | X-ray Crystallography |
| *Azaroff, L* | Elementary X-ray Crystallography |
| *Buerger, MJ* | X-ray Crystallography |
| *Abragam, A* | Introduction to Nuclear Magnetic Resonance |
| *Bacon, GE* | Neutron Diffraction |

Reference Books

| | |
|---|---|
| *Carlson, TA* | Photoelectron and Auger Spectroscopy |
| *Harris, RK* | Nuclear Magnetic Resonance Spectroscopy |
| *Stout, GH and Jensen,LH* | Practical Structure Determination |
| *Stranghan, BP and Walker, S* | Spectroscopy |
| *Sharma, BK* | Spectroscopy |
| *Slichter, CP* | Nuclear Magnetic Resonance |
| *Akitt, JW* | NMR and Chemistry |
| *Willis, BTM and Carlile, CJ* | Experimental Neutron Scattering |
| *Squires, GL* | Introduction Theory of Thermal Neutron Scattering |

## PH509 PARTICLE PHYSICS AND COSMOLOGY (*~75 lectures*)

*Full Marks:* ***100*** (*Examination 80, Tutorial/Terminal 15, and Attendance 5*)

(*5 questions to be answered*) *Examination duration:* ***4*** *hours*

Prerequisite Knowledge: PH403, PH407

**1. a) Relativistic Kinematics:** Lorentz transformations and covariance; Four-vector notation.

**b) Groups and their Representations:** Introductory group theory; Lie groups and algebra; Irreducible representations; SU(2); SU(3); Young's tableaux.

**Intended learning outcomes:** Enables successful students to:

- **(i)** Describe the fundamentals of groups and their representations.
- **(ii)** Describe representations of symmetric group using young's tableaux.
- **(iii)** Calculate dimension of a representation.

2. **Feynman Diagram Techniques:** Fermi's golden rule for lifetimes and Cross-sections; Feynman rules for a toy scalar theory; Cross-sections and Lifetimes, Tree level and Higher order diagrams.

   **Intended learning outcomes:** Enables successful students to:

   **(i)** Draw relevant Feynman diagrams for a given process up to required order in a toy theory of three scalar particles (ABC theory).
   **(ii)** Calculate amplitudes for these diagrams.
   **(iii)** Use Fermi's golden rule to obtain cross sections and decay rates from amplitudes.
   **(iv)** Demonstrate the appearance of divergences in diagrams with loops.
   **(v)** Apply an ultraviolet cutoff to regularize a divergent amplitude.

3. **QED:** Dirac $\gamma$-matrices; Trace theorems; Feynman rules for QED; Calculation of cross-sections and lifetimes; Introduction to renormalization.

   **Intended learning outcomes:** Enables successful students to:
   **(i)** Draw relevant diagrams and calculate amplitudes in QED (including manipulations of Dirac gamma matrices).
   **(ii)** Renormalize a vacuum polarization diagram.
   **(iii)** Calculate running (energy/momentum dependence) of the QED coupling.

4. **QCD:** QCD Feynman rules; Quark-antiquark and quark-quark interaction QCD; Confinement and asymptotic freedom; Perturbative and non-perturbative QCD.

   **Intended learning outcomes:** Enables successful students to:
   **(i)** Calculate potentials between quark and antiquark pairs in perturbative QCD for the possible colour configuration.
   **(ii)** Explain quark binding in hadrons in only one of possible colour configurations.
   **(iii)** Demonstrate the anti-screening of the strong coupling constant-leading to asymptotic freedom and confinement.
   **(iv)** Differentiate between the perturbative and non-perturbative regimes of QCD.

5. **Weak Interaction and Electroweak Unification:** Feynman rules for the weak interaction; Charged and neutral weak currents; Cabibbo angle; CKM matrix; Electroweak unification.

   **Intended learning outcomes:** Enables successful students to:

   **(i)** Explain the strength of flavour-changing weak decays
   **(ii)** Demonstrate the electroweak unification.

6. **Introduction to Lagrangians for Gauge Theories and Physics beyond the Standard Model (BSM):** Gauge Theories: Lagrangians for Scalar, Spinor and

Vector particles; Derivation of Feynman rules; Global and Local gauge invariance; Spontaneous symmetry breaking; Higgs mechanism; BSM: GUTs, Neutrino masses and oscillation; Ideas of Supersymmetry and String Theory; LHC physics.

**Intended learning outcomes:** Enables successful students to:

- **(i)** Have knowledge of Lagrangians for spinor, scalar and vector.
- **(ii)** Have the knowledge of global and local gauge invariance.
- **(iii)** Understand spontaneous symmetry breaking and higgs mechanism.
- **(iv)** Have the basic knowledge of BSM, GUTs, neutrino oscillations, supersymmetry and string theory.

7. **Cosmology:** Expansion of the universe; Hubble's law; Big bang; Friedman equation; Hubble constant; Cosmological Models, Density parameter $\Omega_0$; Deceleration parameter; Cosmological constant; Dark matter and its candidates; Dark energy; Cosmic microwave background; Inflation; Large scale structure; Gravitational waves.

**Intended learning outcomes:** Enables successful students to:

- **(i)** Explain the ultimate fate of the universe.
- **(ii)** Find out whether the expansion of a model universe is acceleratory or not.
- **(iii)** Describe the behavior of matter dominated, radiation dominated or mixed flat universes.
- **(iv)** Explain the importance. of cosmological constant
- **(v)** Understand the dark matter and dark energy.
- **(vi)** Understand cosmic microwave background and its importance.

Books Recommended

Text Books

| | |
|---|---|
| *Griffiths, D* | Introduction to Elementary Particles |
| *Liddle, A* | Introduction to Modern Cosmology |

Reference Books

| | |
|---|---|
| *Halzen, F and Martin, AD* | Quarks and Leptons |
| *Perkins, DH* | High Energy Physics |
| *Georgi, H* | Lie Algebras in Particle Physics |
| *Longair, MS* | High Energy Astrophysics |
| *Collins, PDB, Martin, AD and Squires, FJ* | Particle Physics and Cosmology |
| *Rolnick, WB* | The Fundamental Particles and their Interactions |
| *Kane, G* | Modern Elementary Particle Physics |
| *Aitchison, IJR and Hey, AJG* | Gauge Theories in Particle Physics |

| | |
|---|---|
| *Bettini, A* | An Introduction to Elementary Particle Physics |
| *Mann, R* | An Introduction to Particle Physics and the Standard Model |
| *Ryden, B* | Introduction to Cosmology |
| *Dodelson, S* | Modern Cosmology |
| *Kolb, E and Turner, M* | The Early Universe |
| *Weinberg, S* | Gravitation and Cosmology: Principles and Applications of the General Theory of Relativity |


## PH510 ADVANCED REACTOR PHYSICS (*~75 lectures*)

*Full Marks:* ***100*** (*Examination 80, Tutorial/Terminal 15, and Attendance 5*)

(*5 questions to be answered*) *Examination duration:* ***4*** *hours*

**Prerequisite Knowledge:** PH403, PH407

1. **Nuclear Reactors and Nuclear Power:** Components of nuclear reactors; Non-nuclear components of nuclear power plants; Power reactors and Nuclear steam supply systems; PWR, Organic-cooled reactors; Gas-cooled thermal reactors; Heavy-water reactor; Breeder reactors: LMFBR; MSBR.

   **Intended learning outcomes:** Enables successful students to:

   **(i)** Know about the nuclear and non-nuclear components of a nuclear reactor.
   **(ii)** Calculate the efficiency of a reactor.
   **(iii)** Learn how to convert fertile isotopes into fissile isotopes.
   **(iv)** Learn about breeding and its importance for the future of nuclear energy.
   **(v)** Design a nuclear reactor.

2. **Nuclear Reactor Theory:** One-group reactor equation for different reactor shapes; Two-group critical equations; Calculations of critical size; Reflected reactors.

   **Intended learning outcomes:** Enables successful students to:

   **(i)** Derive one and two group reactor and critical equations.
   **(ii)** Calculate the critical mass and size of the reactor.
   **(iii)** Calculate the critical fuel amount for a particular shape and size of a reactor.
   **(iv)** Know the use of reflectors.

3. **Time Dependent Reactor:** Reactor Kinetics**;** Control rods and chemical shim, Temperature effects on reactivity, Fission production poisoning, Core properties during lifetime.

   **Intended learning outcomes:** Enables successful students to:

   **(i)** Know the time dependent behavior of nuclear reactor.
   **(ii)** Know the use of control rods to control the reactor power and handle the emergency.
   **(iii)** Know the effect of temperature on reactivity.
   **(iv)** Demonstrate fission product poisoning.

4. **Heat Removal:** General thermodynamic considerations; Heat generation in reactors; Heat flow by conduction; Heat transfer to coolants; Boiling heat transfer; Reactor coolants and associated phenomena.

   **Intended learning outcomes:** Enables successful students to:

   **(i)** Know the sources of heat energy in a reactor.
   **(ii)** Know the detail of heat flow and transfer of heat to coolants.
   **(iii)** Know the detail procedure of removing heat for uses from the core.

5. **Reactor Materials:** Structural materials; Moderator and reflector materials; Radiation effects on materials; Corrosion and chemical reactions in coolant circuit materials.

   **Intended learning outcome:** Enables successful students to:

   **(i)** Select the proper material for the construction of different components of a reactor.
   **(ii)** Know how to minimize the radiation damage.

6. **Reactor Shielding and Safety:** Principles of reactor shielding; Different types of shielding systems and materials; Attenuation of fast neutrons and gamma rays; Principles of Nuclear power plant safety; Reactor accidents and risk analysis.

   **Intended learning outcomes:** Enables successful students to:

   **(i)** Know the sources of $\gamma$ and neutron radiation.
   **(ii)** Know the positive uses of radiation.
   **(iii)** Know how to dispose the high level radioactive materials.
   **(iv)** Understand three level of safety.
   **(v)** Design the reactor protector systems.
   **(vi)** Know the future of nuclear power.

Books Recommended

Text Books

*Lamarsh, JR* — Introduction to Nuclear Engineering

| | |
|---|---|
| *Glasstone, S and Sesonske, A* | Nuclear Reactor Engineering |

Reference Books

| | |
|---|---|
| *Stacey, WM* | Nuclear Reactor Physics |
| *Duderstadt, JJ and Hamilton, LJ* | Nuclear Reactor Analysis |
| *Garg, S et al* | Nuclear Reactor Physics |
| *Garland, WJ* | www.nuceng.ca(website) |
| *King, DG* | Nuclear Power Systems |
| *Henry,A* | Nuclear Reactor Analysis |
| *Murray, RL* | Introduction to Nuclear Engineering |
| *Liverhant, SE* | Elementary Introduction to Nuclear Reactor Physics |

## PH511 BIOMEDICAL INSTRUMENTATION AND IMAGING SYSTEM

(*~75 lectures*)

*Full Marks:* ***100*** (*Examination 80, Tutorial/Terminal 15, and Attendance 5*)

(*5 questions to be answered*) *Examination duration:* ***4*** *hours*

1. **Fundamentals of Medical Instrumentation:** Physiological systems of human body; Cardio vascular system; Respiratory system; Nervous system; Source of biomedical signals; Basic medical instrumentation system; Microprocessor; Interfacing of analog signals to microprocessors; PC based medical instruments.

   **Intended learning outcomes:** Enables successful students to:

   i) Understand various physical systems of human body.
   ii) Have basic knowledge about medical instruments.
   iii) Know the interfacing between two systems.
   iv) Gather knowledge about operation of medical instruments controlled by PC.

2. **Bioelectric Signals and Electrodes:** Origin of bioelectric signals; Electrocardiogram (ECG), Electroencephalogram (EEG); Electromyogram (EMG); Recording electrodes; Metal-electrolyte interface; Skin contact impedance; Silver-silver chloride electrodes; Electrodes for: ECG, EEG, EMG; Electrical conductivity of jellies and creams.

   **Intended learning outcomes:** Enables successful students to:

   i) Understand the process of bioelectric signal recording.
   ii) Explain the mechanism of physiological assistance devices.

3. **Instrumentation Amplifier and Recorders:** Principle of instrumentation amplifier; Carrier amplifier; Chopper amplifier; Biomedical signal analysis

techniques; Fourier transform; Signal processing techniques; Writing processes: Ink jet recorder; Potentiometric recorder; Digital recorder, Biomedical recorders; ECG; Vector-cardiograph (VCG); EEG; EMG; Biofeedback instrumentation.

**Intended learning outcomes:** Enables successful students to:

i) Design and use amplifiers used in biomedical instrumentation systems.

ii) Predict the experimental patterns of physiological assistance devices.

4. **Patient Monitoring System:** Cardiac monitor; Cardiac monitor using digital memory; Central monitors; Measurement of: Heart rate, Pulse rate, Blood pressure, Respiration rate, Foetal monitoring instruments.

**Intended learning outcomes:** Enables successful students to:

i) Recognize and monitor various cardiac problems.

5. **Clinical Laboratory Instruments and Blood Cell Counters:** Principles of spectrophotometer; Microprocessor based spectrophotometer; Automated biochemical analysis system; Clinical flame photometer; pH measurements of blood; Blood $pCO_2$; Blood $pO_2$ ; Complete blood gas analyzer; Methods of blood cell counting; Coulter counters; Automatic recognition and differential counting at cells.

**Intended learning outcomes:** Enables successful students to:

i) Understand the construction and measuring procedure of various pathological instruments.

6. **Audiometer and Hearing Aids:** Basic audiometer; Sections of audiometer; Mechanical; Electrical; Evoked response audiometer system; Hearing aids; Conventional, Digital; Cochlear implants.

**Intended learning outcomes:** Enables successful students to:

i) Design and use audiometer and hearing aids.

7. **Modern Imaging Instrumentation:** X-ray machines; Digital radiography; X-ray computed tomography (CT); Position emission tomography (PET); Nuclear medical imaging; Magnetic resonance imaging (MRI); Ultrasonic imaging; Thermal imaging.

**Intended learning outcomes:** Enables successful students to:

i) Explain the working principles of various imaging techniques.

ii) Predict the images obtained from CT, PET and MRI.

iii) Demonstrate the differences among the images obtained from CT, PET and MRI.

8. **Therapeutic Equipments:** Cardiac pacemaker; Cardiac defibrillators; Haemodialysis machines; Lithotripter machine; Radiotherapy equipment; Physiotherapy and electrotherapy equipment.

   **Intended learning outcomes:** Enables successful students to:

   i) Explain the working principles of various therapeutic equipments.

   ii) Use the various therapeutic equipments.

Books Recommended

Text Books

| | |
|---|---|
| *R,S, Khandpur* | Handbook of Biomedical Instrumentation |
| *L Cromwell, F J. Weibell, E A Pfeiffer* | Biomedical Instrumentation and Measuring system |
| *B.L. Chrisfe* | Introduction to Biomedical Instrumentation |

## PH512 QUANTUM FIELD THEORY (*~75 lectures*)

*Full Marks:* ***100*** (*Examination 80, Tutorial/Terminal 15, and Attendance 5*)

(*5 questions to be answered*) *Examination duration:* ***4*** *hours*

1. **Canonical Quantisation:** Real Klein-Gordon field; Complex Klein-Gordon field; Dirac (Spinor) field; Electromagnetic vector field; Choice of gauge.
2. **Perturbative Expansion, Feynman Diagrams Techniques and Path Integral Quantisation:** Perturbative (loop) expansion; Feynman diagrams; Propagators and interactions; S-matrix; Path integral formalism; Generating functional; Green's function for free and interacting fields; Examples using $\phi^4$ theory; Connected and disconnected diagrams; Fermions; LSZ reduction formula; Gauge fields; Gauge invariance; QED: Photon propagator; Self-energy; Ward-Takahashi identities; Cross-sections for some elementary processes.
3. **Renormalisation:** Renormalisability of a theory; Ultraviolet and infrared divergences; Divergences in $\phi^4$ theory; Dimensional regularization; Renormalisation of $\phi^4$ theory; Divergences in QED; Renormalisation of QED; Renormalisation group.
4. **Symmetry Breaking:** Goldstone theorem; Pion as a Goldstone-Nambu boson; Higgs mechanism and Glashow-Salam-Weinberg model.
5. **Applications:**

   **a)** Non-Abelian Gauge Theories: Yang-Mills theory; Faddeev-Popov ghosts; One-loop divergences in QCD; Asymptotic freedom.

**b)** Condensed Matter Physics: Superfluids; Landau-Ginzburg theory; Superconductivity; Quantum Hall fluids.

Books Recommended

Text Books

| | |
|---|---|
| *Peskin, ME and Schroeder, DV* | An Introduction to Quantum Field Theory |
| *Ryder, LH* | Quantum Field Theory |
| *Zee, A* | Quantum Field Theory in a Nutshell |

Reference Books

| | |
|---|---|
| *Ramond, P* | Field Theory: A Modern Primer |
| *Weinberg, S* | Quantum Theory of Fields, vols. 1 and 2 |
| *Itzhykson, C and Zuber, J* | Quantum Field Theory |
| *Kaku, M* | Quantum Field Theory |
| *Srednicki, M* | Quantum Field Theory |

## PH513 OPTICAL FIBRE PHYSICS (~*75 lectures*)

*Full Marks:* ***100*** (*Examination 80, Tutorial/Terminal 15, and Attendance 5*)

(5 *questions to be answered*) *Examination duration:* ***4*** *hours*

1. **Basic Characteristics**: Ray theory; Electromagnetic theory; Single mode fibre; Multimode fibres.

2. **Transmission Characteristics:** Material absorption loss; Linear ion linear scattering loss; Band loss; Splice loss; Different types of dispersions; Polarization.

3. **Fabrication of Optical Fibre:** Liquid phase technology; Vapour phase deposition technique (OVP,VAD, MCVD and PCVD); Fluoride gas fibers.

4. **Optical Communication Systems:** Sources: Different types of LASER and their characteristics; LEDs; Detectors: Principles, PIN photodiodes; APDs; Transmitter; Fibre sensors; Optical interferometers.

5. **Optical Amplifications and Integrated Optics:** Optical amplifier; Fibre amplifier; Integrated optics principle; Planer waveguide; Integrated optical devices.

6. **Measurement Methods in Optical Fibre:** General experimental consideration; Measurement of attenuation; Refractive index profile; Numerical aperture; Pulse dispersion and bandwidth.

Books Recommended

Text Books

| | |
|---|---|
| *Ghatak, A and Thyagarajan, K* | Introduction to Fibre Optics |
| *Senior, JM* | Optical Fibre Communication |

Reference Books

| | |
|---|---|
| *Ghatak, A and Thyagarajan, ZK* | Optical Electronics |
| *Shydev, AW and Love, JD* | Optical Waveguide Theory |
| *Gowav, P* | Optical Communication |
| *Lacy, EA* | Fiber Optics |

## PH523 PRACTICALS

*Full Marks:* **200** (Continuous Assessment-60 marks, Practical *Examination 140 marks. 4 days for experiments and one day for defense on experiment)*

*Examination Duration:* $5\times 6$ *hours*

**Prerequisite:** PH411

### List of Experiments

1. Determination of total cross-section by analyzing bubble chamber photos.

   **Intended Learning outcomes:** Enable successful students to:
   a) Distinguish between partial cross section and total cross section.
   b) Explain the probability of interaction of a nuclear reaction.
   c) Explain the mechanism of happening of a nuclear interaction in superheating condition of a liquid in bubble chamber.
   d) Understand elastic, inelastic and exchange nuclear interactions.

2. Measurement of the range of π-meson in liquid hydrogen.

   **Intended Learning outcomes:** Enable successful students to:
   a) Grasp the knowledge how the range of nuclear particles vary with the density of medium as well as its kinetic energy.
   b) Explain the concept of superheated condition of a liquid.
   c) Demonstrate the columbic collisions of π-meson with atomic electrons while traveling through matter.

d) Calculate the range of π-meson using Sagitta method by measuring the radius of curvature, momentum and velocity.

3. Determination of the maximum energy of beta particles from its energy spectrum.

**Intended Learning outcomes:** Enable successful students to:

a) Perceive the condition for maximum energy of beta particles.
b) Demonstrate the trajectory and energy of beta particle in a homogeneous magnetic field.
c) Explain the energy spectrum of beta particle.

4. Measurement of the mass of π-meson from the analysis of the decay of pions and muons in hydrogen bubble chamber.

**Intended Learning outcomes:** Enable successful students to:

a) Demonstrate the decay modes of pions and muons.
b) Calculate the momentum of meson from the radius of curvature of its daughter's track and that of muons from its daughter's track length.
c) Calculate the mass of π-meson and muon analyzing the bubble chamber photographs using the concept of momentum and energy conservation.

5. Analysis of nuclear interactions on a bubble chamber film using relativistic kinematics.

**Intended Learning outcomes:** Enable successful students to:

a) Demonstrate momentum and energy conservation for an interaction in a bubble chamber.
b) Find out product particle from Ionization code versus momentum curve.
c) Identify missing particle by calculating missing energy, missing momentum and mass.
d) Reveal the interaction type.

6. Determination of the thermal neutron flux using neutron activation method.

**Intended Learning outcomes:** Enable successful students to:

a) Make known induced radioactivity.
b) Explain neutron activation methodology.
c) Know the uses of neutron activation in radiation safety, neutron detection and material analysis.

d) Demonstrate the function of GM counter by explaining threshold voltage, operating voltage, flatness of plateau, quenching, avalanche, breakdown voltage etc.

**7.** Determination of the half-life of a radioisotope using 7mCi Ra-Be neutron source.

**Intended Learning outcomes:** Enable successful students to:

a) Know the production of neutrons.
b) Calculate half-life of radioactive substance and aware to handle its harmful radioisotopes.
c) Learn the application of radioisotopes in medical physics and some other potential fields e.g. agriculture, industry.
d) Calculate the half life of an unknown radioisotope.

**8.** Studies of magnetic properties of a ferromagnetic sample using an oscilloscope.

**Intended Learning outcomes:** Enable successful students to:

a) Explain the distinction between **B** and **H** and their variation with each other.
b) Explain the formation of hysteresis loop as a function of alternating field in a ferromagnetic sample.
c) Calculate retentivity, coercivity, magnetic permeability, magnetic susceptibility and hysteresis loss and explain their variation in materials to materials.
d) Demonstrate the uses of the ferromagnetic materials for preparing permanent magnet, cores for electromagnets, electric motors, transformers, generators, and other electrical equipment of electric technology.

9. Studies of conductivity and activation energy of a semiconducting sample and measurement of TCR.

**Intended Learning outcomes:** Enable successful students to:

a) Know the differences among Boltzmann, Bose-Einstein and Fermi-Dirac statistics.
b) Know the meaning of activation energy and carrier activation from valence band to conduction band happens in a sample.
c) Demonstrate the change of conductivity characteristics of a semiconducting sample due to heat energy through $\sigma$ vs. T graph.
d) Understand the carrier generation mechanism in semiconducting sample.
e) Calculate the temperature coefficient of resistivity and graphical methods of solution of an equation to find experimental value.

**10.** Determination of Hall constant, Hall mobility and other related parameters of a semiconducting sample

**Intended Learning outcomes:** Enable successful students to:

a) Explain the origin of Hall voltage, Measure Hall voltage; determine the magnitude of the voltage for various sample current and magnetic field. And determine the sign of the Hall voltage in a semiconductor.
b) Identify the type of an extrinsic semiconducting sample.
c) Explain Lorentz force and its direction in a sample.
d) Produce magnetic field in a desired direction.
e) Calculate the concentration of charge carriers and its variation with external current in the sample.
f) Calculate Hall mobility and its magnitude?
g) Explain Hall coefficient and electrical conductivity of a semiconducting sample.

**11.** Study of the characteristics of a solar cell/panel

**Intended Learning outcomes:** Enable successful students to:

a) Explain the development of potential barrier due to the presence of positive and negative ions in the junction area of a solar cell (pn diode).
b) Explain the formation of dc voltage developed in a solar cell when light impinges on it.
c) Explain the constructional difference between a rectifier diode and a solar cell.
d) Measure light intensity using thermopile.
e) Plot I-V Characteristics of a solar cell and hence calculate open and short circuit voltage and current, current and voltage at maximum power, fill factor, efficiency, shunt and series resistance as a function of the cell temperature.
f) Explain the availability of current at night while no solar radiation is present.

12. Deconvolution of digitized NMR spectrum and hence identification and quantification of various species present in an amorphous material

**Intended Learning outcomes:** Enable successful students to:

a) Digitize and deconvolute any spectra.
b) Learn the procedure of collecting NMR signal using an NMR spectrometer.
c) Find out the local order, including nearest neighbor and next nearest neighbor, of the investigated nuclei.
d) Know the dominant interactions in solid state materials and their effects in the NMR spectrum.

e) Know the removal mechanism of the effect of chemical shift, dipolar and quadrupolar interactions.
f) Learn the effect of changing local order of the investigated nuclei.
g) Identify and quantify the relative amounts of various species present in the materials.
h) Know the spin-spin and spin-lattice relaxation times and their effects on free induction decay.
i) Know the practical uses of this experiment in our daily life.

13. Identification and quantification of various chemical bonds present in a specific material by using IR Spectrum.

**Intended Learning outcomes:** Enable successful students to:

a) Present block diagram of IR spectrophotometer.
b) Explain the effect of sweeping the IR radiation from its minimum to maximum values.
c) Identify and quantify various chemical bonds present in the material.
d) Know the practical uses of this experiment in our daily life.

14. Estimation of absorption coefficient and optical band gap from absorption edge of amorphous and crystalline semiconductors.

**Intended Learning outcomes:** Enable successful students to:

a) Determine the band gap of a semiconductor sample using its optical transmission spectrum.
b) Learn about Urback energy or Urback-tail and their magnitude with respect to the band gap.
c) Demonstrate the absorption edge in an optical spectrum.
d) Predict direct and indirect band gap energies.
e) Know about allowed and forbidden transitions.
f) Demonstrate the effect of optical interference in a thin film sample prepared on glass substrate.
g) Understand the function of an optical spectrophotometer (Double beam) and know the procedure of collecting transmission spectrum of the sample.

15. Study of pulse width modulation (using 555 timer).

**Intended Learning outcomes:** Enable successful students to:

a) Explain the effect of modulation and demodulation.
b) Demonstrate the effect of pulse width modulation.

# Academic Calendar

## M.Sc. Session: 2020-21; Examination 2021

| Class Starts | Class Ends | Exam starts |
|---|---|---|
| | | |

## Class Routine

| | 0910-0955 | 1000-1045 | | 1105-1150 | 1155-1240 | 1245-1330 | | 1430-1515 | 1520-1605 | 1610-1655 |
|---|---|---|---|---|---|---|---|---|---|---|
| Monday | | | | | | | | | | |
| Tuesday | | | | | | | | | | |
| Wednesday | | | | | | | | | | |
| Thursday | | | | | | | | | | |
| Friday | | | | | | | | | | |