# UNIVERSITY OF GONDAR

## College of Natural and Computational Sciences

## Department of Physics

# A CURRICULUM FOR THE MASTER OF SCIENCE (MSc) IN PHYSICS

Nov, 2013

GONDAR

# 1. Introduction

## 1.1. Background

Physics is one of the basic sciences which study all physical entities in this universe and how these objects interact with each other. It deals systems from a small scale such as subatomic level to far distant stars that are found beyond our universe. This wide range study is usually done by means of a mathematical model that can capture the essential characteristics and carry out a corresponding experiment. These experiments and modeling on these physical entities which we call it research.

Research and development in physics have contributed significantly in human civilizations like the industrial and electronic revolutions. Modern electronic devices like TV, computer, radar, airplane, and so on are largely resulted from Physics research and development. The developed world has benefited economically and culturally from the expansion of physics education at different levels. Perhaps the digital, economic and social divisions between west and developing countries can be narrow down dramatically by expanding physics education and research in developing countries among other things.

Department of Applied Physics, University of Gondar has started its training of undergraduate students in 1994 Ethiopian academic year with four staff members; three of them are academic and one laboratory technician. Since then, the department has been in teaching /training of undergraduate students in applied physics courses such as medical physics, electronic, and geophysics and has produced a lot of professional who are now working in different private and public sectors across the country.

Apart of this training of undergraduate students, the University of Gondar, in particular, department of physics should play a scientific role of providing consultancy and advice to the private and public sectors in some scientific and technical matters. Without a graduate program, it is unlikely that it will be able to embark on a systematic investigation and discussion of these issues. Hence, the department should focus on scientific research activities, by which it will lead/discipline the students to address as well as solve some of the main problem of the society.

## 2. Rationale

In 2012 a team of four people from the physics department has made a need assessment in four different universities such as Addis Ababa [2], Haramaya [5], Mekele[6] and Bahirdar[4] in order to get basic information of the graduate program in the country. In each of these universities, we have made an interview and deep discussion about their physics postgraduate program and we have understood that the current demand of the program in national level is high in both public and private sectors.

On the other hands the number of higher institutions that offer basic physics at undergraduate as well as graduate level is growing rapidly. This scenario has created severe shortage of physicists who can teach in several institutions including universities and colleges.

The rationale behind the MSc program in physics is to alleviate this severe shortage of qualified human resources in physics and related fields which is in line with the mission of University of Gondar. A growing number of faculties in Physics department are specialized in different fields. This proposed Graduate program can benefit from this different expertise. The department of physics is then a graduate program in physics (Msc) both theoretical and experimental research in different fields of physics such as Statistical physics, quantum physics, solid state physics, medical physics, …, etc.

## 3. Mission and vision of the department

### 3.1. Mission of the department

The mission of the department is to render quality education, research and consultancy services to all national and international communities on equal and competitive basis.

### 3.2. Vision of the department

The department has a farsighted vision of being one of the excellent teaching and research centers in the country. Beyond that, the department has the passion to excel and compete at international standards, and to produce citizens of extraordinary productive and creative expertise in the profession.

## 4. Objectives

The post graduate program in physics would work to achieve the following general and specific objectives.

### 4.1. General Objectives

The aim of our graduate physics program is to provide a theoretical and practical knowledge for students who have an interest in developing an inter-disciplinary approach to problem solving in different areas of physics, and in particular those seeking employment as a lecturer in university/college environments, aviation, mining, medical physicists or as biomedical engineers in hospital, industry and so on.

The program has been appropriately designed to equip the students with skills suitable for application in the wider job market as well as for sustainable exploitation of the vast natural resource potential for national development. The study covers both theoretical and experimental Physics, through lectures, tutorials, and laboratory experiments.

### 4.2. Specific Objectives

The main objectives of the MSc program in Physics are to:

- Establish a firm foundation for scientific and technological development by providing basic research techniques in physics.
- Train experts who are needed in national development sectors such as energy, industry, communication, research, and teaching at University/College levels and secondary schools.
- Pursue higher level training in different fields of physics
- Develop skills of numerical manipulation and statistical analysis of data using sophisticated computer software.
- research in a particular field of medical physics, medical image computing, or biomedical engineering and/or medical imaging;
- Detailed understanding of advanced image analysis and computational methods that are used to obtain information from medical images.

- Demonstrate the competence and understanding of nuclear structure, nuclear interactions, nuclear decay and nuclear models by solving problems related to these concepts
- Explain the elementary theories and basic principles of condensed matter physics including many-body theory and band theory of solids.

## 5. Graduate Profile

On completion of the MSc program, a successful student will be able to

- Demonstrate a basic postgraduate level knowledge and understanding in different fields physics
- Implement a set of key transferable skills which will be relevant to a student's career.
- carry out independent research in physics, electrical engineering and so on,
- pursue high level training in physics, electrical engineering and related areas,
- teach in higher institutions including universities & colleges,
- work in industries, environmental institutions, meteorology stations, and
    - Demonstrate self-direction and originality in tackling and solving problems and act autonomously in planning and implementing tasks at a postgraduate level.

## 6. Policy of the M.Sc. program

The philosophy of and objective of the postgraduate program of physics in line with University of Gondar (UOG) which is working to produce highly qualified and competent human resources in the field of physics to accelerate the development of the country.

### 6.1. Staff profiles

To implement this philosophy, the University of Gondar has been given an opportunity to all academic stuffs members to attend both in country or abroad fellowships. The department has begun its teaching and learning process with three academic stuffs and one laboratory technician in the year 2002. Currently, the department has the following academic staff members

| No | Name | Academic Rank | Remark |
|---|---|---|---|
| 1 | Teweldebrhan Gebru | M.Sc. | Head, Department |
| 2 | Aman Wassie | PhD | |
| 3 | Yahya Ali | M.Sc. | |
| 4 | Amdeselassie Atseke | M.Sc. | |
| 5 | Birhanu Tsegaye | M.Sc. | Study leave (PhD) |
| 6 | Birhanu Tulu | M.Sc. | Study Leave (PhD) |
| 7 | Abdela Mohammednur | M.Sc. | Study Leave (PhD) |
| 8 | Hagos Aregay | M.Sc. | Study Leave (PhD) |
| 9 | P. Arul | PhD | |
| 10 | Samuel Mulugeta | M.Sc. | |
| 11 | Selamawit Shawul | M.Sc. | |
| 12 | Fentahun Muluneh | M.Sc. | |
| 13 | Assefa Getaneh | M.Sc. | |
| 14 | Daniel Bahiru | M.Sc. | |
| 15 | Abera Mebrahtu | M.Sc. | |
| 16 | Markos Mehretie | M.Sc. | |
| 17 | Yenesil Temare | M.Sc. | |
| 18 | Solomon Getachew | M.Sc. | |
| 19 | Amanuel Mengistie | B.Sc | Study leave (Msc) |
| 20 | Dereje Getachew | M.Sc. | |
| 21 | Tesfaye Abay | M.Sc. | |
| 22 | Teshager Aklie | M.Sc. | |
| 23 | Mulubrhan Tesfakiros | M.Sc. | |
| 24 | Yonas Endale | B.Sc | |
| 25 | Mulugeta Tegnegne | Diploma | Technical Ass. |
| 26 | Amsalu Binega | Diploma | Study Leave(Bsc) |
| 27 | Sintayehu Fenta | Diploma | Study Leave(Bsc) |

## 7. Guideline for postgraduate Studies

The provision of this postgraduate program is in accordance with the new policy and senate legislations of postgraduate programs of Gondar University [1]

### 7.1. Provision of the program

The overall progress of this graduate program is by department graduate committee (DGC) which consists of at least three and at most seven staff members of the department of physics. This committee supervises all activities of the program such as prepare periodic reports about the progress of the program, approve status of a student, …, etc.[1]

### 7.2. Admission Requirements

Any person who:

- Meet the general admission requirements of the University of Gondar [1].
- Successfully completed undergraduate training in physics from a recognized university.
- pass the entrance examination of the department

### 7.3. Registration

A student should register at the beginning of each semester in according to the schedule of the registrar office of the university.

### 7.4. Program Divisions

The department has planned to give this graduate program in the following divisions;

- Regular program
- Summer program
- Extension program

### 7.5. Program Duration

The duration of this program in normal condition will be given within four semesters in two years' time. However, this duration may vary depending up on the program divisions which is three years for extension and 4 summers for summer program and it is shown as follows

| Program of divisions | Minimum | Maximum |
|---|---|---|
| Regular | 2 years | 3 years |
| Extension | 3 years | 4 years |
| Summer | 4 Summers | 6 Summers |

Extension of the study period which is stated in the above table may be allowed, if the student would provide be acceptable reason for an extension of this period and it should be approved by the department.

## 8. List of courses

The postgraduate program of physics will give both a compulsory and elective courses which are described below

### 8.1. Compulsory Courses

A graduate student must take the following seven compulsory modules.

| No | Course No | Course title | C.hrs |
|---|---|---|---|
| 1.0 | Phys 603 | Mathematical Methods | 3 |
| 2.0 | Phys 631 | Classical Mechanics at Nano scale | 3 |
| 3.0 | Phys 621 | Thermodynamics & Statistical Mechanics | 3 |
| 4.0 | Phys 602 | Numerical methods & Computational physics | 4 |
| 5.0 | Phys 642 | Quantum Mechanics | 3 |
| 6.0 | Phys 671 | Classical Electrodynamics | 3 |
| 7.0 | Phys 600 | Research methodology | 2 |

## 8.2. Specialization Courses

A graduate student has an option to choose in any one of the following field of specialization following the compulsory courses that are shown above.

| **Specialization** | **Course No &their title within the Specialization** | **Cr.hrs** |
|---|---|---|
| Statistical and computational Physics | • Phys-622 Basic Methods of Stochastic Processes<br>• Phys-623 Approximate Methods in Stochastic Processes<br>• Phys-624 Distributed Systems and Bistability | |
| Atmospheric physics | • Phys 661 Introduction to Atmospheric Physics<br>• Phys 662 Radiative Transfer in the Atmosphere I<br>• Phys 663 Radiative Transfer in the Atmosphere II | |
| Medical Physics | • Phys-686 Introduction to medical Physics I<br>• Phys-687 Introduction to medical Physics I<br>• Phys-688 Image-Based Anatomy | |
| Nuclear physics | • Phys-681 Advanced Nuclear Physics-I<br>• Phys-682 Advanced Nuclear Physics-II<br>• Phys-683 Nuclear Techniques | |
| Quantum field theory | • Phys 741 Quantum Field Theory I<br>• Phys 742 Quantum Field Theory II<br>• Phys 743 Quantum Field Theory III | |
| Quantum Optics | • Phys 771 Quantum state of light<br>• Phys 772 Cavity mode and atom dynamics<br>• Phys 773 Resonance fluorescence &laser dynamics | |
| Condensed Matter | • Phys 751 Principles of Condensed Matter<br>• Phys 752 Electronic Structure of Condensed Matter<br>• Phys 753 Advanced Condensed Matter Theory | |
| Thesis/project | • Phys 693 Graduate Thesis<br>• Phys 694 Graduate project | |

### 8.3. Summary of course requirement

| Graduation Requirements | | |
|---|---|---|
| No | **Module** | **Cr.hrs** |
| 1 | Compulsory Physics courses | 21 |
| 2 | Specializations modules/courses | 9 |
| 3 | Thesis/Project Work | 6 |
| **Total** | | **36** |

NB.* regarding course numbering, we only extend the course number of undergraduate curriculum of department physics of university of Gondar [7]

### 8.4. Course Breakdown

#### 8.4.1. Regular program

| **Year I, Semester I** | | | |
|---|---|---|---|
| **No.** | **Course Title** | **Course code** | **Cr. Hr.** |
| 01 | Mathematical Methods | Phys 603 | 3 |
| 02 | Classical Mechanics | Phys 631 | 3 |
| 03 | Thermodynamics & Statistical Mechanics | Phys 621 | 3 |
| Total | | | 9 |

| Year I, Semester II | | | |
|---|---|---|---|
| **No.** | **Course Title** | **Course Code** | **Cr. Hr.** |
| 01 | Numerical methods & Computational physics | Phys 602 | 4 |
| 02 | Quantum mechanics | Phys 642 | 3 |
| 03 | Classical electrodynamics | Phys 671 | 3 |
| 04 | Research methodology | Phys 600 | 2 |
| **Total** | | | 12 |

**Year II, Semester I**

| | | | |
|---|---|---|---|
| 01 | Specialization I | Phys xxx | 3 |
| 02 | Specialization II | Phys xxx | 3 |
| 03 | Specialization III | Phys xxx | 3 |
| **Total** | | | 9 |

**Year II, Semester II**

| No. | Course Title | Course Code | Cr. Hr. |
|---|---|---|---|
| 01 | Seminar | Phys 692 | P/F |
| 02 | Thesis/ project | Phys 693/ Phys 694 | 6 |
| **Total** | | | 6 |

**NB.** All students in the Physics Graduate Program will be required to attend at least one non-credit Physics Seminar as part of their physics course requirements.

* Here **'xxx'** represents the course number which a student may choose among those specialization courses

### 8.4.2. Summer program

## Summer I

| No. | Course Title | Course code | Cr. Hr. |
|---|---|---|---|
| 01 | Mathematical Methods | Phys 603 | 3 |
| 02 | Classical Mechanics | Phys 631 | 3 |
| 03 | Thermodynamics & Statistical Mechanics | Phys 621 | 3 |
| Total | | | 9 |

| **Summer II** | | | |
|---|---|---|---|
| **No.** | **Course Title** | **Course Code** | **Cr. Hr.** |
| 01 | Numerical methods & Computational physics | Phys 602 | 4 |
| 02 | Quantum mechanics | Phys 642 | 3 |
| 03 | Classical electrodynamics | Phys 671 | 3 |
| 04 | Research methodology | Phys 600 | 2 |
| Total | | | 12 |

| Summer III | | | |
|---|---|---|---|
| **No.** | **Course Title** | **Course Code** | **Cr. Hr.** |
| 01 | Specialization I | Phys xxx | 3 |
| 02 | Specialization II | Phys xxx | 3 |
| 03 | Specialization III | Phys xxx | 3 |
| Total | | | 9 |

## Summer IV

| No. | Course Title | Course Code | Cr. Hr. |
|---|---|---|---|
| 01 | Seminar | Phys 692 | P/F |
| 02 | Thesis/ project | Phys 693/ Phys 694 | 6 |
| **Total** | | | 6 |

**NB.** All students in the Physics Graduate Program will be required to attend at least one non-credit Physics Seminar as part of their physics course requirements.

NB * Here **'xxx'** represents the course number which a student may choose among those specialization courses

### 8.4.3. Extension program

**Year I, Semester I**

| No. | Course Title | Course Co | Cr. Hr. |
|---|---|---|---|
| 01 | Mathematical Methods | Phys 603 | 3 |
| 02 | Classical Mechanics | Phys 631 | 3 |
| Total | | | 6 |

**Year I, Semester II**

| No. | Course Title | Course Co | Cr. Hr. |
|---|---|---|---|
| 01 | Thermodynamics & Statistical Mechanics | Phys 621 | 3 |
| 02 | Numerical methods &Computational physics | Phys 602 | 3 |
| Total | | | 6 |

**Year II, Semester I**

| No. | Course Title | Course Co | Cr. Hr. |
|---|---|---|---|
| 01 | Quantum mechanics | Phys 642 | 3 |
| 02 | Classical electrodynamics | Phys 671 | 3 |
| 03 | Research methodology | Phys 600 | 2 |
| Total | | | 8 |

**Year II, Semester II**

| No. | Course Title | Course Co | Cr. Hr. |
|---|---|---|---|
| 01 | Specialization I | Phys xxx | 3 |
| 02 | Specialization II | Phys xxx | 3 |
| Total | | | 6 |

**Year III, Semester I**

| No. | Course Title | Course Co | Cr. Hr. |
|---|---|---|---|
| 01 | Seminar | Phys 692 | p/F |
| 02 | Specialization III | Phys xxx | 3 |
| Total | | | 3 |

**Year III, Semester II**

| No. | Course Title | Course Code | Cr. Hr. |
|---|---|---|---|
| 01 | Thesis/ project | Phys 693/ Phys 694 | 6 |
| **Total** | | | 6 |

**NB.** All students in the Physics Graduate Program will be required to attend at least one non-credit Physics Seminar as part of their physics course requirements.

NB * Here **'xxx'** represents the course number which a student may choose among those specialization courses

## 9. Course Delivery Methods

The courses will be delivered to students in form of active teaching and learning methods.

## 10. Assessment and Evaluation

The program will give due attention to continuous assessment method to follow the progress of the student. Typical marks and assessment method may depend up on the type of course and instructor who will in charge it.

## 11. Grading Systems

Grading is based on the fixed scale where University of Gondar has recently started implementing see details in [1]. To complete the program, the student should score a minimum CGPA of 3.0 and a maximum of one C grade in all courses

## 12. Academic status of students

The academic status of the student shall be governed by the UOG rules and regulations. For detail, see hand book of University of Gondar, postgraduate policy and guideline [1]

## 13. General requirement of thesis

In addition to the compulsory and area of specialization courses that is described above, a student may take at least six (6) credit hours of supervised thesis research.

- Whether a graduate student will undertake a graduate project or thesis will be decided by the department graduate committee.
- The graduate project/thesis shall constitute individual effort to carry out a fairly adequate investigation of a selected problem in theoretical or experimental physics with some degree of originality.
- The graduate student must undertake a graduate project/thesis on an approved topic under the supervision of an advisor.
- To obtain their M.Sc. degree, candidates have to write and orally present his M.Sc. thesis and pass a final exam (viva) before a committee.

## 14. Graduation and award of credentials

A candidate who fulfills the general requirements of the new postgraduate legislation of University of Gondar and those who registered for Thesis / Project Course should get at least ***"Satisfactory"*** in this course to obtain his/her MSc. degree in Physics.

## 15. Degree Nomenclature

- English

The Degree of Master of Science in Physics (specialization)

- በአማርኛ

የሳይንስ ማስተር ዲግሪ በፊዚክስ ( ስፔሻላይዜሽን)

The Degree of Master of Science in Physics (Nuclear Physics)

የሳይንስ ማስተር ዲግሪ በፊዚክስ (ኒዩክሌር ፊዚክስ)

The Degree of Master of Science in Physics (Statistical & computational physics)

የሳይንስ ማስተር ዲግሪ በፊዚክስ (ስታቲስቲካል እና ቀመር ፊዚክስ)

The Degree of Master of Science in Physics (Quantum Optics)

የሳይንስ ማስተር ዲግሪ በፊዚክስ (ካንተም ኦፕቲክስ)

The Degree of Master of Science in Physics (Medical physics)

የሳይንስ ማስተር ዲግሪ በፊዚክስ (መዲካል ፊዚክስ)

The Degree of Master of Science in Physics (Quantum field theory)

የሳይንስ ማስተር ዲግሪ በፊዚክስ (ካንተም ፊልድ ቲኦሪ)

The Degree of Master of Science in Physics (Condensed Matter Physics)

የሳይንስ ማስተር ዲግሪ በፊዚክስ (ኮንደንስድ ማተር ፊዚክስ)

The Degree of Master of Science in Physics (Atmospheric Physics)

የሳይንስ ማስተር ዲግሪ በፊዚክስ (አትሞስፈሪክ ፊዚክስ)

## 16. Quality Assurance

The department of Physics will monitor and maintain the quality of the program according the quality assurance standards set by the university.

To this effect, the department will:

- Ensure that contents of the course are covered
- Ensure that appropriate technology is employed in the teaching learning process
- Conduct short term courses and seminars for staff members in order to make use of modern technology and IT.
- Make sure that tutorial classes are well organized, relevant exercises home works and assignments are carefully set to enhance and strengthen the student's ability to solve problems and understand the underlining theory.
- Ensure that appropriate and recent text books are used for the courses.
- Provide enough reference books for each course.
- Full fill laboratories with the necessary equipment.
- Evaluate at the end of each semester based on the feedback obtained from the instructors, tutors and the students, so as to make the course more relevant.

- Ensure that the lectures are conducted by appropriate instructors

# 17. Course Descriptions

## 17.1. Compulsory Courses

**Phys 603:** Mathematical Methods for Physics 3

**COURSE DESCRIPTION**

Vector Calculus, Eigen value problems and orthogonal functions, matrix theory, tensor analysis, Laplace and Fourier transformations, partial differential equations, integral equations, special functions, complex analysis (residue calculus, method of steepest descent), and advanced topics (Grassman variables, path integrals, super symmetry).

**Objectives:**

Upon successful completion of this course, the student should be able to :

- How to calculate partial and total derivatives of functions of more than one variable;
- How to evaluate single, double and triple integrals using commonly occurring coordinate systems;
- How to state properties of vector calculus operators & theorems & relate them with physical phenomena
- How to solve simple problems using these operators & theorems to solve physical problems
- state the rules & techniques of ODE, Fourier series & integral transform & use them to solve physical problems

**Methodology**

Lectures for those contents which need theoretical explanation and those contents like numerical values/models of the course will be covered in form of exercise and assignments to each student and the students are expected to do these assignments and exercise in the next class. In general, the course covered with lecture, exercise, and presentation of an independently project on some selected topics of the course

**Assessment:**

Successful participation in exercises, Presentation of an independently completed project on some specific topics.

## Chapter-I: Complex Variables

Analytic function - kinds of singularity - Line integrals and Cauchy's theorem - Taylor and Laurent expansions - Residue theorem - Application to evaluation of definite integrals - conformal mapping and invariance of Laplacian in two dimensions - Representation of functions by contour integral.

## Chapter -II : Linear Differential equations and Green's function

Second order linear differential equations - Sturm - Lowville's Theorem - Orthogonality of Eigen functions - Illustration with Legendre, Laguerre, Hermite and Chebyshev differential equations - Location of Zeros of these polynomials - Wronskian, ordinary and singular points - Green's function- Eigenfunction expansion of Green's function - Reciprocity theorem - Sturm - Liouville type equations in one dimension and their Green's function.

## Chapter -III : Laplace and Fourier transforms

Laplace transforms - Solution of linear differential equations with constant Coefficients - Fourier integral - Fourier transforms, Fourier sine and consine transforms - Convolution theorems - Applications.

## Chapter -IV : Tensor Analysis

Definition of scalars - contravariant Vectors and Covariant Vectors - Einstein's summation convention - Definition of tensors - Second rank cartesian tensor as operator - Symmetric and antisymmetric tensors - tensors of rank higher than two Specific Tensors - Covariant derivatives

## Chapter -V: Group Theory

Definition of groups, subgroups and conjugate classes - Symmetry elements, Transformation, Matrix representation - Point groups - representation of a group - Reducible and irreducible representations - Orthogonality theorem - character of a representation - character Table C2v and C3v - Application to Infrared and Raman active vibrations of XY3 type molecules - Projection operators applied to an equilateral triangle - Rotation group and angular momenta.

**Text:** G. Arfken and H.J Weber, Mathematical Methods for Physicists, Academic press sixth edition

**Recommended Literature:**

- P. Dennery and A. Kryzwicki, Mathematics for physicists, Indian Edition 2005
- K. F. Riley, M. P. Hobson and S.J. Bence, Mathematical Methods for Physics, Engineering, Cambridge University Press, 1999.
- Foundations of Mathematical Physics, Sadri Hassani, Allyn and Bacon Press.

**Phys 631: Classical Mechanics 3**

**COURSE DESCRIPTION:**

Review: Application of Newton's Laws and Conservation Laws, Lagrangian Dynamics: Mechanics of a system of particles, constraints and generalized coordinates, Lagrange's equations, applications. Variational calculus and Least Action Principle.Central force problem: Equations of motion, orbits, Virial theorem, Kepler problem, scattering in a central force field. Rigid body motion: Orthogonal transformations, Euler angles, coriolis effect, angular momentum and kinetic energy, tensors and dyadic, inertia tensor, Euler equations, applications, heavy symmetrical top. Hamiltonian formulation: Legendre transformations, Hamilton equations, cyclic coordinates and conservation theorems, principle of least action, canonical transformations, Poisson brackets, Hamilton-Jacobi theory, Action-angle variables. Small oscillations: Eigenvalue problem, frequencies of free vibrations and normal modes, forced vibrations, dissipation. Classical field theory: Lagrangian and Hamiltonian formulation of continuous system.

**Objective:**

Upon successful completion of this course, the student should be able to :

- Describing base vectors, their reciprocal,& generalized coordinate systems
- obtain the velocity, acceleration and momentum in generalized coordinate,

- Interpret results described in terms of generalized coordinates,
- Explain the fundamental concepts of Newtonian formulation of mechanics,
- Develop the capability to determine the Lagrangian and Hamiltonian of mechanical systems and use these functions to obtain the corresponding equations of motion,
- Solve dynamical problems using Langragian and Hamiltonian formulations
- Analyzing mechanical systems applying basic conservation laws with emphasis given to central force problem and rigid body motion,
- Describe application of advanced theoretical techniques including small oscillations and wave propagation to analyze certain mechanical systems, acquainted with basic theoretical methods required in contemporary classical mechanics,

**Methodology**

Lectures for those contents which need theoretical explanation and those contents like numerical values/models of the course will be covered in form of exercise and assignments to each student and the students are expected to do these assignments and exercise in the next class. In general, the course covered with lecture, exercise, and presentation of an independently project on some selected topics of the course

**Assessment:**

Successful participation in exercises, Presentation of an independently completed project on some specific topics.

## Chapter– I: Lagrangian and Hamiltonian Formulation of Mechanics

Calculus of variations – Hamilton's principle of least action – Lagrange's equations of motion – conservation laws – systems with a single degree of freedom – rigid body dynamics – symmetrical top – Hamilton's equations of motion – phase plots – fixed points and their stabilities.

## Chapter – II: Two-body Central Force Problem

Equation of motion and first integrals – classification of orbits – Kepler problem –scattering in central force field – transformation to laboratory frames.

**Chapter – III: Small Oscillations**

Linearization of equations of motion – free vibrations and normal coordinates – free vibration of a linear tri-atomic molecule – forced oscillations and the effect of dissipative forces – beyond small oscillations.

**Chapter – IV: Special Theory of Relativity**

Principles and postulates of relativity – Lorentz transformation – relativistic kinematics and dynamics – E = mc2 – momentum four-vector for a particle – relativistic invariance of physical laws.

**Chapter – V: Hamiltonian Mechanics and Chaos**

Canonical transformations – Poisson brackets – Hamilton-Jacobi theory – action-angle variables – perturbation theory – integrable systems – introduction to chaotic dynamics.

**Texts**

- H. Goldstein, *Classical Mechanics,* 2nd Edition, Narosa, (1985).

**References**

- H. Goldstein, Classical Mechanics. 3rd Edition., C. Poole and J.Safko, Pearson Education, Asia, New Delhi.
- S.N. Biswas, 1998, Classical Mechanics, Books and Allied Ltd., Kolkata.
- L. Landau and E. Lifshitz, *Mechanics,* Oxford (1981).
- F. Scheck, *Mechanics,* Springer (1994).

**Phys 621:** Thermodynamics & Statistical Mechanics 3

**Contents of the Course:**

**Thermodynamics:** Basic ideas about heat, temperature, work done – laws of thermodynamics and their significance – specific heats – thermodynamic potentials – Maxwell relations – significance of entropy.

**Ensembles:** Concepts of phase space, microstates, macro states – equal priori probability – ensemble of particles – micro canonical ensemble – macro canonical ensemble – grand canonical ensemble – derivation of partition function – derivation of thermodynamic quantities from each ensembles.

**Classical Statistical Mechanics:** Connection between entropy and probability – Boltzmann's equation - elementary ideas about three different statistics - classical statistics – Maxwell & Boltzmann statistics – classical ideal gas equation – equipartition theorem.

**Fermi-Dirac Statistics:** Basics for quantum statistics – system of identical indistinguishable particles – symmetry of save functions – bosons, fermions - Fermi & Dirac statistics – Fermi free electron theory – Pauli paramagetism.

**Bose-Einstein Statistics:** Bose & Einstein statistics – black body radiation – Rayleigh Jeans' formula – Wien's law – Planck radiation law – Bose Einstein condensation – Einstein model of lattice vibrations – Phonons – Debye's theory of specific heats of solids.

*Ideal Fermi System :* Fermi energy, Mean energy of fermions at absolute zero, Fermi energy as a function of temperature , Electronic specific heat, White – Dwarfs, Compressibility of Fermi gas,

**Preparation:** Theoretical courses at the Bachelor degree level

**Objective:**

Upon successful completion of this course, the student should be able to :

- How to demonstrate clear understanding of microscopic and macroscopic systems,
- How to relate the concept of heat and temperature,
- The basic statistical concepts required to describe physical systems,
- obtain various mean values using the statistical distribution function, apply statistical approaches in studying different properties of a system, The applications of laws of thermodynamics,
- How to employ Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac statistics in describing a given system,
- Explain magnetic properties of substances at low temperature,
- Discuss about different properties of substances related with their movement by using kinetic theory of transport process,

**Learning Outcomes**

At the end of this course, students should be able to apply their newly acquired knowledge in their research.

**Methodology**

Lectures for those contents which need theoretical explanation and those contents like numerical values/models of the course will be covered in form of exercise and assignments to each student and the students are expected to do these assignments and exercise in the next class. In general, the course covered with lecture, exercise, and presentation of an independently project on some selected topics of the course

**Assessment:**

Successful participation in exercises, Presentation of an independently completed project on some specific topics.

### Chapter – I: Thermodynamics

Basic ideas about heat, temperature, work done – laws of thermodynamics and their significance – specific heats – thermodynamic potentials – Maxwell relations – significance of entropy.

### Chapter – II: Ensembles

Concepts of phase space, microstates, macro states – equal priori probability – ensemble of particles – micro canonical ensemble – macro canonical ensemble – grand canonical ensemble – derivation of partition function – derivation of thermodynamic quantities from each ensembles.

### Chapter – III: Classical Statistical Mechanics

Connection between entropy and probability – Boltzmann's equation - elementary ideas about three different statistics - classical statistics – Maxwell & Boltzmann statistics – classical ideal gas equation – equipartition theorem.

### Chapter– IV: Fermi-Dirac Statistics

Basics for quantum statistics – system of identical indistinguishable particles – symmetry of save functions – bosons, fermions - Fermi & Dirac statistics – Fermi free electron theory – Pauli paramagetism.

### Chapter – V: Bose-Einstein Statistics

Bose & Einstein statistics – black body radiation – Rayleigh Jeans' formula – Wien's law – Planck radiation law – Bose Einstein condensation – Einstein model of lattice vibrations – Phonons – Debye's theory of specific heats of solids.

**Text:** F. Reif, Fundamentals of Statistical and Thermal Physics, McGraw – Hill, International Edition

**References**

- K. Huang, Statistical Physics, 2nd edition, John Wiley's and Sons.
- R. K. Pathria, Statistical Mechanics, 2nd edition, Butterworth Heinemann.
- Statistical Mechanics, R.K.Pathria, Bufferworgh Heinemann(2nd Edition)
- Statistical Mechanics,K.Huang, John Willey & Sons (2nd Edition)
- Statistical Mechanics,Satya Prakash, Kedar Nath Ram Nath Publication (2008)
- Statistical Mechanics by Loknathan and Gambhir

**Phys 602: Numerical Methods & Computational Physics 4**

**Requirements:** Knowledge of a modern programming language (like C, C++, Python, MATLAB)

**Preparation:** Basic theoretical courses at the Bachelor degree level

**Course Description:**

The course covers: Errors, Its sources, propagation and analysis, computer representation of numbers. Roots of Nonlinear Equations: Bisection, Newton-Raphson, secant method. System of Nonlinear equations, Newton's method for Nonlinear systems. Interpolation and Curve fitting: Introduction to interpolation, Lagrange approximation, Newton and Chebyshev polynomials. Least square fitting,

programming in a couple of modern programming languages e.g. Python and C, …, etc, implement advanced computer oriented numerical methods to solve problems in numerical algebra and differential equations, the application of numerical methods to physical problem from different subfields of physics, Dealing the different physical problems using Monte-Carlo or molecular dynamics methods.

**Objectives:**

After the end of this course the student able to:

- Find numerical solution for mathematical models of physical phenomena,
- Transform a physical problem to a suitable form for numerical treatment, as well as to analyze the calculated result.
- Develop algorithms and use programming language to write efficient larger codes by using existing program libraries
- Outline the essential features of each of the simulation techniques introduced and give examples of their use in contemporary science,
- Develop computer simulation for science problems,& investigate the problems using statistical, graphical & numeric a packages
- Use free-open packages & tools for writing graphical interference, plotting graph and doing Visualizations

**Methodology**

Lectures for those contents which need theoretical explanation and those contents like numerical values/models of the course will be covered in form of exercise and assignments to each student and the students are expected to do these assignments and exercise in the next class. In general, the course covered with lecture, exercise, and presentation of an independently project on some selected topics of the course

**Assessment:**

Successful participation in exercises, Presentation of an independently completed project on some specific topics.

**Chapter – I:** Introduction to computation Computer architectures, Stored program computers,How to map problems into a computational framework, Declarative and Imperative knowledge Programming languages, options of Programming languages, Low and high level languages Interpreted and compiled programing languages

**Chapter – II: Python programming**

Python programming basics - arithmetic operators– library functions – data input and output – relational operators – control statements – looping arrays functions – simple programs – user defined functions – passing arguments file operations ,Arrays in python, Object oriented programming and its structures

**Chapter – *III*:** Numerical methods

Solutions of equations - Simple iterative methods - Newton - Raphson method - Numerical Integration - Simpson's 3/8 rule - Runge Kutta method II order - Solution of Simultaneous equation - Differentiation - Numerical differentiation with interpolation polynomials.

**Chapter – IV:** Python Scientific computing tools, Data processing – toolbox, logical variables and operators – array and X-Y Plotting – simple graphics – data types matrix, string, cell and structure – manipulating of data of different types – file input –output – matplotlib files – simple programs. Numpy and scipy

**Chapter – V:** Statistical Parameters**,** Linear least square fitting – Lagrange's interpolation, cubic spline fitting – arithmetic mean-median-mode-standard deviation-correlation

**Chapter – VI: Introduction to Monte Carlo**

Stochastic phenomena, Some of the basic properties of stochastic process, Stochastic versus deterministic process, Deterministic Randomness , Random Sequences (Theory), Monte Carlo Applications , A Random Walk (Problem), Radioactive Decay (Problem), Decay Implementation and Visualization

**Recommended Literature:**


- S. S. M. Wong, Computational Methods in Physics, World Scientific (1992).
- K. E. Atkinson, Numerical Analysis, John Wiley (Asia) (2004).
- W.H. Press et al.: Numerical Recipes in C (Cambridge University Press) http://library.lanl.gov/numerical/index.html
- C.P. Robert and G. Casella: Monte Carlo Statistical Methods (Springer 2004)
- Tao Pang: An Introduction to Computational Physics (Cambridge University Press)

- Binder, Kurt and Heermann, Dieter W.: Monte Carlo Simulation in Statistical Physics (Springer)

**Phys 642 : Quantum Mechanics** 3

**Preparation:** Theoretical courses at the Bachelor degree level

**Course description:**

Postulates of quantum mechanics, Expectation values, The Schrödinger and Heisenberg representation, The state function propoagator, Angular momentum eigen values and eigen states, Addition of angular momenta, Orbital angular momentum eigen functions, The hydrogen energy eigen values and eigen states, Time independent perturbation theory, Spin orbit coupling, The Zeeman effect, The WKB approximation, Time dependent perturbation, The classical radiation field, The quantum radiation field, transition rates for stimulated and spontaneous emission, The lifetime of an excited atomic state.

**Objective:**

Upon successful completion of this course, the student should be able to :

- Explain some of the fundamentals of quantum mechanics useful for solving various physical problems.
- Apply the acquired skills in quantum mechanics to solve scientific problems.
- Show how quantization arises from boundary conditions and calculate energy levels in simple model systems,
- Discuss the energy levels, angular momenta and spectra of atoms,
- Derive Eigen states of energy, momentum and angular momentum,
- Use perturbation theory to explain different problems at atomic & Molecular level
- Discuss modern application of quantum mechanics

**Methodology**

Lectures for those contents which need theoretical explanation and those contents like numerical values/models of the course will be covered in form of exercise and assignments to each student and the students are expected to do these assignments and exercise in the next class. In general, the course covered with lecture, exercise, and presentation of an independently project on some selected topics of the course

**Assessment:**

Usually regular and successful participation in the exercises. Presentation of an independent and completed project on some specific topics

## Chapter -I : Basic formalism

Wave functions for a free particle - Interpretation and conditions on the wave function - Postulates of quantum Mechanics and the Schroedinger equation - Ehrenfest's theorem - Operator formalism - Linear operators - Self adjoint operators - Expectation Value - Stationary States - Hermitian Operators for dynamical variables - Eigen values and eigen function - Orthonormality - Uncertainty Principle.

## Chapter -II : Applications

Ladder operators and simple harmonic oscillator - Rigid rotator - Step Potential - Particle in a central potential - Particle in a periodic potential - Orbital angular momentum and spherical harmonics - Central forces and reduction of two body problem - Particle in a Spherical well - Hydrogen atom.

**Chapter -III : General formalism**:

Hilbert's space - Dirac notation - Representation theory - Co-ordinate and momentum representations - Time evolution - Schroedinger, Heisenberg and Interaction pictures - Symmetries and conservation laws - Unitary transformations associated with translations and rotations.

**Chapter -IV : Approximation methods**

Time-independent perturbation theory for non- degenerate and degenerate levels - Application to ground state of anharmonic oscillator and Stark effect in Hydrogen - Variation method - Application to ground state of Helium atom - WKB approximation - WKB quantization rule - Application to simple Harmonic Oscillator.

**Chapter -V : Angular momentum and identical particles**

Commutation rules for angular momentum operators - Eigen value spectrum from angular momentum algebra - Matrix representation - Spin angular momentum - Non-relativistic Hamiltonian including spin - Addition of two angular momenta - Clebsch - Gordan coefficients - Symmetry and anti symmetry of wave functions - Pauli's spin matrices.

**Text:**

- Modern Quantum Mechanics by J.J. Sakurai.

**Recommended reference:**

- Quantum Mechanics by B.Craseman and J.D. Powell, Addison Wesley.
- Quantum Mechanics by Cohen and Tannoudji, Volume 1 and 2.

**Phys 671 : Classical Electrodynamics** 3

**Preparation:** Theoretical courses at the Bachelor degree level

**Course description:**

The course includes topics in Gauss law, Poisson and Laplace quations, Boundary value problem, Green´s functions, Method of images, Orthogonal functions and the solution of boundary value problems, Legendre and associated Legendre polynomials and Spherical harmonics, Multipole expansion, Dielectric media and displacement vector, Continuity equation, Magnetostatics in vacuum and media, Faraday's law of induction, Maxwell's equations in vacuum and media, Scalar and Vector potentials, Gauge transformations, Wave equation, Electromagnetic energy densities and Poynting's theorem, Rotations and discrete symmetries, Special relativity and the Lorentz group, Covariant formulation of electrodynamics. Solutions of Maxwell's equations: Plane waves, Greens functions, Jefimenko's equations, Radiation from oscillating sources, Dipole fields, Reflection and Refraction of electromagnetic waves.

**Objective:**

Upon successful completion of this course, the student should be able to :

- Describing electromagnetic waves and wave propagation and their interaction with matter.
- Demonstrate skills in the use of vector algebra and analysis, using Maxwell's equations in integral and differential form.
- Demonstrate electromagnetic concepts in other fields of physics such as electronics, condensed matter physics and laser physics.
- Identify the relationship between magnetic field of steady current and magnetic vector potential
- Explain Conservation laws for systems of charges and electromagnetic fields.

**Methodology**

Lectures for those contents which need theoretical explanation and those contents like numerical values/models of the course will be covered in form of exercise and assignments to each student and the students are expected to do these assignments and exercise in the next class. In general, the course covered with lecture, exercise, and presentation of an independently project on some selected topics of the course

**Assessment:**

Usually regular and successful participation in the exercises. Presentation of an independent and completed project on some specific topics.

**Chapter - *I***

Homogeneous and inhomogeneous Lorentz groups, Spacetime rotations, rapidity, Proper, improper, orthochronous, antichronous Lorentz groups, Light cone interpretation of Lorentz transformations, Four-vectors, orthogonality, Four-tensors, Jacobians, Contravariant and Covariant tensors, Trace of a tensor, Contraction, Symmetric and Antisymmetric tensors, Inner and outer products, Quotient Law, Metric tensor, Pseudotensors, completely antisymmetric unit tensor, Four-velocity, fourmomentum, four-acceleration, Minkowski force.

**Chapter – *II***

2-Form electromagnetic field strength tensor, Covariant formulation of Maxwell's field equations with gauge invariance, Lorentz force equation in covariant form, Transformation of electromagnetic fields as tensor components, Invariants of the field, Canonical approach to electrodynamics, Lagrangian and Hamiltonian formulation for a relativistic charged particle in external electromagnetic field, Canonical and Symmetric Stress Tensors, Conservation laws, Solution of the wave equation in covariant form, Invariant Green function.

**Chapter – *III***

Retarded and advanced potentials, Lienard-Wiechert potentials for a moving point charge, Fields produced by a charge in uniform and accelerated motion, Radiated power, Larmor's formula and its relativistic generalization, Angular distribution of radiation due to an accelerated charge, bremsstrahlung, synchrotron radiation, Thomson scattering of radiation, Thomson cross section, Multipole expansion of electromagnetic fields, Properties of multipole fields, Energy and Angular momentum of multipole radiation.

**Chapter – *IV***

Radiation damping, Radiative reaction force and its derivation, Difficulties with classical Abraham-Lorentz model, Integro-differential equation of motion, Preacceleration, Line breadth and Level shift of an oscillator, Scattering by free and bound electrons, Rayleigh Scattering, Frequency dependence of total cross section, Resonance fluorescence.

**Text:** Classical Electrodynamics by J.D. Jackson ($3^{rd}$ Edition).

**Recommended reference:**

- D. J. Griffiths, Introduction to Electrodynamics, Pearson Prentice Hall, 3nd edition (1999).
- J.R. Reitz., F.J. Milford and R.W. Christy, Foundations of Electromagnetic Theory, 3rd edition, Narosa Publishing House (1979).
- E.C. Jordon and K.G. Balmain, Electromagnetic Waves and Radiating Systems, 2nd edition, Prentice Hall of India (1998).

**Phys 600:** Research Methodology 2

**Course Description**

This course aims to demonstrate the writing process and teaches the fundamentals of effective scientific writing. It includes basic principles of Scientific Research Identification of the problem, Literature survey, Reference collection, Familiarity with ideas and concept of investigation, Internet Browsing, Drawing Inferences from data Qualitative and Quantitative analysis, Art of writing a Research paper and Thesis Power point presentation. Instruction will focus primarily on the process of writing and publishing scientific manuscripts using latex systems.

**Objective:**

Upon successful completion of this course, the student should be able to :

- Differentiate the different types of research approaches including qualitative, quantitative and systematic review.
- Explain how to formulate a research question and design a project.
- Describe the role of peer review and user involvement in research design.
- Appraise research and research proposals with respect to costs and benefits
- Explain the application of common statistical techniques for dealing with data.
- Explain a range of methods to disseminate research findings and discuss the advantages and disadvantages of each method

**Methodology**

The course will be presented in two segments: Part (1) teaches students how to write effectively, concisely, and clearly and part (2) takes them through the preparation of an actual scientific manuscript or grant.

**Assessment:**

Usually regular and successful participation in the exercises. Presentation of an independent and completed project on some specific topics

**Chapter – *I*** :

Principles of Scientific Research Identification of the problem - Literature survey - Reference collection - Familiarity with ideas and concept of investigation - Internet Browsing

**Chapter – *II:***

Drawing Inferences from data - Qualitative and Quantitative analysis - Results - Seminar

**Chapter – *III***

Synopsis writing - Art of writing a Research paper and Thesis - Power point presentation - OHP Presentation.

**Required Texts:**

- J. Andersson B.H. Burston and M. Poole, 1977, Thesis and Assignment writing, Wiley Eastern, London.
- Rajammal. P. Devadas, 1976, A hand book of methodology of research, RMM Vidyalaya Press.
- Sin and Syntax, Constance Hale
- Successful Scientific Writing: A step-by-step guide for biomedical scientists, Matthews and Bowen

## 17.2. Specialization Courses

# Statistical and computational physics

| | | |
|---|---|---|
| Phys 622 | Basic Methods of Stochastic Processes | **3** |
| Phys 623 | Approximate Methods in Stochastic Processes | **3** |
| Phys 624 | Distributed Systems and Bi-stability | **3** |

**Phys 622: Basic Methods of Stochastic Processes 3**

## Course description:

Probability, Probability density function of a stochastic random variables, Random walks, Brownian motion, Markov processes and Markov chains, discrete and continuous Markov process, Stochastic differential equations, Langevin equation, Kolmogorov forward and backward equations, Fokker-Planck equation.

***Objective***

Upon successful completion of this course, the student should be able to :

- Develop models which will be explained by random walks
- Extract important parameters of stochastic process
- Identify some physical systems which shows stochastic behaviors
- Demonstrate markov process using Stochastic differential equations
- Treat a single physical system using both Stochastic differential equations, Langevin equation

**Chapter – *I***: Probability Concepts, Events and sets of events, Probability and probability axioms, Random variables, Joint and conditional probabilities, dependence and independence Relationship between joint probabilities of different orders, Mean values and probability density, Determination of probability density by means of arbitrary function, Moments, correlations and covariance, The law of large numbers, Characteristic functions, The different probability distribution functions

**Chapter – *II:*** Introduction to stochastic process

The different physical systems in our environment, Deterministic versus stochastic process, Main characteristics of stochastic process, Some example of stochastic process such as, Brownian particles, Random walk, Describe mathematically these process, Langevin equation, Birth death process

**Chapter – *III*** : Markov process

The main characteristics of Markov process, The main characteristics of stochastic process, The Chapman-Kolmogrov equation, Discrete and continuous state space, Continuity in stochastic process, Mathematical description of Continuity in stochastic process, Derivation of the differential Chapman-Kolmogrov equation, Different condition and its in stochastic process, Jump process, diffusion process and determistic process

**Chapter – *IV***: Time development of Markov process

Forward and Backward Kolmogrov equation, Stationary and homogenous Markov process, Approaches to Stationary systems, Example of Markov process, The Wiener process, The random walks in one dimension, Poisson process, Ornstein-Uhlenbeck process

**Chapter – *V***: Ito calculus and stochastic differential equations

Definition of stochastic integration, The Stratonovich integral, Properties of the Ito stochastic integral, Stochastic differential equations, Ito stochastic differential equations, Connection between Fokker Planck equation and stochastic differential equations, Statonovich stochastic differential equations, Some examples and their solution

**References**


- Handbook of Stochastic Methods by C.W. Gardiner, 3rd Ed., Springer Verlag (1990).
- Stochastic Processes in Physics and Chemistry by N.G. van Kamper, 2nd Ed., Elesevier (1992).


**Phys 623: Approximate Methods in Stochastic Processes 3**

## Course description:

Stochastic process and their dynamics, Master equation. Detailed balance, solutions of Master equation, Master equation and Jump processes. Birth-death master equations and Stationary Solutions, Boundary conditions for Birth-death Processes, Approximation of Master Equations by Fokker-Planck Equations. Mean first passage time calculation using master equation and FPE.

***Objective***

Upon successful completion of this course, the student should be able to :

- Describe stochastic systems with Master equation
- Compare these two equation Master equation, and Jump processes
- Apply Birth-death master equations and Stationary Solutions, some physical systems
- Demonstrate Master Equations and by Fokker-Planck Equations for those stochastic process

- Identify the main difference of these two equations

**Chapter – *I*** : The diffusion process

Dealing diffusion process, The two main methods to approximate diffusion process, Small noise and adiabatic elimination method, Small noise perturbation theories, Small noise expansion and stochastic differential equation, Stationary and homogenous process, Mean, variance and time correlation function

**Chapter – *II:*** Fokker Planck equation

Small noise expansion and Fokker Planck equation, Main parameters of Fokker Planck equation, Equations for moments autocorrelation function, Stationary systems and auto correlation functions, Describe systems with Fokker Planck equation

**Chapter – *III***: Adiabatic elimination of fast variables

The main characteristics of Markov process

Dynamic systems and stochastic differential equation Operators and projectors

Laplace Transform, Boundary conditions, Long-Time perturbation theory, Short –Time behavior, White Noise process

**Chapter – *IV***: Mater equation and jump process

Birth-Death master equation- for one variable, Detail Balance interpretation, Rate equations, Chemical reaction, Generating functions, a chemical bi stable system

**Chapter – *V***: Master and Fokker Planck equations

Approximation of Master by Fokker Planck equations, Jump process approximation of a diffusion process, General approximation of a diffusion process, Birth-Death process and master, Kramer_Moyal expansion, Vankampen system expansion Some examples, Kutz's thermo, Critical fluctuations, Boundary condions for master and Birth-Death process, Mean first passage time

## References


- Handbook of Stochastic Methods by C.W. Gardiner, 3$^{rd}$ Ed., Springer Verlag (1990).
- Stochastic Processes in Physics and Chemistry by N.G. van Kamper, 2$^{nd}$ Ed., Elesevier

**Phys 624: Distributed Systems and Bi-stability 3**

## Course description:

Spatially distributed systems, reaction diffusion systems and their description with Langevin and Master equation, consequence of such equation in spatial and temporal correlation structure that arise near instability points, the connection between local and global description of systems, Bistability, and Escape problems, evaluation of the mean first passage time as well as mean waiting time of a particle in stable or bistable state.

## Objectives

Upon successful completion of this course, the student should be able to :

- Show how the diffusion and reaction diffusion in any physical systems could be explained with Langevin and Master equation,
- Calculate the mean time that a particle take to travel from one point to another
- Identify the connection between local and global description of systems
- Specify the stable and bistability of a physical system
- Handle some Escape problems

**Chapter –** ***I*** : The different physical systems

Reaction diffusion process or systems, Reaction diffusion and spatially distributed systems Describe them mathematically, Functional Fokker Planck equation, Multivariate master equation, Diffusion, Continuum form of diffusion and master equation

**Chapter –** ***II:*** Spatial and Temporal correlation

Spatial and Temporal correlation structures, Reaction and its Spatial correlation, Space time correlation, Nonlinear model, Nonlinear model with second order phase transition, Connection between local and global description, The Boltzman master equation

**Chapter –** ***III*** : Biastability

Systems which have two or more stable states, How stable these states relative one another

How long the system does it takes to transfer itself from one state to the other, Describing these state changing process, Diffusion in a bi-stable double well potential, one variable, Calculating the diffusion coefficient (D), The different Behavior of D

**Chapter – *IV***: Biastability in multivariable systems

Distribution of Exit points, Boundary conditions, The exit time solution at these boundary conditions, A asymptotic analysis of mean exit times, Kremers method in several dimensions Brownian in a double well potential and its mean exit time

**Chapter – *V***: First passage time

Exact one dimensional first passage time , First passage time with Smoluski equation, Kramers result of first passage time, Corrected Smoluski equation, Jump process approximation of a diffusion process, General Expression of jump process and first passage time, Some examples in calculating first passage time of a system, Mean first passage time

### References


- Handbook of Stochastic Methods by C.W. Gardiner, 3rd Ed., Springer Verlag (1990).
- Stochastic Processes in Physics and Chemistry by N.G. van Kamper, 2nd Ed., Elesevier (1992).


## Medical physics

| **Course Number** | **Course Name** | **Credit Hours** |
|---|---|---|
| Phys 686 | Introduction to medical Physics I | **3** |
| Phys 687 | Introduction to medical Physics II | **3** |
| Phys 688 | Image-Based Anatomy | **3** |

**Phys 686: Introduction to medical Physics I 3**

**Requirements:**

Basic physics of both theoretical and experimental courses at undergraduate level

## *Course description:*

**The Physics of Diagnostic Radiology**: Physics of medical imaging, the production of ionization radiation, Basic instruments for production these radiation, the physics behind this technology

**Imaging techniques**: radiography, fluoroscopy, and mammography.

**Physics of Planar Imaging** (***Nuclear medicine):*** Topics covered include: basic fundamental concepts of nuclear physics and radioactivity, nuclear detectors, Introduction to the instrumentation and physics used in clinical nuclear medicine with an emphasis on detector systems, gamma cameras. **Tomographic reconstruction**: Includes conceptual, mathematical / theoretical, and practical clinical physics aspects. **Computed tomography: X-ray computed tomography,** X-ray detectors in CT, CT Equipment, Clinical use of this instrument. Imaging, Image quality and radiation dose and its protection.

## Objective:

Upon successful completion of this course, the student should be able to:

- Demonstrate the competence and understanding of nuclear structure, nuclear interactions, nuclear decay and nuclear models by solving problems related to these concepts,
    - Solve several problems concerning nuclear decay and nuclear structure.
- State the theories of various modes of nuclear decay, nuclear forces and nuclear structure so that they can solve the variety problems connected with nuclear Physics,
- Discuss the physical laws, principles and operations of nuclear structure and nuclear models

**Chapter -I Ionizing radiation dose**

Absorbed dose and kinetic energy released to matter

Effects of ionizing radiation on living tissue

Equivalent dose and effective dose

Radiation risk

Population dose from natural and artificial sources

**Chapter -II Radiography with x-rays**

Construction, function and operation of computed and

digital radiographic systems.

X-ray tube and x-ray beam

Image receptors for computed and digital radiography

Scatter rejection

Contrast media-iodine, barium and air

Dual energy radiography

Film-screen radiography

Mammography

Radiographic tomography and tomosynthesis

**Chapter -III Fluoroscopy with x-rays**

Construction, function and operation of a fluoroscopy system

Image receptor-image intensifier and flat panel detector

Scatter rejection

Automatic brightness control

Image digitization

Angiography with contrast media, including digital subtraction techniques

**Chapter -IV Safety in radiography and fluoroscopy with x-rays**

Radiation detectors and dose meters

Measurement of absorbed dose and dose rate in air

Estimation of patient absorbed dose

Typical dose-area products, entrance surface doses and effective doses in radiography & fluoroscopy. Detector dose indicators Factors affecting radiation dose

Time, distance and shielding for dose reduction

Children and pregnant patients

Estimation and control of radiation dose to staff and members of the public

Operational dose quantities, Personal dosimetry, Pregnant staff

**Chapter –V Tomographic reconstruction**

Angular and linear sampling of projection data

Filtered back-projection and reconstruction filters

Iterative reconstruction

**Chapter- VI X-ray computed tomography**

Construction, function and operation of a CT scanner

Helical and multi-slice scanners

Image reconstruction

CT angiography, CT fluoroscopy and gated imaging

CT perfusion

Radiation dose to patients, staff and the public

Radiation safety and factors affecting radiation dose

***Book for References:***


- Medical Imaging Physics, William R. Hendee (A JOHN WILEY & SONS, 2002)
- The Essential of Physics of Medical Imaging, Jerrold T. Bushberg, second Edition (2002)
- Fundamentals of Medical Imaging, Paul Suetens, Second Edition(2009)
- Training modules in medical radiation physics, Emerald web site

**Phys 687: Introduction to medical Physics II 3**

## Course description

**Physics of *Nuclear medicine:*** Topics covered include: Introduction to the instrumentation and physics used in clinical nuclear medicine with an emphasis on gamma cameras used SPECT, PET and SPECT /CT or PET /CT system. **Magnetic Resonance Imaging (MRI)**; Physics and technology of magnetic resonance imaging (MRI), emphasizing techniques employed in medical diagnostic imaging. Major topics: physics of MR, pulse sequences, imaging techniques, artifacts, and spectroscopic localization. **Diagnostic Ultrasound Physics**; Plane wave propagation; reflection and transmission at interfaces; acoustical properties of biological media; transducer operation and beam patterns; gray scale, Doppler and color-flow instruments; acoustical power and intensity levels for clinical equipment.

## Objective

Upon successful completion of this course, the student should be able to:

- Identify the basic difference between planar and tomographic imaging techniques
- Explain the basic physics under Magnetic resonance imaging modality
- Demonstrate how sound uses in Diagnostic Ultrasound instruments
- Point of the major difference/ similarity of images from PET /CT, MRI and Ultrasound

**Chapter -I Radioactivity**

Nuclear stability
Mechanisms of radioactive transformation
Nuclear energy states and gamma emission
Activity and radioactive decay
Natural radioactivity
Artificial radionuclides and their production
Radiopharmaceuticals and their production

**Chapter - II Planar radionuclide imaging**

Construction, function and operation of a digital gamma camera

Imaging collimators

Image receptor-scintillation detector

Scatter rejection

Mechanisms and quantification of radiopharmaceutical localization

Static, whole-body, dynamic and gated imaging

**Chapter - III Ethiopian framework for ionizing radiation protection**

Hierarchy of recommendations, legislation and guidance

Justification, optimization and dose limitation

Ionizing Radiations Regulations and Approved Code of Practice

Risk assessment, restriction of exposure and dose monitoring

Radiation Protection Adviser and Radiation Protection Supervisor

Local Rules and work procedures

Designation of working areas and classification of workers

Dose limits and dose constraints

Notification and reporting of radiation incident

**Chapter - IV Single photon emission computed tomography**

Construction, function and operation of a rotating multi-head gamma camera

Image reconstruction

SPECT/CT Radiation safety and factors affecting radiation dose

Typical activities and effective doses to patients, staff and the public

**Chapter - V Positron emission tomography**

Construction, function and operation of a multi-detector ring system

2D and 3D acquisition Image reconstruction

Standardized uptake value (SUV)

PET/CT

Radiation safety and factors affecting radiation dose

Typical activities and effective doses to patents, staff and the public

**Chapter – VI Nuclear magnetic resonance**

Nuclear spin angular momentum and nuclear magnetic moment

Bulk magnetization and the effect of magnetic field strength

Precession in a magnetic field and the Larmor equation

Resonance with radiofrequency pulses

Relaxation mechanisms and relaxation times

Free induction decay signal

**Chapter - VII Magnetic resonance imaging**

Construction, function and operation of a superconducting MRI scanner

Permanent and resistive magnets

Radiofrequency receiver coils

Spin-echo pulse sequence

Spatial localization of the signal

K-space, image acquisition and image reconstruction

Multi-echo, fast spin-echo and single shot techniques

Gradient echo imaging-basic spoiled and non-spoiled techniques

Tissue suppression methods- short TI inversion recovery (STIR), fluid attenuated inversion recovery (FLAIR) and fat saturation

Standard gadolinium extracellular space contrast agents

Magnetic resonance angiography (MRA)

Basic principles of diffusion techniques and diffusion weighted imaging

Dynamic contrast enhancement and perfusion imaging

Principles of magnetic resonance spectroscopy (MRS)

Spatial misregistration, chemical shift, susceptibility, motion, flow and other artifacts **Safety in magnetic resonance imaging**

Static magnetic field: projectiles, induced voltage, implants

Fringe field and controlled area

Time–varying gradient, fields–eddy currents, stimulation, implanted devices, acoustic noise

Radiofrequency fields – specific absorption rate, heating

Safety of patients, staff and members of the public

Pregnant patients

Shielding and imaging room design

Safely Guidelines for Magnetic Resonance Imaging Equipment in Clinical Use

**Chapter - X Physics of ultrasound**

Nature and properties of ultrasound

Propagation and interaction of ultrasound in matter

Scattering of ultrasound waves

Piezoelectric effect

Design and construction of ultrasound transducers

Continuous and pulsed wave ultrasound

Beam shape from a single transducer and an annular array

The Doppler effect

**Chapter – XI Ultrasound imaging**

A-mode and B-mode imaging

Time-gain compensation

Construction, function and operation of a real-time B-mode scanner

Image acquisition and reconstruction

M-mode

Microbubble and particle suspension contrast agents

Harmonic imaging

Measurement of flow with continuous and pulsed Doppler ultrasound

Duplex scanners

Colour-flow and power Doppler imaging

***Book for References:***


- Magnetic Resonance Image Characteristics, Perry Sprawls
- Training modules in medical radiation physics, Emerald web site
- Fundamental of Nuclear Physics – N. A. Jelley (Cambridge Uni. Press,1990)
- Medical Imaging Physics, William R. Hendee (A JOHN WILEY & SONS, 2002)
- The Essential of Physics of Medical Imaging, Jerrold T. Bushberg, second Edition (2002)
- Fundamentals of Medical Imaging, Paul Suetens, Second Edition(200)

**Phys 688: Image-Based Anatomy 3**

## Course description

A systemic approach to the study of the human body from a medical imaging point of view. This medical physics course will focus on major organ systems and disease areas: skeletal, respiratory, cardiovascular, digestive, and urinary systems, breast and women's issues, head and neck, and central nervous system. Lectures are reinforced by examples from clinical two- and three-dimensional and functional imaging (CT, MRI, PET, SPECT, U/S, etc.).

## Objective

Upon successful completion of this course, the student should be able to:

- Identify the major part or organ of a human anatomy
- Demonstrate the main techniques of imaging these human organs
- Explain the main relationship between human organs
- Describe the main characterstic of human organs and what kind of imaging modalities we use to visualize them

***Book for References:***

- Clinically Oriented Anatomy.
- Applied radiological Anatomy
- Manual of clinical oncology 6th edition. UICC. Springer-Verlag. 1994
- Atlas de Histologia y organografia microscopica. J. Boya. Panamericana. 1998.

# Nuclear physics

| | | |
|---|---|---|
| Phys 681 | Advanced Nuclear Physics-I | **3** |
| Phys 682 | Advanced Nuclear Physics-II | **3** |
| Phys 683 | Nuclear Techniques | **3** |

**Phys 681**: **Advanced Nuclear Physics-I 3**

**Course description**

Modes of radioactive decay of nucleus, Alpha decay and Gamow's theory of alpha decay, Beta decay and Fermi theory of beta decay, electron capture, Parity and non-conservation of parity in weak interactions, Electromagnetic decay, Internal conversion, Selection rules for gamma decay, Properties of nuclear forces, Deuteron problem, n-p and p-p scattering, Exchange character of nuclear forces, S-wave effective range theory, Liquid drop model of the nucleus, Shell model picture of nucleus and explanation of properties of nuclear levels, Collective model and unified model of the nucleus.

***Objective***

Upon successful completion of this course, the student should be able to :

- Demonstrate the competence and understanding of nuclear structure, nuclear interactions, nuclear decay and nuclear models by solving problems related to these concepts,
    - Solve several problems concerning nuclear decay and nuclear structure.
- State the theories of various modes of nuclear decay, nuclear forces and nuclear structure so that they can solve the variety problems connected with nuclear Physics,
- Discuss the physical laws, principles and operations of nuclear structure and nuclear models

**Books for study:**

- K. S. Krane, 1987, Introductory Nuclear Physics, Wiley, New York.
- Introductory Nuclear Physics, Samuel S.M.Wong, Prentice-Hall International
- Introductory Nuclear Physics, P.E.Hodgson et al , Clarendon press, Oxford

- Radiation detection and Measurement, F.Knoll, John Wiley & sons.
- Techniques for Nuclear and Particle Physics Experiments by W. R. Leo.

## References


- Atomic Nucleus, R.D. Evans, Mc Graw Hill.
- Theoretical Nuclear Physics, J.M. Blatt and V.F. Weisskoff, John Wiley and Sons.
- Introductory Nuclear Physics, Samuel S.M. Wong, Prentice-Hall International.
- Physics of the Nucleus, M.A. Preston, Addison-Wesley.
- Introductory Nuclear Physics, D. Halliday, John Wiley and Sons.
- Particle Accelerator, M.S. Livingston and J.P. Blewett, McGraw Hill Book Co.
- Nuclear Physics, S.B. Patel, John Wiley and Sons.


**Phys 682**: **Advanced Nuclear Physics-II** **3**

**Course description**

Production of various types of nuclear probes viz. neutrons, alpha particles, protons, electrons and Heavy Ions, Radioactive sources for alpha and neutrons, Linear accelerators for protons and electrons, Cyclic accelerators, Cyclotron and synchrotron, Betatron and betatron oscillations, Nuclear reactions, Elastic and inelastic processes and nuclear crops-section, Partial wave and quantum mechanical analysis of nuclear cross-sections, Compound nucleus theory, level density and statistical model, Resonances, Potential scattering and resonance scattering, Breit-Wigner formula for a resonance, Optical model theory, Pre-equilibrium decay in nuclear reactions and direct reactions, Reactions induced by heavy ions, R-matrix theory of the nuclear reactions.

***Objective***

Upon successful completion of this course, the student should be able to :

- Solve several problems concerning the different nuclear reactions.
- Describe the different methods of radioisotope production
- Demonstrate the compound nucleus theory, Optical model theory
  - Explain Resonances, Potential scattering and resonance scattering, Breit-Wigner formula for a resonance

## References


- Atomic Nucleus, R.D. Evans, McGraw Hill.
- Theoretical Nuclear Physics, J.M. Blatt and V.F. Weisskoff, John Wiley and Sons.
- Introductory Nuclear Physics, Samuel S.M. Wong, Prentice-Hall International.
- Physics of the Nucleus, M.A. Preston, Addison-Wesley.
- Introductory Nuclear Physics, D. Halliday, John Wiley and Sons.
- Particle Accelerator, M.S. Livingston and J.P. Blewett, McGraw Hill Book Co.
- Nuclear Physics, S.B. Patel, John Wiley and Sons.


***Phys 683:* Nuclear Techniques 3**

**Course description**

Interactions of electromagnetic radiations with matter, Photo-electric effect, Compton effect and pair production, Resonant absorption of electromagnetic radiations by atom and nucleus, Mossbauer effect and some of its applications, Scintillation spectrometer, Solid state charged particle and gamma ray spectrometer and analysis of the energy spectrum, Nuclear electronics; pre-amplifier, amplifier, S.C.A. and M.C.A., Coincidence circuit and scalars, Interaction of heavy charged particles with matter, Stopping power and range-energy relations, Various types of gas filled detectors, Radioisotopes and their applications, Chemical and biological effects of radiations, Neutron activation analysis and its applications

## Objective

Upon successful completion of this course, the student should be able to:

- Identify the various modes of Interaction of nuclear radiations with matter,
- Detection of different types of radiations and various applications of Nuclear radiations
- Solve the variety of problems connected with nuclear radiations and their detections.

## References


- Nuclear Radiation Detectors, W.J. Price, McGraw Hill.
- Alpha beta and gamma ray spectroscopy, K. Siegbahn, North Holland Publishing Co.
- Nuclear radiation detectors, S.S. Kapoor and V.S. Ramamurthy, Wiley Eastern.
- Radiation detection and measurement, F. Knoll, John Wiley and Sons.


**Modes of Evaluation**

For each course within the module, the students' performance will be assessed through:

- Written examinations involving various types of questions, Viz. very short answer, short answers, derivations and essay type.
- Problem sheets can be given as home assignment. Problems based on these assignments may be the part of written examinations.

Each course will be nearly 4 weeks duration. After two weeks teaching there will be one examination on Monday. After further two weeks teaching there will be another examination. Both the examination carry 40 marks each. Home assignment carries 20 marks.

# Quantum field theory

| **Course Number** | **Course Name** | **Credit Hours** |
|---|---|---|
| Phys 741 | Quantum Field Theory I | **3** |
| Phys 742 | Quantum Field Theory II | **3** |
| Phys 743 | Quantum Field Theory III | **3** |

**Phys 741: Quantum Field Theory I 3**

**Course description**

Relativistic wave equations: Klein-Gordon equation, Free particle solutions, Dirac equation, Eigen functions and eigenvalues, Negative energy states, Anti-particles, Covariant form of Dirac equation, Dirac matrices, Invariance under Lorentz-transformations, 3-dimensional rotations, parity transformations and charge conjugation; Classical Fields: Lagrangian field theory, Gauge theories, Global and local gauge invariance, Classical scalar, Complex scalar, Dirac and electromagnetic fields and their equations of motion; Quantum Fields: Quantization of Scalar, Dirac and electromagnetic fields, Free propagators for Scalar, Dirac and electromagnetic fields, Interacting quantum fields, Wick's theorem, S-matrix expansion, Feynman diagrams.

**Objectives**

Upon completion of this course, the student is able to:

- Demonstrate basic knowledge of relativistic wave equations and Quantum Electrodynamics
- Calculate transition amplitudes and cross sections using Feynman diagrams for various processes at tree-level.
- Apply the techniques of renormalization in Quantum Electrodynamics and also calculate transition amplitudes and cross sections for various fourth-order processes (involving loops) in Quantum Electrodynamics.
- Use lagrangian formulation of non-abelian gauge theories like QCD and also Feynman rules and calculation of some elementary processes in QCD.
- Identify weak interactions, electro-weak theory, Weinberg-Salam model and the Standard model of particle physics.

## References


- Quantum Field Theory by M.E. Peskin and D.V. Schroeder.
- Advanced Quantum Mechanics by J.J. Sakurai.
- Relativistic Quantum Mechanics by J.D. Bjorken and S.D. Drell.
- Quantum Field Theory by L.H. Ryder.


**Phys 742: Quantum Field Theory II 3**

## Course description

Cross sections for Moller scattering, Bhabha scattering, Compton scattering, Pair annihilation, Pair creation, Crossing symmetry; Renormalization: Self energy of electron, Vacuum polarization and Vertex corrections, Charge and mass renormalization in Quantum

Electrodynamics (QED), QED coupling constant and its variation; Non-abelian gauge theories: Yang-Mills theory: SU(2) gauge invariance, Quantum Chromodynamics (QCD): SU(3) gauge invariance, SU(3) Colour group, Gell-Mann matrices, Feynman rules for QCD, Quark-quark and quark-anti-quark interactions, Calculation of color factors, Pair annihilation (qq-bar -> gg) cross section in QCD.

**Objectives**

Upon completion of this course, the student is able to:

- Show higher-order processes (beyond tree level) in Quantum Electrodynamics and also the techniques of renormalization.
- State non-abelian gauge theories like QCD.
- Using renormalization in Quantum Electrodynamics to calculate transition amplitudes and cross sections for various fourth-order processes (involving loops) in Quantum Electrodynamics.
- Explain lagrangian formulation of non-abelian gauge theories like QCD and also Feynman rules and calculation of some elementary processes in QCD.

**References**


- Quantum Field Theory by M.E. Peskin and D.V. Schroeder.
- Advanced Quantum Mechanics by J.J. Sakurai.
- Relativistic Quantum Mechanics by J.D. Bjorken and S.D. Drell.
- Quantum Field Theory by L.H. Ryder.
- Quarks and Leptons by F. Halzen and A.D. Martin.
- Quarks, leptons and gauge fields by K. Huang.


**Phys 743: Quantum Field Theory III 3**

## Course description

The e+e- annihilation to hadrons, Derivation of e+e- □gqq-bar cross section, Asymptotic freedom and confinement in QCD; Spontaneous symmetry breaking: Higgs mechanism; Weak

Interactions: Parity violation and V-A form of weak current, Muon and pion decays, Charged current neutrino-electron scattering, neutrino-quark scattering, neutral currents, Weak mixing angles; Electro-Weak theory: Weak iso-spin and hypercharge, Feynman rules for electro-weak interactions, Weinberg-Salam model, Higgs mechanism, Massive gauge bosons W and Z.

**Objectives**

Upon completion of this course, the student is able to:

- Demonstrate some of the weak interactions, electro-weak theory and the Weinberg-Salam model.
- Use these theories in a number of areas like particle physics, nuclear theory.
- Describe the Weinberg-Salam model and the Standard model of particle physics.

**References**


- Quantum Field Theory by M.E. Peskin and D.V. Schroeder.
- Quantum Field Theory by L.H. Ryder.
- Quarks and Leptons by F. Halzen and A.D. Martin.
- Quarks, leptons and gauge fields by K. Huang.
- Gauge theories in particle physics by I.J.R. Aitchison and A.J.G. Hey.


## Atmospheric Physics

| Course Number | Course Name | Credit Hours |
|---|---|---|
| Phys 661 | Introduction to Atmospheric Physics | **3** |
| Phys 662 | Radiative Transfer in the Atmosphere | **3** |
| Phys 663 | Inverse Methods for Atmospheric Sounding | **3** |

**Phys 661: Introduction to Atmospheric Physics 3**

## Course description

Earth’s atmosphere-Its origin, Composition and properties, Heat and thermodynamics of the atmosphere, Physics of clouds and precipitation, Physics of radiation-fundamental laws, Atmospheric dynamics, Introduction to numerical methods in atmospheric physics.

**Objectives**

Upon completion of this course, the student is able to:

- State some of the fundamental laws of physics that govern atmospheric kinematics, dynamics and thermodynamics.
- Apply these theoretical concepts to analyze and interpret observations of real atmospheric systems as well as to develop simple conceptual models of atmosphere at different spatial and temporal scales in order to simulate the system and understand them.
- Identify interaction of radiation with matter and describe them with physical model measured electromagnetic signal after attenuation by the atmosphere.

## References


- Introduction to Theoretical Meteorology, Seymour L. Hess, Henry Holt and Company, New York.
- An introduction to Dynamics Meteorology, Jmaes R. Holton, Third edition, Academic Press INC.
- The Earth's Atmosphere: Its Physics and Dynamics, Kshudiram Saha, Spring-Verlag, Berlin.
- Fundamentals of Atmospheric Modeling, 2nd Edition, Mark Z. Jacobson.
- Essentials of Meteorology-An Invitation to the Atmosphere, 3rd Edition, C. Donald Ahrens
- Dynamics of the Atmosphere: A Course in Theoretical Meteorology, Wilford Zdunkowski and Andreas Bott, Cambridge University Press.


**Phys 661: Radiative Transfer in the Atmosphere 3**

## Course description

Radiometric quantities, Molecular transitions, Absorption by gases, The radiative transfer equation, Transmission in individual spectral lines and in bands of lines, Light scattering theory for spheres, Optical properties of earth-atmosphere system.

**Objectives**

Upon completion of this course, the student is able to:

- Solve practical problems which often arise in interpretation of radiation measurement from new ground or space based instrumentations or feasibility study of design of new instrumentations.
- Apply these theoretical concepts to analyze and interpret observations of real atmospheric systems as well as to develop simple conceptual models of atmosphere at different spatial and temporal scales in order to simulate the system and understand them.
- Identify interaction of radiation with matter and describe them with physical model measured electromagnetic signal after attenuation by the atmosphere.

## References


- Introduction to Atmospheric Radiation, Kuo-Nan Liou.
- Molecular Spectroscopy, Jeanne L. McHale, Prentice-Hall, Inc.
- Basic Atomic and Molecular Spectroscopy, J. Michael Hollas, The Royal Society of Chemistry.
- Molecular Physics: Theoretical Principles and Experimental Methods, Wolfgang Demtroder, Wiley-VCH Verlag GmbH and Co. KGaA.
- Non-LTE Radiative Transfer in the Atmosphere, M. Lopez Puertas and F. W. Taylor, World Scientific.


**Phys 661: Inverse Methods for Atmospheric Sounding 3**

## Course description

Introduction to inverse methods, Information aspects of atmospheric measurements, Error analysis and characterization in inverse problems, Optimal linear inverse methods, Optimal methods for non-linear inverse problems, Designing an observing system, Testing and validating an observing system.

**Objectives**

Upon completion of this course, the student is able to:

- Use practical methods of inferring some atmospheric state from radiation measurements, and physics employed in remote detection techniques including in other disciplines and applications.
- Apply mathematical Inversion techniques, for the description of various observing system of the atmosphere.
- solve inverse problems which often arises in indirect measurement systems using numerical and programming skills

## References


- Inverse methods for Atmospheric Sounding: Theory and Practice, Clive D. Rodgers, World Scientific.
- Introduction to Mathematics of Inversion in Remote Sensing and Indirect Measurements, S. Twomey, Dover Publications, INC.
- Geophysical Inverse Theory and Regularization Problems, M.S. Zhdanov.
- Introduction to Atmospheric Radiation, Kuo-Nan Liou.
- Molecular Spectroscopy, Jeanne L. McHale, Prentice-Hall, Inc.
- Molecular Physics: Theoretical Principles and Experimental Methods, Wolfgang Demtroder, Wiley-VCH Verlag GmbH and Co. KGaA.
- Non-LTE Radiative Transfer in the Atmosphere, M. Lopez Puertas and F. W. Taylor, World Scientific.

# Condensed matter

| Course Number | Course Name | Credit Hours |
|---|---|---|
| Phys 751 | Principles of Condensed Matter | **3** |
| Phys 752 | Electronic Structure of Condensed Matter | **3** |
| Phys 753 | Advanced Condensed Matter Theory | **3** |

**Phys 751: Principles of Condensed Matter 3**

## Course description

Energy levels in periodic potential and Bloch theorem, Electrons in a weak periodic potential, Tight binding model, Pseudopotential method, and other methods of calculating band structure, Density functional theory, Hartree Fock theory, Transport theory, Defects in condensed media, Quantum many-body theory, Interacting subsystems, Homogenous and inhomogeneous semiconductors.

## Objective

Upon completion of this course, the student is able to:

- Apply the dispersion laws to determination of some equilibrium and nonequilibrium physical properties of crystals and metals.
- calculate band structure using Pseudopotential and other methods of Density functional theory
    - Identify the use of homogenous and inhomogeneous semiconductors.

### References


- Principles of Condensed Matter Physics, P.M. Chaikin and T.C. Lubenskii, Cambridge University Press.
- Condensed Matter Physics, Michael P. Marder, John Willey and Sons.
- Solid State Physics, Neil W. Ashcroft, N. David Mermin, Thomson Learning.
- Ch. Kittel, Quantum Theory of Solids, 2$^{nd}$ revised Edition, N.Y., John Willey and Sons, 1987.
- Ch. Kittel, Introduction to Solid State Physics, 8$^{th}$ Edition, John Willey and Sons, 200

**Phys 751: Electronic Structure of Condensed Matter 3**

# Course Description

Plasmons, Polaritons, Polarons and other elementary excitations, Optical processes and excitons, Dielectric properties of insulators, Diamagnetism, Paramagnetism, Ferromagnetism, Antiferromagnetism, Spin glasses, Spinwaves, Giant magnetoresistance, Diluted magnetic semconductors, Magnetic ordering, Theory of superconductivity and superfluidity, Introduction to Polymer Physics.

# Objective

Upon completion of this course, the student is able to:

- Calculate magnetic permeability and magnetoresistance, thermodynamic functions associated with magnons and other excitations.
- Clarify the basic physics on polymers and strongly correlated systems.
    - State dielectric properties of insulators, Diamagnetism, Paramagnetism, Ferromagnetism, Antiferromagnetism,
    - Identify the main theory of superconductivity and superfluidity,.

## References


- Principles of Condensed Matter Physics, P.M. Chaikin and T.C. Lubenskii, Cambridge University Press.
- Condensed Matter Physics, Michael P. Marder, John Willey and Sons.
- Solid State Physics, Neil W. Ashcroft, N. David Mermin, Thomson Learning.
- Ch. Kittel, Quantum Theory of Solids, 2nd revised Edition, N.Y., John Willey and Sons, 1987.
- Ch. Kittel, Introduction to Solid State Physics, 8th Edition, John Willey and Sons, 2005.


**Phys 751: Advanced Condensed Matter Theory 3**

# Course Description

Many-body theory for low dimensional systems, Nanosystems, Density of states of nanostructures, Single electron systems, Photonic crystals, Corrals, Quantum Hall effect, Nanophotonics, Heterostructures, Plasmonics, NEMS, Imaging techniques using STM and

AFM, Nanodevices, Nanomachines and Mesoscopic systems, Nano polymer physics, Strongly correlated systems, Fermi and Bose Systems at ultra-low temperatures.

## Objective

Upon completion of this course, the student is able to:

- Describe how mesoscopic systems, nanostructures and their properties, low dimensional electron gas, nanophotonics and varieties of applications of nanosystems in modern devices.
- Obtain density of states of different nanostructures, the energy band gap and its size, shape and geometry dependence.
- Application of electronic, photonic and optoelectronic in nanosystems.

### References


- The Nanomaterials by C.N.R. Rao, A. Muller, and A.K. Cheetham (Volume 1 and 2), Wiley VCH (2004).
- Mesoscopic Electronics in Solid State Nanostructures by Thomas Heinzel, Wiely – VCH (2007).
- Photonic Crystals: Molding the Flow of light by J.D. Joannopoulos, S.G. Johnson, J.N. Winn and R.D. Meade, Princeton University Press (2008).
- Solid State Physics, Neil W. Ashcroft and N. David Mermin, Thomson Learning.
- C. Kittel, Introduction to Solid State Physics, 8$^{th}$ Edition, John Willey and Sons, 2005.
- Nanotechnology Demystified by L. Williams and D.W. Adams, McGraw Hill (2007).
- Metamaterials and Plasmonics: Fundamentals, Modeling and Applications by S. Zouhdi, A. Sihvola, A.P. Vinogradov, Springer (2008).

# Quantum optics

| Course Number | Course Name | Credit Hours |
|---|---|---|
| Phys 771 | Quantum state of light | **3** |
| Phys 772 | Cavity mode and atom dynamics | **3** |
| Phys 773 | Resonance fluorescence &laser dynamics | **3** |

**Phys 771: Quantum state of light 3**

## Course Description

The quantum radiation field, Number states, Coherent states, Chaotic states, The P function, The Q function, The photon number distribution, Squeezed states.

## Objective

Upon completion of this course, the student is able to:

- Describe the properties of light modes in different quantum states.
- Analysis of various quantum optical systems of interest

**References**


- Fesseha Kassahun, Fundamentals of Quantum Optics (Lulu, Raleigh, NC, 2008).
- M.O. Scully and M.S. Zubairy, Quantum Optics (Cambridge University Press, Cambridge, 1997).
- D.F. Walls and G.J. Milburn, Quantum Optics (Springer-Verlag, Berlin, 1994).


**Phys 771: Cavity Mode and Atom Dynamics 3**

## Course Description

Cavity mode dynamics: The master equation, The Fokker-Planck equation, The quantum Langevin equation, Input-output relation; Two-level atom dynamics: The interaction Hamiltonian, Collapse and revival, The master equation, Power spectrum.

## Objective

Upon completion of this course, the student is able to:

- Describe the different methods of analyzing quantum optical systems.
- Apply the Fokker-Planck equation in different quantum states.
- Differentiate the use of the master equation and Fokker-Planck equation

### References


- Fesseha Kassahun, Fundamentals of Quantum Optics (Lulu, Raleigh, NC, 2008).
- M.O. Scully and M.S. Zubairy, Quantum Optics (Cambridge University Press, Cambridge, 1997).
- D.F. Walls and G.J. Milburn, Quantum Optics (Springer-Verlag, Berlin, 1994).


**Phys 771: Resonance Fluorescence and Laser Dynamics 3**

## Course Description

Resonance fluorescence in open space and in a cavity: Atomic expectation values, Power spectrum, Photon antibunching, Photon statistics; Laser dynamics: Fokker-Planck equation, Photon statistics, Spectrum of intensity fluctuations, Power spectrum

## Objective

Upon completion of this course, the student is able to:

- Describe or analyzing the interaction of light with a two-level atom in open space as well as in a cavity.
- Clarify the quantum properties of laser light.
- Apply the Fokker-Planck equation in laser dynamics

## References


- Fesseha Kassahun, Fundamentals of Quantum Optics (Lulu, Raleigh, NC, 2008).
- M.O. Scully and M.S. Zubairy, Quantum Optics, (Cambridge University Press, Cambridge, 1997).
- D.F. Walls and G.J. Milburn, Quantum Optics (Springer-Verlag, Berlin, 1994).


**Phys 693/ Phys 694: Thesis/ project**

| **Course Number** | **Course Name** | **Credit Hours** |
|---|---|---|
| Phys 693/ Phys 694 | Graduate Thesis/ Graduate Project | **6** |
| **Total** | | **6** |

**Course Content**

Students should have their own research project, on which they work under the instructions of a supervisor. The research project may have scientific specialization, preliminary knowledge of the subject Master thesis, learning scientific methods of problem solving approaching, planning of research oriented projects and preparation of an independent research work, present and discuss for a group of researches

**Learning outcomes**

- Knowledge of specialized topics in physics,
- Planning of a research project
- Systematic / scientific approach of any problem
- Ability for scientific disclosure

**Assessment**

The written thesis will be valued as academic record, and its oral presentation with scientific discourse will be counted as course achievement

## 18. References


- University of Gondar, postgraduate policy and Guide line, 2013.
- Addis Ababa University, physics department Msc program, 2012
- University of Bonn, MSc program of physics department, 2012
- Bahr Dar University, Physics department postgraduate program, 2010
- Haramaya University Physics department postgraduate program, 2010
- Mekelle University of Physics department postgraduate program, 2010
- Applied physics harmonized curriculum of University of Gondar, 2011