MASTER OF SCIENCE

SPACE SCIENCE

PROGRAM STRUCTURE AND SYLLABUS

2020-21 ADMISSION ONWARDS

(UNDER MAHATMA GANDHI UNIVERSITY PGCSS REGULATIONS 2019)

BOARD OF STUDIES IN PHYSICS (PG)

MAHATMA GANDHI UNIVERSITY

2021

CONTENTS

CHAPTER I

INTRODUCTION

M.Sc. Space Science Degree Program of Mahatma Gandhi University, Kottayam

1. **Aim of the program**

The new generation course MSc. Space Science forms the final formal training of Physics with a specialization in Space Science. The program aims to provide in-depth knowledge of Physics together with concepts of Atmospheric and Space Science to the students. After completing the program, a student should pursue research in theoretical/experimental Physics, Astrophysics, Space Science and related areas. The student is expected to acquire a thorough understanding of the fundamentals of Physics and concepts of atmospheric and space science to select an academic career at the secondary or tertiary level. The program also aims at enhancing the employability of the student. Rigorous training requires phased teaching. With this intention, the credit and semester system is followed in this program. An M.Sc. student should be capable of researching at least in a preliminary way. To this aim, an oriented research project is made part of the curriculum.

2. **Eligibility for admission:**

Graduated in Physics (Model 1/Model2 / Model 3) **or** Space Science with not less than CGPA of 2.00 out of 4. 00 in the Core Group (Core + Complementary + Open Courses)	Graduated in Physics (Model 1/Model2 / Model 3) **or** Space Science with not less than CCPA of 5.00 out of 10. 00 in the Core Group (Core + Complementary + Open Courses)	Graduated in Physics (Model 1/Model2 / Model 3) **or** Space Science with not less than 50% marks in the Part III subjects (Main/Core+ subsidiaries/Complementaries)

3. Medium of instruction and assessment : English
4. Faculty under which the degree is awarded : Science
5. Note on compliance with the UGC minimum standards for the conduct and award of postgraduate degrees:

MSc. Space Science is a two-year program in which credit and semester system is followed. An MSc student should be capable of researching at least in a preliminary way. For this, research-oriented project is made part of this curriculum. There are 18 weeks in a semester, and in each week, there are15 lecture hours and 10 laboratory hours. Each semester there are 270 lecture hours and 180 practical hours. Thus the total calendar hours in each semester are 450, which comply with the minimum 390 hours stipulated by the UGC.

CHAPTER II

GENERAL SCHEME OF THE SYLLABI

1. Theory Courses:

There are **fifteen** theory courses in all four semesters in the M.Sc. Space Science Program. The distribution of theory courses is as follows. There are **two** core courses and **ten** common courses which are mandatory to all students. There are **three** elective courses also. Semester I and Semester II will have four core/common courses and Semester III will have three core/common courses and Semester IV will have one common course. One elective course is in semester III and two elective courses are in semester IV. There are two Elective Bunch offered in this syllabus. An Elective Bunch has three theory courses. A college can choose one Elective Bunch in one academic year.

2. Practical:

All four semesters will have a course on laboratory practical. All the practicals are core courses. A minimum of 10 (or 12 as insisted in the syllabus) experiments should be done and recorded in each semester. The practical examinations will be conducted at the respective examination centers by two external examiners appointed by the university at the end of even semesters only. The first and second semester examinations of practical laboratory courses will be conducted at the end of Semester II, while the third and fourth-semester practical examinations will be conducted at the end of Semester IV.

3. Project:

The project of the PG program should be relevant and innovative. The topic of the project can be selected by the student with the consultation of supervisor (a faculty of the department or other department/ college/ university/ institutions). The project should be aimed to motivate the inquisitive and research aptitude of the students. The students must present the results of the project as a seminar during the evaluation. The project work may start at the beginning of Semester III, with its evaluation scheduled at the end of Semester IV along with the practical examination. Students may be encouraged to undergo project work in other reputed institutions also with prior consent of the parent department. The external examiners evaluate the project report and presentation. The project guide or a faculty member deputed by the department head may be present at the time of project evaluation to facilitate the project's proper assessment. Project is a core course of the programme.

4. **Comprehensive Viva Voce:**

The two external examiners will conduct a viva voce examination when evaluating the project. The viva components consist of basic physics & presentation skills, topics covering all semesters and topic of interest. Comprehensive Viva is a core course of the programme.

5. **Course Code:**

M.Sc. Space Science programme consists of 8 **core** courses (including theory, practicals, project and viva), 10 **common** courses and 3 **elective** courses. The 8 core courses in the program are coded according to the following criteria. The first two letters of the code (PH) indicates the Board of Studies/Expert Committee under which the programme comes. PH stands for Physics. The next two digits (03) indicate the stream. The next two digits indicate the semester and the last two digits run for the core courses in that semester. The 10 common courses are common to M.Sc. Space Science and M.Sc. Physics programmes; therefore have the same courses codes as that of M.Sc. Physics programme. The 3 elective courses of each bunch are coded as follows. The first two letters of the code (PH) indicates the Board of Studies under which the programme comes. The next two digits (88, 89 etc.) indicate the elective bunch. The next two digits indicate the semester and the last two digits stands for the ordinal number of the course in the Elective Bunch.

6. **Grading & Evaluation:**

The scheme of grading and evaluation are the same as that of MSc. Physics program of M.G. University (PGCSS) 2019.

MSc. Space Science
Structure of Syllabus

Semester	Course Code	Name of the Courses	No. of hrs / week	Credits
I	PH010101	Mathematical methods in Physics – I	3	4
	PH010102	Classical Mechanics	4	4
	PH010103	Electrodynamics	4	4
	PH030101	Introduction to Atmospheric Science and Space Physics	4	4
	PH030201	General Physics Practicals	5	Evaluation at the end of sem 2
	PH030202	Space Physics Practicals	5	
		Total for Semester 1	**25**	**16**

II	PH010201	Mathematical methods in Physics – II	4	4
	PH010202	Quantum Mechanics – I	3	4
	PH010203	Statistical Mechanics	4	4
	PH010204	Condensed Matter Physics	4	4
	PH030201	General Physics Practicals	5	4
	PH030202	Space Physics Practicals	5	4
		Total for Semester 2	**25**	**24**
III	PH010301	Quantum Mechanics – II	4	4
	PH010302	Computational Physics	4	4
	PH030301	Spectroscopy and Lasers	4	4
		Elective – 1	3	4
	PH030401	Astronomy Practicals	5	Evaluation at the end of sem 4
	PH030402	Physics Computation Practicals	5	
		Total for Semester 3	**25**	**16**
IV	PH010401	Nuclear and Particle Physics	5	4
		Elective – 2	5	3
		Elective – 3	5	3
	PH030401	Astronomy Practicals	5	4
	PH030402	Physics Computation Practicals	5	4
	PH030403	Project	-	4
	PH030404	Comprehensive viva voce	-	2
		Total for Semester 4	**25**	**24**
		Grand Total		**80**

THE ELECTIVE BUNCHES

There are two Electives Bunches offered in this PGCSS Program. Each elective consists of a bunch of three theory courses. The first theory course of a bunch is placed in the Semester III, while the second and third theory courses are in Semester IV. An institution can select only one Elective Bunch in an academic year. The course structure of the Electives Bunches is given below.

The Electives Bunches are named as

Elective Bunch A – Astrophysics
Elective Bunch B – Atmospheric Science

Bunch A: Astrophysics Specialisation : Course Code: 88

Semester	Course Code	Course Title	No. of hours/week	Credits
3	PH880301	Solar & Astrophysics	3	4
4	PH880402	Plasma Physics	5	3
4	PH880403	Instrumentation in Space Physics and Astrophysics	5	3

Bunch B: Atmospheric Science Specialisation : Course Code: 89

Semester	Course Code	Course Title	No. of hours/week	Credits
3	PH890301	Numerical Weather Prediction	3	4
4	PH890402	Cloud Physics and Atmospheric Electricity	5	3
4	PH890403	Satellite Meteorology	5	3

GRADING AND EVALUATION

Grading and evaluation of M.Sc. Space Science program will be done **strictly** according to the '**Regulations of the Post Graduate Programmes under Credit Semester System, 2019**' of Mahatma Gandhi University, and as per the grading and evaluation process of '**M.Sc Physics**' program of Mahatma Gandhi University (refer Chapter 2 of M.Sc Physics (CSS) Syllabus 2019).

CHAPTER III

SYLLABUS – CORE AND COMMON COURSES

This chapter deals with the syllabi of all core and common courses of M.Sc. Space Science program. Common courses are courses which are common to M.Sc. Physics programme and M.Sc. Space Science programme. Common courses bear the same title and course codes as that of M.Sc. Physics programme. Two theory courses and all the four practical courses are core courses. There are ten common courses and three elective courses. The semester wise distribution of the courses is given. In semesters III and IV, the courses from elective bunch will come as opted by the colleges concerned.

SEMESTER – I

PH010101: MATHEMATICAL METHODS IN PHYSICS – I

Total Credits: 4

Total Hours: 54

Objective of the course: The objective of this course is to make students have an idea of vector, matrices and tensors, it's physical interpretation and applications.

UNIT I

Vector analysis (8 hrs)

1.1 Line, Surface and Volume integrals. 1.2 Gradient, divergence and curl of vector Functions 1.3 Gauss Divergence Theorem 1.4 Stoke's Theorem 1.5 Green's Theorem 1.6 Potential Theory 1.6.1 Scalar Potential-Gravitational Potential, Centrifugal Potential.

Curvilinear co-ordinates (8 hrs)

1.7 Transformation of co-ordinates 1.8 Orthogonal Curvilinear co-ordinates 1.9 Unit Vectors in curvilinear systems 1.10 Arc Length and Volume Elements 1.11 Gradient, Divergence and Curl in orthogonal curvilinear co-ordinates 1.12 Special Orthogonal co-ordinates system 1.12.1 Rectangular Cartesian Co-ordinates 1.12.2 Cylindrical Co-ordinates 1.12.3 Spherical Polar Co-ordinates .

UNIT II

Linear vector space (8 hrs)

2.1 Definition of linear vector space 2.2 Inner product of vectors 2.3 basis sets 2.4 Gram schmidt ortho normalization 2.5 Expansion of an arbitrary vector 2.6 Schwarz inequality.

Probability theory and distribution (6 hrs)

2.7 Elementary Probability Theory 2.8 Binomial Distribution 2.9 Poisson Distribution 2.10 Gaussian Distribution 2.11 Central Limit Theorem.

UNIT III

Matrices (12 hrs)

3.1 Direct Sum and Direct Product of Matrices 3.2 Diagonal matrices 3.3 Matrices inversion (Gauss Jordan Inversion Methods) 3.4 Orthogonal, unitary and Hermitian Matrices 3.5 Pauli spin matrices, Dirac matrices, Normal matrices 3.6 Cayley Hamilton Theorem 3.7 Similarity transformation 3.8 Orthogonal & Unitary Transformations 3.9 Eigen values & Eigen Vectors 3.10 Diagonalization using normalized Eigen vectors 3.11 Solution of linear equation Gauss Elimination method.

UNIT IV

Tensors (12 hrs)

4.1 Definition of Tensors 4.2 Basic Properties of Tensors 4.3 Covariant, Contra variant & Mixed Tensors 4.4 Kronecker delta, Levi-Civita Tensor 4.5 Metric Tensor and its properties 4.6 Tensor algebra 4.7 Associated Tensors 4.8 Christoffel Symbols & their transformation laws 4.9 Covariant Differentiation 4.10 Geodesics.

Recommended Text Books:

1. Mathematical methods for Physicists, G.B. Arfken& H.J. Weber 5th edition, Academic Press.
2. Mathematical Physics , V.Balakrishnan, Ane Books Pvt Limited
3. Introduction to Mathematical Physics – Charles Harper, PHI
4. Vector Analysis & Tensor Analysis – Schaum’s Outline Series, M.R.Speigel, Mc Graw hill
5. Mathematical methods for physics and engineering, K F Riley, M P Hobson, S J Bence, Cambridge university press.

Recommended References:

1. An Introduction to Relativity, Jayant V. Narliker,Cambridge University Press.
2. Advanced Engineering Mathematics E.Kreyszig 7thedition John Wiley
3. Mathematical Physics, B.S.Rajput,Y.Prakash 9th editionPragatiPrakashan

4. Mathematical Physics, B.D.Gupta ,Vikas Publishing House
5. Matrices and tensors in Physics, A.W.Joshi
6. Mathematical Physics , P.K.Chatopadhyay ,New Age International Publishers
7. Mathematical Physics, Sathyaprakash, Sultan Chand & Sons

PH010102: CLASSICAL MECHANICS

Total Credits: 4

Total Hours: 72

Objective of the course: After completing the course, the students will (i) understand the fundamental concepts of the Lagrangian and the Hamiltonian methods and will be able to apply them to various problems; (ii) understand the physics of small oscillations and the concepts of canonical transformations and Poisson brackets; (iii) understand the basic ideas of central forces and rigid body dynamics; (iv) understand the Hamilton-Jacobi method and the concept of action-angle variables. This course aims to give a brief introduction to the Lagrangian formulation of relativistic mechanics.

UNIT 1

Lagrangian formulation (14 hrs)

1.1 Review of Newtonian Mechanics: Mechanics of a Particle; Mechanics of a System of Particles; Constraints; 1.2 D' Alembert's principle and Lagrange's equations; velocity-Dependent potentials and the Dissipation Function; Lagrangian for a charged particle in electromagnetic field; 1.3 Application of Lagrange's equation to: motion of a single particle in Cartesian coordinate system and plane polar coordinate system; bead sliding on a rotating wire.1.4 Hamilton's Principle; Technique of Calculus of variations; The Brachistochrone problem. 1.5 Derivation of Lagrange's equations from Hamilton's Principle. 1.6 Canonical momentum; cyclic coordinates; Conservation laws and Symmetry properties- homogeneity of space and conservation of linear momentum; isotropy of space and conservation of angular

momentum; homogeneity of time and conservation of energy; Noether's theorem(statement only; no proof is expected).

Hamiltonian formulation: (4hrs)

1.7 Legendre Transformations; Hamilton's canonical equations of motion; Hamiltonian for a charged particle in electromagnetic field. 1.8 Cyclic coordinates and conservation theorems; Hamilton's equations of motion from modified Hamilton's principle

UNIT II

Small oscillations (8hrs)

2.1 Stable equilibrium unstable equilibrium and neutral equilibrium; motion of a system near stable equilibrium-Lagrangian of the system and equations of motion. 2.2 Small oscillations-frequencies of free vibrations; normal coordinates and normal modes 2.3 system of two coupled pendula-resonant frequencies normal modes and normal coordinates; free vibrations of CO2 molecule- resonant frequencies normal modes and normal coordinates.

Canonical transformations and Poisson brackets (10 hrs)

2.4 Equations of canonical transformations; Four basic types of generating functions and the corresponding basic canonical transformations. Examples of canonical transformations - identity transformation and point transformation. 2.5 Solution of harmonic oscillator using canonical transformations.

2.6 Poisson Brackets ; Fundamental Poisson Brackets; Properties of Poisson Brackets 2.7 Equations of motion in Poisson Bracket form; Poisson Bracket and integrals of motion; Poisson's theorem; Canonical invariance of the Poisson bracket.

UNIT III

Central force problem (9 hours)

3.1 Reduction of two-body problem to one-body problem; Equation of motion for conservative central forces - angular momentum and energy as first integrals; law of equal areas 3.2 Equivalent one-dimensional problem –centrifugal potential; classification of orbits. 3.3 Differential Equations for the orbit; equation of the orbit using the energy method; The Kepler Problem of the inverse square law force; Scattering in a central force field - Scattering in a Coulomb field and Rutherford scattering cross section.

Rigid body dynamics (9 hrs)

3.4 Independent coordinates of a rigid body; Orthogonal transformations; Euler Angles. 3.5 Infinitesimal rotations: polar and axial vectors; rate of change of vectors in space and body frames; Coriolis effect. 3.6 Angular momentum and kinetic energy of motion about a point; Inertia tensor and the Moment of Inertia; Eigenvalues of the inertia tensor and the Principal axis transformation. 3.7 Euler equations of motion; force free motion of a symmetrical top.

UNIT IV

Hamilton-Jacobi theory and action-angle variables (12 hrs)

4.1 Hamilton-Jacobi Equation for Hamilton's Principal Function; physical significance of the principal function. 4.2 Harmonic oscillator problem using the Hamilton-Jacobi method. Hamilton-

Jacobi Equation for Hamilton's characteristic function 4.3 Separation of variables in the Hamilton-Jacobi Equation; Separability of a cyclic coordinate in Hamilton-Jacobi equation; Hamilton-Jacobi equation for a particle moving in a central force field (plane polar coordinates). 4.4 Action-Angle variables; harmonic oscillator problem in action-angle variables.

Classical mechanics of relativity (6 hrs.)

4.5 Lorentz transformation in matrix form; velocity addition; Thomas precession. 4.6 Lagrangian formulation of relativistic mechanics; Application of relativistic Lagrangian to (i) motion under a constant force (ii) harmonic oscillator and (iii) charged particle under constant magnetic field.

Recommended Text Books

1. Classical Mechanics: Herbert Goldstein , Charles Poole and John Safko, (3/e); Pearson Education.
2. Classical Mechanics: G. Aruldhas, Prentice Hall 2009.

Recommended References:

1. Theory and Problems of Theoretical Mechanics (Schaum Outline Series): Murray R. Spiegel, Tata McGraw-Hill 2006.
2. Classical Mechanics : An Undergraduate Text: Douglas Gregory, Cambridge University Press.
3. Classical Mechanics: Tom Kibble and Frank Berkshire, Imperial College Press.
4. Classical Mechanics (Course of Theoretical Physics Volume 1): L.D. Landau and E.M. Lifshitz, Pergamon Press.
5. Analytical Mechanics: Louis Hand and Janet Finch, Cambridge University Press.
6. Classical Mechanics: N.C.Rana and P. S. Joag, Tata Mc Graw Hill.
7. Classical Mechanics: J.C. Upadhyaya, Himalaya Publications, 2010.
8. www.nptelvideos.in/2012/11/classicalphysics.html.

PH010103: ELECTRODYNAMICS

Total credits: 4

Total hours: 72

Objective of the course: Electromagnetic force is one of the four forces that exist in nature with a prominent role in the daily activities of human being. So it is necessary to know the physics of this force from the basics of two inter twinned phenomena called electricity and magnetism. Hence the course aims to impart proper understanding of electricity magnetism and electrodynamics; wave nature of electromagnetic field and its properties; electromagnetic field radiating out of accelerated charges and the impact of relativity in electromagnetism along with confined propagation of electromagnetic wave.

UNIT 1

Electrostatics, Magnetostatics and basics of Electrodynamics (18 hrs)

1.1 Electrostatics: Electric field of a polarized object- Electric field in a - conductor- dielectric - electric displacement -Gauss's law in dielectric medium-linear dielectric medium-. Boundary condition across dielectric (εr1)-dielectric (εr2), conductor-dielectric (εr), conductor-free space (εr=1) interface. 1.2 Uniqueness theorem and electrostatic potential-Solving Poisson's and Laplace equations for boundary value problems 1.3 Method of images- point charge -line charge above a grounded conducting plane. 1.4 Potential at large distance-multipole expansion due to a localized charge distribution - Electric field of a dipole. 1.5 Magnetostatics: Biot-Savart law - divergence and curl of B - Ampere's law. Magnetic vector potential - multipole expansion of vector potential-boundary conditions - Magnetic field inside matter-Magnetization (M) -Magnetic flux density (B) -Auxiliary field (H). 1.6 Electrodynamics: Electromotive force - motional emf - Faraday's law- electrodynamic equations - displacement current. 1.7 Uniform sinusoidal time varying fields E and B and Maxwell's equations in free space and matter. Boundary conditions of electric and magnetic field. 1.8 Conservation laws- continuity equation- Poynting's theorem - Maxwell's stress tensor- momentum conservation.

UNIT II

Electromagnetic waves (18 hrs)

2.1 Wave equation for E and B - monochromatic plane waves- energy- momentum 2.2 Propagation of EM waves through linear media- Reflection and transmission of a plane wave at normal - oblique incidence. 2.3 Electromagnetic waves in a conducting medium. Reflection at conducting surface- frequency dependence of permittivity 2.4 Dispersion of electromagnetic waves in non-conductors, conductors and plasma medium.

UNIT III

Electromagnetic radiation (18 hrs)

3.1 Potential formulation of electrodynamics- Gauge transformations-Coulomb and Lorentz gauge 3.2 Continuous charge distribution-Retarded potential-Jefmenko's equation. 3.3 Point charges- Lienard-Wiechert potentials -Field of a point charge in motion - Power radiated by a point charge 3.4 Electric dipole radiation-magnetic dipole radiation -radiation from arbitrary distribution of charges 3.5 Radiation reaction -Abraham-Lorentz formula.

UNIT IV

Relativistic electrodynamics and Waveguides (18 Hrs)

4.1 Relativistic electrodynamics 4.1.1 Structure of spacetime- Four vectors-Proper time and proper velocity- Relativistic energy and momentum -Relativistic dynamics- Minkowski force. 4.1.2 Magnetism as a relativistic phenomenon. 4.1.3 Lorentz transformation of em field- field tensor-electrodynamics in tensor notation. 4.1.4 Potential formulation of relativistic electrodynamics. 4.2 Waveguides 4.2.1 Waves between parallel planes -TE-TM-TEM waves 4.2.2 Rectangular waveguide- TE-TM waves -impossibility of TEM wave. 4.2.3 Cylindrical waveguide- TE-TM waves.

Recommended textbooks:

1. Introduction to Electrodynamics, David J. Griffiths, PHI.
2. Electromagnetics, John D.Kraus, McGraw-Hill International
3. Classical electrodynamics, J.D Jackson, John Wiley & Sons Inc

Recommended References:

1. Electromagnetic waves and radiating systems Edward C Jordan, Keith G Balamin, Printice Hall India Pvt.Ltd
2. Elements of Electromagnetic, Mathew N. O Sadiku, Oxford University Press
3. Antenna and wave propagation, K.D Prasad, Satyaprakashan, New Delhi
4. Electromagnetism problems with solutions, Ashutosh Pramanik, PHI.

PH030101:

INTRODUCTION TO ATMOSPHERIC SCIENCE AND SPACE PHYSICS

Total Credits: 4

Total Hours: 72

Objective of the course: The objective of this course is to provide students have an idea on fluid mechanics, communication systems, ionosphere and GPS.

Unit I

Motion of rigid bodies and Fluid Mechanics (20 Hrs)

Kinematics of rigid body motion. Infinitesimal rotations, Coriolis force, rigid body equation of motion. Central force motion, Scattering & centre of mass. Theory of small oscillations, normal modes of the system- Fluid Mechanics- equation of state and equation of continuity- Bernoulli's theorem- interpretation of Lagragian formalism of continuous system- sound vibration in gases.

Unit II

Electromagnetic radiation and propagation of waves (16 Hrs)

EM Radiation, fundamentals of EM waves, effects of environment, Antennas- basic considerations, types of antennas. Propagation of waves: ground wave, sky wave, and space wave propagation, troposcatter communication and extraterrestrial communication.

Unit III

The Neutral atmosphere and Ionosphere (12 Hrs): Atmospheric nomenclature, the Hydrostatic equation, geopotential height, expansion and contraction, fundamental forces in the atmosphere, apparent forces, atmospheric composition, solar radiation interaction with the neutral atmosphere, climate change.

The Ionosphere (12 Hrs): Morphology of ionosphere, the D, E and F-regions, chemistry of the ionosphere, ionospheric parameters, E and F region anomalies and irregularities in the ionosphere.

Unit IV

Global Positioning systems (GPS) (12 Hrs) - Basic concepts, overview of GPS system, augmentation services, GPS system segment, GPS signal characteristics, GPS errors, multi path effects, GPS performance, satellite navigation system and applications.

Reference Books:

1. An Introduction to Dynamic Meteorology by James R Holton, Academic Press Inc.
2. Climatology, An atmospheric Science by John E. Oliver and John J. Hindore, Pearson Education
3. Electronic Communication systems by George Kennedy and Bernard Davis, Tata McGraw Hill publishing Co., Ltd.
4. Introduction to Ionospheric Physics by Henry Rishbeth and Owen K. Garriot, Academic press
5. Understanding GPS principles and applications by Elliot D. Kaplan and Christopher J. Hegarty, Artech House, Boston.
6. Classical Mechanics: Herbert Goldstein , Charles Poole and John Safko, (3/e); Pearson Education.
7. Classical Mechanics: N.C.Rana and P. S. Joag, Tata Mc Graw Hill.

SEMESTER II

PH010201: MATHEMATICAL METHODS IN PHYSICS - II

Total Credits: 4

Total Hours: 72

Objective of the course: Introduce the concepts of Laplace and Fourier transforms. Introduce the Fourier series and its application to solutions of partial differential equations. Also student must familiar with the special functions.

UNIT 1

Complex analsis (18 hrs)

1.1 Functions of a complex variable 1.2 Analytic functions 1.3 Cauchy-Riemann equation 1.4 Integration in a complex plane 1.5 Cauchy Theorem 1.6 Cauchy's integral formulas 1.7 Taylor expansion & Laurent expansion 1.8 Residue, poles 1.9 Cauchy residue theorem 1.10 Cauchy's principle value theorem 1.11 Evaluation of integrals.

UNIT II

Integral transforms (18 hrs)

2.1 Fourier Series 2.2 Application of Fourier series 2.2.1 Square Wave 2.2.2 Full Wave Rectifier 2.3 Fourier Integral 2.4 Fourier Transform 2.4.1 Finite Wave Train 2.5 Convolution Theorem of parseval's relation 2.6 Momentum representation 2.6.1 Hydrogen atom 2.6.2 Harmonic oscillator 2.7 Laplace Transform, Inverse Laplace transform 2.8 Earth Mutation 2.9 Damped Oscillator 2.10 LCR circuit.

UNIT III

Special functions and differential equations (18 hrs)

3.1 Gamma Function 3.2 Beta Function 3.3 Symmetry Property of Functions 3.4 Evaluation of Beta functions 3.5 Other forms of Beta Functions --Transformation of P Functions 3.6 Evaluation of Gamma Functions 3.7 Other forms of Gamma Functions- Transformation of Gamma Functions 3.8 Relation between Beta and Gamma Functions 3.9 Evaluation of Integrals 3.10 Bessel's Differential Equation, 3.11 Legendre Differential Equation 3.12 Associated Legendre Differential Equations 3.13 Hermite Differential Equations 3.14 Laguerre Differential Equations (Generating function, recurrence relation, orthogonality condition, Rodrigues formulae for all functions).

UNIT IV

Partial differential equations (18 hrs)

4.1 Characteristics of boundary conditions for partial differential equation 4.2 Solution of partial differential equations by the method of separation of variables in Cartesian, cylindrical and spherical polar co-ordinates 4.3 Solution of Laplace equation in cartesian, cylindrical and spherical polar co-ordinates 4.4 Heat equation in Cartesian co-ordinates 4.5 Non-Homogeneous equation 4.6 Green's function 4.7 Symmetry of Green's Function 4.8 Green's Function for Poisson Equation, Laplace equation, Helmholtz equation 4.9 Application of Greens equation in scattering problem.

Recommended Text Books:-

1. Mathematical methods for Physicists, G.B. Arfken& H.J. Weber 5th edition, Academic Press.
2. Mathematical Physics , V.Balakrishnan,Ane Books Pvt Limited

Recommended Reference Books:

1. Advanced Engineering Mathematics E.Kreyszig 7thedition John Wiley
2. Mathematical Physics, B.S.Rajput,Y.Prakash 9th edition PragatiPrakashan
3. 3.Mathematical Physics,B.D.Gupta ,Vikas Publishing House
4. 4.Matrices and tensors in Physics,A.W.Joshi
5. 5.Mathematical Physics , P.K.Chatopadhyay ,New Age International Publishers
6. 6.Mathematical Physics, Sathyaprakash, Sultan Chand & Sons

PH010202: QUANTUM MECHANICS - I

Total Credits: 4

Total Hours: 54

Objective of the course: This course aims to develop the basic structure of Quantum Mechanics. After completing the course, the student will (i) understand the fundamental concepts of the Dirac formalism (ii) understand how quantum systems evolve in time; (iii) understand the basics of the quantum theory of angular momentum. Also, this course enables the student to solve the hydrogen atom problem which is a prelude to more complicated problems in quantum mechanics.

UNIT I

Basics Formulation of Quantum Mechanics (20 hours)

1.1 Development of the idea of state vectors from sequential Stern-Gerlach experiments ;Dirac notation for state vectors: ket space, bra space and inner products; 1.2 Operators; Associative axiom; outer product; 1.3 Hermitian adjoint; Hermitian operator; Eigenkets and eigenvalues of Hermitian operators. Eigenkets of observables as base kets; concept of complete set. Projection operators. 1.4 Matrix representations of operators, kets and bras 1.5 Measurements in quantum mechanics; expectation value; Compatible observables and existence of simultaneous eigenkets; General Uncertainty Relation. 1.6 Unitary operator, change of basis and transformation matrix, unitary equivalent observables. 1.7 Position eigenkets, infinitesimal translation operator and its properties, linear momentum as generator of translation, canonical commutation relations. Wavefunction as an expansion coefficient; eigen functions, momentum eigen function 1.8 momentum space wavefunctions and the relation between wavefunctions in position space and momentum space. Gaussian wave packet- compuatation of dispersions in position and momentum.

UNIT II

Quantum Dynamics (16 hours)

2.1 Time evolution operator and its properties 2.2 Schrodinger equation for the time evolution operator; solution of the Schrodinger equation for different time dependences of the Hamiltonian 2.3 Energy eigenkets; time dependence of expectation values 2.4 time evolution of a spin half system and spin precession 2.5 Correlation amplitude; time-energy uncertainty relation and its interpretation. 2.6 Schrodinger picture and Heisenberg picture; behavior of state kets and observables in Schrodinger and Heisenberg pictures; Heisenberg's equation of motion 2.7 Ehrenfest's theorem; time evolution of base kets; transition amplitudes. 2.8 Simple Harmonic Oscillator: Energy eigenvalues and energy eigenkets.

UNIT III

Theory of Angular Momentum (14 hours)

3.1 Non-commutativity of rotations around different axes; the rotation operator; fundamental commutation relations for angular momentum operators 3.2 rotation operators for spin half systems; spin precession in a magnetic field 3.3 Pauli's two component formalism; 2X2 matrix representation of the rotation operator 3.4 ladder operators; eigenvalue problem for angular momentum operators 3.5 matrix representation of angular momentum operators.3.6 Orbital angular momentum ; orbital angular momentum as a generator of rotation 3.7 Addition of orbital angular momentum and spin angular momentum; addition of angular momenta of two spin-1/2 particles. General theory of Angular Momentum addition-Computation of Clebsch - Gordon coefficients.

UNIT IV

The Hydrogen Atom (4 hours)

4.1 Behaviour of the radial wavefunction near the origin; the Coulomb potential and the hydrogen atom; hydrogenic wavefunctions; degeneracy in hydrogen atom.

Recommended Text Books:

1. Modern Quantum Mechanics : J. J. Sakurai, Pearson Education.
2. A Modern Approach to Quantum Mechanics: J S Townsend, Viva Books.

Recommended References:

1. Quantum Mechanics (Schaum's Outline) :Yoav Peleg *etal*. Tata Mc Graw Hill Private Limited, 2/e.
2. Quantum Mechanics: 500 Problems with Solutions: G Aruldhas, Prentice Hall of India.
3. Quantum Mechanics Demystified: David McMohan, McGrawHill 2006.
4. Introductory Quantum Mechanics: Richard L Liboff, Pearson Education .
5. Introduction to Quantum Mechanics: D.J. Grifith, Pearson Education.
6. Quantum Mechanics : V. K. Thankappan, New Age International.
7. Quantum Mechanics: An Introduction: Walter Greiner and Allan Bromley, Springer.
8. Quantum Mechanics : Non-Relativistic Theory(Course of Theoretical Physics Vol3): L. D. Landau and E. M. Lifshitz, Pregamon Press.
9. Nouredine Zettili, *Quantum Mechanics: Concepts and Applications*, Second Edition, John Wily & Sons Ltd, 2009
10. The Feynman Lectures on Physics Vol3, Narosa.
11. www.nptel/videos.in/2012/11/quantum-physics.html
12. https://nptel.ac.in/courses/115106066/

PH010203: STATISTICAL MECHANICS

Credits: 4

Total Hours: 72

Objective of the course: This course aims to familiarise the students with concepts of Statistical Mechanics such as ensemble theory, Phase transition etc. and its applications.

UNIT I (22 hrs)

1.1. The Statistical Basis of Thermodynamics 1.1.1. Macroscopic and microscopic states. 1.1.2.Connection between thermodynamics and statistics. 1.1.3. Classical ideal gas.1.1.4.Entropy of mixing and Gibbs paradox. 1.1.5. Correct enumeration of micro states.1.2. Elements of Ensemble Theory 1.2.1. Phase space of a classical system. 1.2.2. Liouville's theorem. 1.2.3. Micro-canonical ensemble. 1.2.4. Quantum states and phase space. 1.3. Canonical ensemble.1.3.1. Equilibrium between a system and a heat reservoir. 1.3.2. System in canonical ensemble. 1.3.3. Physical significance of statistical quantities in canonical ensemble. 1.3.4. Classical systems. 1.3.5. Energy fluctuations in canonical ensemble. 1.3.6. Equipartition theorem.

UNIT II (18 hrs)

2.1. Grand canonical Ensemble 2.1.1. Equilibrium between system and energy-particle reservoir. 2.1.2 .A system in grand canonical ensemble. 2.1.3 Physical significance of various statistical quantities. 2.1.4. Examples. 2.1.5. Fluctuations in grand canonical ensemble. 2.2. Formulation of Quantum Statistics 2.2.1.Quantum mechanical ensemble theory. 2.2.2.Density matrix. 2.2.3. Statistics of various ensembles. 2.2.4.Examples (an electron in magnetic fields, free particle in a box). 2.2.5. A system composed of indistinguishable particles.

UNIT III (22 hrs)

3.1. Quantum Theory of Simple Gases 3.1.1. Ideal gas in quantum-micro canonical ensemble. 3.1.2. Ideal gas in other quantum mechanical ensembles. 3.1.3.Statistics of the occupation numbers 3.2. Ideal Bose Systems 3.2.1. Thermodynamic behaviour of ideal Bose gas. 3.2.2. Thermodynamics of black body radiation. The field of sound waves. 3.3. Ideal Fermi Systems 3.3.1. Thermodynamics of ideal Fermi gas. 3.3.2. Magnetic behaviour of ideal fermi gas. 3.3.3. Electron gas in metals.

UNIT IV (10 hrs)

4.1. Phase Transitions 4.1.1. Phases. 4.1.2. Thermodynamic potentials, 4.1.3. Approximation. 4.1.4. First order phase transition. 4.1.5. Clapeyron equation.

Recommended Text books:

1. Text book- R.K. Pathria, Statistical Mechanics, second edition (1996), Butterworth, Heinemann. (For Modules I, II and III.)
2. R Bowley and M. Sanchez, Introductory Statistical Mechanics, second edition, Oxford University Press. (For Module IV)

Recommended Reference Books:

1. Kerson Huang, Statistical Mechanics, John Wiley and Sons (2003).
2. F. Rief, Fundamentals of Statistical and Thermal Physics, McGraw Hill (1986).
3. D. Chandler, Introduction to Statistical Mechanics, Oxford University Press (1987)
4. L.D Landau and E.M Lifshitz, Statistical Physics (Vol-1),3rd Edition. Pergamon Press(1989)
5. Yung-Kuo Lim, Problems and Solutions in Thermodynamics and Statistical Mechanics, World Scientific (1990).

PH010204: CONDENSED MATTER PHYSICS

Total Credits: 4

Total Hours: 72

Objective of the course: This course aims to develop concepts on wave diffraction in crystals, energy bands, thermal and magnetic properties of solids.

UNIT 1

Wave Diffraction and the Reciprocal Lattice (5 Hrs)

1.1 Diffraction of waves by crystals-Bragg's Law- **1.2** Scattered wave amplitude-reciprocal lattice vectors- diffraction condition-Laue equations-Ewald construction- **1.3** Brillouin zones- reciprocal lattice to SC, BCC and FCC lattices-properties of reciprocal lattice- **1.4** diffraction intensity - structure factor and atomic form factor- physical significance.

Crystal Symmetry (7 Hrs)

1.5 Crystal symmetry-symmetry elements in crystals-point groups, space groups **1.6** Ordered phases of matter-translational and orientational order- kinds of liquid crystalline order-Elements of Quasi crystals.

Free Electron Fermi Gas (12 Hrs)

1.7. Energy levels in one dimension-quantum states and degeneracy- density of states-**1.8** Fermi-Dirac statistics -Effect of temperature on Fermi-Dirac distribution –**1.9** Free electron gas in three dimensions- **1.10** Heat capacity of the electron gas- relaxation time and mean free path - **1.11** Electrical conductivity and Ohm's law - Widemann-Franz-Lorentz law - electrical resistivity of metals.

UNIT II

Energy Bands (8 Hrs)

2.1 Nearly free electron model- Origin of energy gap-Magnitude of the Energy Gap-**2.2** Bloch functions – **2.3** Kronig-Penney model – **2.4** Wave equation of electron in a periodic potential-Restatement of Bloch theorem- Crystal momentum of an Electron- Solution of the central equations- **2.5** Brillouin zone- construction of Brillouin zone in one and two dimensions – extended, reduced and periodic zone scheme of Brillouin zone (qualitative idea only) **-2.6** Effective mass of electron **-2.7** Distinction between conductors, semiconductors and insulators.

Semiconductor Crystals (10 Hrs)

2.8. Band Gap- **2.9.**Equations of motion-Effective mass-Physical interpretation of effective mass - Effective mass in semiconductors- Silicon and Germanium- **2.10** Intrinsic carrier concentration- **2.11** Impurity conductivity- Thermal ionization of Donors and Acceptors-Thermoelectric effects-semimetals-super lattices-Bloch Oscillator -Zener tunnelling.

UNIT III

Phonons

Crystal Vibrations and Thermal Properties (16 Hrs)

3.1 Vibrations of crystals with monatomic basis –First Brillouin zone-Group Velocity-**3.2** Two atoms per Primitive Basis – **3.3** Quantization of elastic waves –**3.4** Phonon momentum-**3.5** Inelastic scattering of phonons.-**3.6** Phonon Heat Capacity-Plank distribution-Density of States in one and three dimensions-Debye model for density of states-Debye T3 Law-Einstein Model for Density of states- **3.7** Anharmonic Crystal interactions-Thermal Expansion- **3.8** Thermal Conductivity-thermal resistivity of phonon gas-Umklapp Processes-Imperfections.

UNIT IV

Magnetic Properties of Solids (14 hrs)

4.1 Quantum theory of paramagnetism–Hunds rules-crystal field splitting-spectroscopic splitting factor-**4.2** Cooling by adiabatic demagnetization – Nuclear Demagnetization- **4.3** Ferromagnetic order-Curie point and the exchange integral-Temperature dependence of the saturation-Magnetization-Saturation Magnetization at absolute Zero-**4.4** Magnons- Quantization of spin waves-Thermal excitation of Manganons-**4.5** Neutron Magnetic Scattering-**4.6** Ferromagnetic order-curie temperature and Susceptibility-**4.7** Antiferromagnetic order-susceptibility below Neel-Temperature-**4.8** Ferromagnetic domains-Anisotropic Energy-transition region between Domains-origin of domains - Corecivity and Hysteresis-**4.9** Single Domain Particles-Geomagnetism and Biomagnetism-Magnetic scope microscopy **4.10** Elements of super fluidity.

Recommended Textbooks:

1. Introduction to Solid State Physics, Charles Kittel, Wiely, Indian reprint (2015).
2. Solid State Physics, A.J. Dekker, Macmillan & Co Ltd. (1967)
3. Introduction to Solids, L V Azaroff, McGRAW-HILL BOOK COMPANY, INC.New York (1960)

Recommended References:

1. Solid State Physics, N.W. Ashcroft & N.D. Mermin, Cengage Learning Pub.11th IndianReprint (2011).
2. Solid State Physics, R.L. Singhal, KedarNath Ram Nath& Co (1981)
3. Elementary Solid State Physics, M. Ali Omar, Pearson, 4th Indian Reprint (2004).
4. Solid State Physics, C.M. Kachhava, Tata McGraw-Hill (1990).
5. Elements of Solid State Physics, J. P. Srivastava, PHI (2004)
6. Solid State Physics, Dan Wei, Cengage Learning (2008)
7. Solid State Physics, J S Blackemore, Cambridge University Press (1985).
8. Electronic Properties of Crystalline Solids, Richard Bube, Academic Press New York (1974).

PH030201: GENERAL PHYSICS PRACTICALS

Total credits: 4

Total hours: 180

* *Minimum number of experiments to be done 12*

***Error analysis of the result is a compulsory part of experimental work*

1. Hall Effect in Semiconductor. Determine the Hall coefficient, carrier concentration and carrier mobility.
2. Ultrasonic- acoustic optic technique-elastic property of a liquid.
3. Magnetic susceptibility of a paramagnetic solution using Quinck’s tube method.
4. Curie temperature of a magnetic material.
5. Dielectric Constant and Curie temperature of ferroelectric Ceramics.
6. Draw the hysteresis curve (B – H Curve) of a ferromagnetic material and determination of retentivity and coercivity.

7. Cornu's method- Determination of elastic constant of a transparent material
8. Determination of e/m by Thomson's method.
9. Determination of e/k of Silicon.
10. Determination of Planck's constant (Photoelectric effect).
11. Measurement of resistivity of a semiconductor by four-probe method at different temperature and determination of band gap.
12. Determination of magnetic susceptibility of a solid by Guoy's method.
13. Measurement of wavelength of laser using reflection grating.
14. Fraunhoffer diffraction pattern of a single slit, determination of wavelength/slit width.
15. Fraunhoffer diffraction pattern of wire mesh, determination of wavelength/slit width.
16. Fraunhoffer diffraction pattern of double slit, determination of wavelength/slit width.
17. Diffraction pattern of light with circular aperture using Diode/He-Ne laser.
18. Fresnel diffraction pattern of a single slit.
19. Study the beam divergence, spot size and intensity profile of Diode/He-Ne laser.
20. Determine the numerical aperture of optical fibre and propagation of light through it.
21. Determine the refractive index of the material using Brewster angle setup.
22. Measure the thermo emf of a thermocouple as function of temperature. Also prove that Seebeck effect is reversible.
23. Determine the Young's modulus of the material of a bar by flexural vibrations.
24. Using Michelson interferometer determine the wavelength of light.
25. Study the temperature dependence of dielectric constant of a ceramic capacitor and verify Curie-Wiess law
26. Determine the dielectric constant of a non-polar liquid.
27. Determine the charge of an electron using Millikan oil drop experiment.
28. Linear electro optic effect (Pockel effect), Frank Hertz experiment.
29. Koening's method, Poisson's ratio of the given material of bar.
30. Determination of Stefan's constant of radiation from a hot body.

Books for Reference:

1. A.C. Melissinos, J.Napolitano : "Experiments in Modern Physics" (Academic
2. Press, 2003)
3. B.L. Worsnop and H.T. Flint :"Advanced Practical Physics for students"
4. (Methusen & Co., 1950)
5. E.V. Smith :" Manual of experiments in applied Physics" (Butterworth 1970)

6. R.A. Dunlap :"Experimental Physics - Modern methods"(Oxford University
7. Press, 1988)
8. D. Malacara (ed) : " Methods of experimental Physics - series of volumes "
9. (Academic Press Inc., 1988)
10. S.P. Singh : "Advanced Practical Physics – Vol I & II (13th Edition, Pragati
11. Prakasan, Meerut , 2003)
12. Advanced practical physics for students, B.L Worsnop and H.T Flint, University of California.

PH030202: SPACE PHYSICS PRACTICALS

Credit: 4
Total hours: 180

Students will be required to perform at least Twelve (**12**) experiments from the following:

1. To plot the Radiation pattern of Dipole, Yagi, Folded dipole and Loop antenna and to make comparative study between them (for minimum three antenna).
2. To study the operation of Amplitude Modulation and Demodulation.
3. To study the variation of Modulation index with modulating voltage and frequency.
4. To observe the linearity curve of the modulator.
5. To observe the spectrum of AM-signal.
6. To study and trace the operation of envelop-detector.
7. To calculate modulation sensitivity of frequency modulator.
8. To calculate the non-linearity of frequency modulator.
9. To trace frequency demodulation curve.
10. To study and observe Signal to noise ratio (SNR) plot window of GPS satellites.
11. To study and observe the sky plot using azimuth and Elevation window of GPS.
12. To calculate ionospheric pierce point (IPP) for any three GPS satellites over any particular station.
13. To study the diurnal variation of atmospheric temperature and pressure using AWS.
14. To study the monthly variation of atmospheric temperature and pressure using AWS.
15. To study 3-day or 5 – day average variation of atmospheric temperature and pressure using AWS.

16. To study the monthly variation of atmospheric Humidity and Solar Flux using AWS.
17. To study 3-day or 5 – day variation of atmospheric Humidity and Solar Flux using AWS.
18. To study and observe the pulse amplitude modulation (PAM) and draw the variation of modulation index with modulating voltage.
19. To study and observe the pulse width modulation (PWM) and demodulation.
20. To study and observe the pulse code modulation (PCM) and demodulation.
21. To observe the effect of different RADAR parameters in detecting two targets on an active radar screen using radar simulation software.
22. Analysis of aerosols using aerosol spectrometer.
23. Aerosol properties using solar radiometer.
24. Analysis of aerosols using satellite based sensors.
25. To study the numerical aperture (NA) of the optical fiber.
26. To measure the propagation loss and binding loss of the Optical fiber.
27. To study PWM and pure width demodulation.
28. To study PPM and pulse position demodulation.
29. To measure the total ozone column and water vapor column as well as aerosol optical thickness (AOT) at 1020 nm using a hand-held multiband Sun-photometer MICROTOPS II.
30. To determine the electric field configuration of a GEM detector by MAXWELL-2D simulation of given dimension.
31. To plot the contour of potential and electric field using GARFIELD-9.
32. To set up an active and a passive satellite communication link.
33. To measure the balanced analog signal parameters link frequency response of analog channel of satellite communication.
34. To measure C/N and S/N ratio of satellite communication.
35. To study the time variations of components of geomagnetic field using magnetometer.
36. Analysis of cloud characteristics using ground based instruments; Ceilometer (LIDAR).

SEMESTER III

PH010301: QUANTUM MECHANICS - II

Credits: 4

Total Hours: 72

Objective of the course: This course aims to extend the concepts developed in the course 'Quantum Mechanics-I. After completing this course, the student will (i) understand the different stationary state approximation methods and be able to apply them to various quantum systems; (ii) understand the basics of time-dependent perturbation theory and its application to semi-classical theory of atom-radiation interaction; (iii) understand the theory of identical particles and its application to helium; (iv) understand the idea of Born approximation and the method of partial waves. Also, this course will introduce the student to the basic concepts of relativistic quantum mechanics.

UNIT I

Approximation Methods for Stationary States (18 hrs)

1.1 Non-degenerate Perturbation Theory: First order energy shift; first order correction to the energy eigenstate; second order energy shift. Harmonic oscillator subjected to a constant electric field. 1.2 Degenerate Perturbation theory First order Stark effect in hydrogen; Zeeman effect in hydrogen and the Lande g-factor.

1.3 The variational Method; Estimation of ground state energies of harmonic oscillator and delta function potential 1.4 Ground State of Helium atom ; Hydrogen Molecule ion.

1.5 The WKB method and its validity; The WKB wavefunction in the classical region; non-classical region ; connection formulas(derivation not required) 1.6 Potential well and quantization condition; the harmonic oscillator. 1.7 Tunneling; application to alpha decay.

UNIT II

Time-Dependent Perturbation Theory (18 hrs)

2.1 Time dependent potentials; interaction picture; time evolution operator in interaction picture; Spin Magnetic Resonance in spin half systems 2.2 Time dependent perturbation theory; Dyson series; transition probability 2.3 constant perturbation; Fermi's Golden Rule ; Harmonic perturbation 2.4 interaction of atom with classical radiation field; absorption and stimulated emission; electric dipole approximation; photoelectric effect 2.5 Energy shift and decay width.

UNIT III

Identical Particles and Scattering Theory (18hrs)

3.1 Bosons and fermions; anti-symmetric wave functions and Pauli's exclusion principle. 3.2 The Helium Atom. 3.3 The Asymptotic wave function - differential scattering cross section and scattering amplitude 3.4 The Born approximation- scattering amplitude in Born approximation; validity of the Born approximation; Yukawa potential ; Coulomb potential and the Rutherford formula. 3.5 Partial wave analysis- hard sphere scattering; S-wave scattering for finite potential well; Resonances and Ramsauer-Townsend effect.

UNIT IV

Relativistic Quantum Mechanics (18 hrs)

4.1 Klein-Gordon Equation; continuity equation and probability density in Klein-Gordon theory. 4.2 Non-relativistic limit of the Klein-Gordon equation 4.3 Solutions of the Klein –Gordon equation for positive, negative and neutral spin0 particles; Klein-Gordon equation in the Schrodinger form.

4.4 Dirac Equation in the Scrodinger form; Dirac's matrices and their properties 4.5 Solutions of the free particle Dirac equation; single particle interpretation of the plane waves; velocity operator; zitterbewegung 4.6 Non-relativistic limit of the Dirac equation; spin of Dirac particles; Total angular momentum as a constant of motion. 4.7 Negative energy states and Dirac's hole theory.

Recommended Text Books:

1. Modern Quantum Mechanics: J. J. Sakurai, Pearson Education.
2. A modern Approach to Quantum Mechanics: John Townsend, Viva Books New Delhi
3. Introduction to Quantum Mechanics: D.J. Griffith, Pearson Education
4. Relativistic Quantum Mechanics: Walter Greiner, Springer-Verlag

Recommended References:

1. Quantum Mechanics (Schaum's Outline Series): Yoav Peleg etal., Tata McGraw Hill .Education Private Limited, 2/e.
2. N.Zettili: "Quantum Mechanics – Concepts and applications" (John Wiley & Sons, 2004)
3. Quantum Mechanics: 500 Problems with Solutions: G Aruldhas, Prentice Hall of India.
4. Problems and Solutions in Quantum Mechanics: Kyriakos Tamvakis, Cambridge University Press.
5. Introductory Quantum Mechanics: Richard L Liboff, Pearson Education.
6. Quantum Mechanics: V. K. Thankappan, New Age International.

7. A Textbook of Quantum Mechanics: P M Mathews and R Venkatesan, Tata McGraw Hill.
8. Quantum Mechanics: Non Relativistic Theory (Course of Theoretical Physics Course Vol3) : L. D. Landau and E. M. Lifshitz, Pregamon Press.
9. Relativistic Quantum Mechanics: James D Bjorken and Sidney D Drell, Tata McGraw Hill 2013
10. www.ntpel/videos.in/2012/11/quantum-physics.html
11. https://nptel.ac.in/courses/115106066/

PH010302: COMPUTATIONAL PHYSICS

Total Credits : 4

Total Hours : 72

Objective of the Course: To help the students to have the basic idea about the techniques used in physics to solve problems with the help of computers when they cannot be solved analytically with pencil and paper since the underlying physical system is very complex. After the completion of this course students might be able to develop their own Algorithms of every method described in the syllabus.

UNIT I

Curve Fitting and Interpolation (20Hrs)

1.1 The least squares method for fitting a straight line, 1.2 The least squares method for fitting a parabola, 1.3 The least squares method for fitting a power curves, 1.4 The least squares method for fitting an exponential curves. 1.5 Interpolation - Introduction to finite difference operators, 1.6 Newton's forward and backward difference interpolation formula, 1.7 Newton's divided difference formula, 1.8 Cubic spline interpolation.

UNIT II

Numerical Differentiation and Integration (16 Hrs)

2.1 Numerical differentiation, 2.2 cubic spline method,2.3 Errors in numerical differentiation, 2.4 Integration of a function with Trapezoidal Rule, 2.5 Simpson's 1/3 2.6 Integration of a function with Simpson's 3/8 Rule and error associated with each. 2.7 Relevant Algorithms for each.

UNIT III

Numerical Solution of Ordinary Differential Equations (20Hrs)

3.1 Euler method, 3.2 Modified Euler method 3.3 Runge - Kutta 4th order methods – 3.4 adaptive step size R-K method, 3.5 Higher order equations. 3.6 Concepts of stability.

Numerical Solution of System of Equations

3.7 Gauss-Jordan elimination Method, 3.8 Gauss-Seidel iteration method, 3.9 Gauss elimination method 3.10 Gauss-Jordan method to find inverse of a matrix. 3.11 Power method 3.12 Jacobi's method to solve eigenvalue problems.

UNIT IV

Numerical solutions of partial differential equations (16Hrs)

4.1 Elementary ideas and basic concepts in finite difference method, 4.2 Schmidt Method, 4.3 Crank - Nicholson method, 4.4 Weighted average implicit method. 4.5 Monte Carlo evaluation of integrals, 4.6 Buffon's needle problem, 4.7 requirement for random number generation.

Recommended Text Books:

1. Numerical Methods for Scientists and Engineers , K Sankara Rao, PHI Pvt. Ltd .
2. Introductory Methods of Numerical Analysis, S.S. Sastry, PHI Pvt. Ltd.
3. Mathematical Methods, G. Shanker Rao, K. Keshava Reddy, I.K. International Publishing House, Pvt. Ltd.

Recommended Reference Books:

1. .An Introduction to Computational Physics, Tao Pang, Cambridge University Press
2. Numerical methods for scientific and Engineering computation M.K Jain,S.R.KIyengar, R.K. Jain, New Age International Publishers
3. Computer Oriented Numerical Methods, V. Rajaraman, PHI, 2004.
4. Numerical Methods, E. Balagurusami, Tata McGraw Hill, 2009.
5. Numerical Mathematical Analysis, J.B. Scarborough, 4PthP Edn, 1958
6. Explorations in Monte Carlo Methods Ronald W Shonkwiler and Franklin Mendivil , Springer

PH030301: SPECTROSCOPY AND LASERS

Credits : 4

Total Hours: 72

Objective of the course: This course is intended to develop the basic philosophy of spectroscopy. Its aims to equip the student with the understanding of (1) the theory of microwave and infra-red spectroscopies as well as the electronic spectroscopy of molecules; (2) the basics of Raman spectroscopy and the nonlinear Raman effects; (3) the spin resonance spectroscopies such as NMR and ESR. This course also introduces the student to the ideas of Mossbauer spectroscopy and LASER theory as well as its applications in Space Science and Atmospheric Science.

UNIT I

Microwave and Infra-Red Spectroscopy (18 hrs)

1.1 Width of spectral lines-natural width, collision broadening, Doppler broadening. Classification of molecules- linear, symmetric top, asymmetric top and spherical top molecules 1.2 Rotational spectra of rigid diatomic molecules; effect of isotopic substitution; intensity of spectral lines; energy levels and spectrum of non-rigid rotor 1.3 Information derived from rotational spectra (molecular structure, dipole moment, atomic mass and nuclear quadrupole moment). 1.4 Vibrational energy of a diatomic molecule - simple harmonic oscillator energy levels; diatomic molecule as anharmonic oscillator - energy levels; infrared selection rules; spectrum of a vibrating diatomic molecule. 1.5 Diatomic vibrating rotator P and R branches; break down of Born-Oppenheimer approximation. 1.6 Vibrations of polyatomic molecules fundamental vibrations and their symmetry; overtone and combination frequencies; Analysis by IR techniques- skeletal vibrations and group frequencies.

UNIT II

Raman Spectroscopy and Electronic Spectroscopy (18 hrs)

2.1 Quantum theory of Raman effect**;** classical theory-molecular polarizability; Pure rotational Raman spectra of linear molecules 2.2 Raman activity of vibrations; rule of mutual exclusion; vibrational Raman spectra; rotational fine structure 2.3 Structure determination from Raman and IR spectroscopy. 2.4 Non- linear Raman effects - hyper Raman Effect - classical treatment; stimulated Raman Effect - CARS, PARS - inverse Raman effect. 2.5 Electronic spectra of diatomic molecules - Born-Oppenheimer approximation, vibrational coarse structure-progressions and sequences; intensity of spectral lines- Franck Condon principle 2.6 Dissociation energy and dissociation products; Rotational fine structure of electronic-vibrational transition; Fortrat parabola; Predissociation.

UNIT III

Spin Resonance Spectroscopy (18 hrs)

3.1Nuclear Magnetic Resonance (NMR)-resonance condition; relaxation processes - Bloch equations 3.2 Chemical shift; indirect spin spin interaction, 3.3 CW NMR spectrometer; Magnetic Resonance Imaging. 3.4 Electron Spin Resonance (ESR) - Principle of ESR; thermal equilibrium and relaxation; ESR spectrometer; characteristics of the g-factor. 3.5 Total Hamiltonian for an electron; Hyperfine Structure- ESR spectrum of hydrogen atom 3.6 Mossbauer effect - recoilless emission and absorption; Experimental techniques in Mossbauer spectroscopy 3.7 Isomer shift; quadrupole interaction; magnetic hyperfine interaction.

UNIT IV

Lasers (18 hours)

4.1 Laser Modes: Longitudinal and Transverse modes, Properties of Gaussian laser beams, Spatial frequencies, Pulsed high power lasers; 4.2 Q switching, Methods of producing Q switching, Mode locking; Methods of producing mode locking; 4.3 Lasers for space applications: Optical Rotation sensors and their applications for space navigation: Sagnac effect, Sagnac Interferometers and their applications for space, Fiber Optic Gyros –application for space navigation 4.4 Laser in Atmospheric Science: Lasers for Remote Sensing of Environment. Aerosols, Pollutants, CBW Agents, Toxicity Levels, Nd:YAG Laser, Carbon dioxide Laser, Excimer Laser, LIDAR applications - Doppler wind LIDAR, Differential Absorption LIDAR for water vapor monitoring, Aerosol Lidar.

Text books

1. Molecular structure and spectroscopy, G. Aruldhas, PHI Learning Pvt. Ltd.
2. Fundamentals of molecular spectroscopy, C.N. Banwell and E M McCash, TataMcGraw Hill Education Pvt. Ltd.
3. Optical Electronics-Ghatak & Thyagarajan, Cambridge University Press
4. Lasers: theory and applications - Ghatak & Thyagarajan, New York, Plenum Press.
5. Laser applications, V.1, ROSS, monte, New York/Academic Press
6. Laser gyros and fibre optic gyros: Proceedings, London/Royal aeronautical society/1987.
7. Laser Remote Sensing: Fundamentals and Applications. RM Measures. John Wiley

Reference Books

1. Spectroscopy volume I and II - Straughan and Walker
2. Raman Spectroscopy, D.A. Long, Mc Graw Hill international, 1977.
3. Principles of lasers, Orazio Svelto, Springer.
4. Quantum Electronics, Amnon Yariv, John Wiley & Sons.
5. Laser fundamentals, William T.Silfvast, CUP 2nd Edn. (2009).
6. Fiber-optic gyroscope, Lefevre, Herve, Boston/Arcteh House/1993
7. Hecht, E and A R Ganesan, Optics 4th Ed., Pearson (2019).

<u>**SEMESTER IV**</u>

PH010401: NUCLEAR AND PARTICLE PHYSICS

Credits: 4

Total Hours: 90

Objective of the course: This course aims to provide the student to build up the fundamentals of nuclear and particle physics. After undergoing this course, the student will have knowledge about (1) the basic properties of the nucleus and the nuclear forces. (2) Major models of the nucleus and the theory behind the nuclear decay process; (3) the physics of nuclear reactions (4) the interaction between elementary particles and the conservation laws in particle physics. This course also intent to impart some idea about nuclear astrophysics and the practical applications of nuclear physics.

Unit I

Nuclear Properties and Force between Nucleons (18 hrs)

1.1 The nuclear radius- distribution of nuclear charge (isotope shift, muonic shift, mirror nuclei); distribution of nuclear matter. Mass and abundance of nuclides, nuclear binding energy. 1.2 Nuclear angular momentum and parity ; Nuclear electromagnetic moments- quadrupole moment. 1.3 The deuteron-binding energy, spin, parity, magnetic moment and electric quadrupole moment. 1.4 Nucleon-nucleon scattering; proton-proton and neutron-nuetron interactions 1.5 Properties of nuclear forces 1.6 Exchange force model.

Unit II

Nuclear Models and Nuclear Decay (18 hrs)

2.1 Liquid drop model, Bethe–Weizacker formula, Applications of semi- emperical binding energy formula. 2.2 Shell Model-Shell model potential, Spin-orbit potential, Magnetic dipole moments, Electric quadrupole moments, Valence Nucleons .2.3 Collective structure- Nuclear vibrations, Nuclear rotations.

2.4 Beta decay- energy release in beta decay ; Fermi theory of beta decay 2.5 Angular momentum and parity selection rules- allowed and forbidden transitions. Comparative half lives and forbidden decays; non-conservation of parity in beta decay 2.6 Gamma decay- angular momentum and parity selection rules ; internal conversion.

Unit III

Nuclear Reactions (18 hrs)

3.1 Types of reactions and conservation laws, energetics of nuclear reactions, isospin. 3.2 Reaction cross sections, Coulomb scattering- Rutherford formula, nuclear scattering. 3.3 Scattering and reaction cross sections in terms of partial wave amplitudes. 3.4 Compound-nucleus reactions; Direct reactions. 3.5 Resonance Reactions.

Unit IV

Particle Physics (18 hrs)

4.1 Yukawa‘s hypothesis; properties of pi mesons- electric charge, isospin, mass, spin and parity. 4.2 Decay modes and production of pi-mesons 4.3 Types of interactions between elementary particles, Hadrons and leptons .4.4 Symmetries and conservation laws, C P and CPT invariance, applications of symmetry arguments to particle reactions, parity non-conservation in weak interactions.4.5 Quark model, confined quarks, coloured quarks and gluons, experimental evidences for quark model, quark-gluon interaction, quark dynamics.4.6 Grand unified theories, standard model of particle physics.

Unit V

Nuclear Astrophysics and Practical Applications of Nuclear Physics (18 hrs)

5.1 Particle and nuclear interactions in the early universe, primordial nucleosynthesis 5.2 Stellar nucleosynthesis (for both $A<60$ and $A>60$) 5.3 Higg‘s boson and the LHC experiments; detection of gravitational waves and LIGO (qualitative ideas only)

5.4 Rutherford Backscattering spectroscopy and applications 5.5 Computerized Axial Tomography (CAT) 5.6 Positron Emission Tomography (PET)

Recommended Text Books:

1. Introductory Nuclear Physics, K. S. Krane JohnWiley
2. Nuclear Physics, S.N. Ghoshal, S. Chand & Company.
3. Nuclear Physics: Problem-based Approach Including MATLAB, Hari M Agarwal, PHI Learning Private Limited, Delhi .

Recommended References:

1. Problems and Solutions in Atomic, Nuclear and Particle Physics: Yung-Kuo Lim, World Scientific.
2. Nuclear Physics, S.N. Ghoshal, S. Chand & Company.

3. Introduction to Nuclear and Particle Physics : V M Mittal , R C Verma, S C Gupta (Prentice Hall India .
4. Concepts of Nuclear Physics: B L Cohen, Tata McGrawHill
5. Nuclear Physics: An Introduction – S B Patel, New Age International.
6. Nuclear Physics: R R Roy and B P Nigam, New Age International.
7. Nuclear Physics: R Prasad, Pearson.
8. Atomic Nucleus: R D Evans, Mc GrawHill, New York.
9. Nuclear Physics: I Kaplan, Narosa, New Delhi (2/e)
10. Nuclear and Particle Physics, B R Martin, John Wiley & Sons, New York, 2006.
11. Introduction to Elementary Particles : David Griffith, Wlley-VCH.
12. https://nptel.ac.in/ course/115104043
13. https://www.ias.ac.in/article/fulltext/reso/022/03/0245-0255
14. https://www.ias.ac.in/article/fulltext/reso/017/10/0956-0973
15. https://atlas.cern/updates/atlas-feature/higgs-boson.

PH030401: ASTRONOMY PRACTICALS

Credit: 4

Total hours: 180

Note:

Student must complete at least **10 experiments** from the following list. There are observational as well as data analysis astronomical experiments included. Also it is important to note that good weather conditions and a clear sky is a prerequisite for astronomical observation.

1. Measuring distance to the moon by Parallax
2. To study the characteristics of CCD camera
3. Polar Alignment of an astronomical telescope
4. Estimating relative magnitude by a group of stars by a CCD camera.
5. Estimate the Color composite of Orion Nebula using CCD and telescope.
6. Imaging star clusters with various filters and plotting of H-R diagram.
7. Measuring the "seeing" from Kochi - the brightness of a star is monitored by taking CCD images at regular time intervals from the time the star rises in the eastern horizon, till it crosses the zenith.
8. Distance determination to Cepheid variables based on their light curves.

9. Detection of 21-cm line of neutral hydrogen from our galaxy.
10. To estimate the night sky brightness with a photometer.
11. To estimate the temperature of an artificial star by photometry.
12. To study the effective temperature of stars by B-V photometry.
13. Estimating atmospheric extinction in different colours (filters).
14. Fitting techniques (linear and non-linear, fits to data with experimental errors, evaluating goodness of fit, etc.) and error analysis.
15. Handling of data and getting familiar with data analysis packages like IRAF, AIPS and CASA (This includes an introduction, beginners tutorials and exercises in these softwares as well as X-ray data analysis)
16. Experiments using photodiodes.
17. To measure the polarization of day/moon light.

PH030402: PHYSICS COMPUTATION PRACTICALS

Credit: 4
Total hours: 180

A minimum number of Twelve (**12**) experiments have to be done from the following list.

Note:

- Develop algorithm / Flowchart for all experiments
- Codes can be developed in any package / programming language. Candidate should be trained to explain parts of the codes used.
- Plotting can be done in any plotting package and can be separate from the programming package / environment.
- Verify numerical results with analytical results wherever possible.
- Repeat experiments for various initial values / functions / step-sizes.
- Training may be given to use methods discussed below to solve real physics problems.

Introduction to computational facility in the Centre:

Introduction to the IDE used in the center and commands for execution of a program. Inputting data and variables, outputting results on a console. Achieving arithmetic operations and use of data and variables in the software used at the Centre .Usage of decisions and loops. Creating an array and using array operations. Method of declaring functions and function calling. Writing data to a file and reading data from a file. Getting a graph from a data available using plotting software available with the Centre.

1. Find the root of the given non-linear equations by the bisection method
2. Find the root of the given non-linear equations by the Newton-Raphson method
3. A thermistor gives following set of values. Calculate the temperature corresponding to the given resistance using Lagrange interpolation.

Temperature	1101.0 K	911.3 K	636.0 K	451.1 K	273 K
Resistance	25.113 Ω	30.131 Ω	40.120 Ω	50.128 Ω	?

(This is only a sample data. Students should be capable to interpolate any set of data)

4. Newton's forward interpolation / backward interpolation.
5. Using appropriate technique and the given "Table", Calculate the pressure at the temperature asked.

Steam Table

Temperature in C	140	150	160	170	180
Pressure kgf/cc	3.685	4.854	6.302	8.076	10.22

Temperature: 1750 C (This is only a sample data. Students should be capable to handle another set of data from any other physical phenomena)

6. Value of some trigonometric function [say f(θ) = tan (θ)] for θ=15,30,45,60,75 are given to you. Using appropriate interpolation technique calculate value of f(θ) for a given value.
7. Numerical integration by the trapezoidal rule.
8. Using the trapezoidal rule, calculate the inner surface area of a parabolic reflecting mirror. (length of semi major axis, semi minor axis and height are to be given)
9. Numerical integration by the Simpson rule (both 1/3 and 3/8 rule).
10. Fit a straight line using method of least square to a set of given data without using any built in function of curve fitting. Compare your result with any built in curve fitting technique.
11. Fit an exponential curve to the given set of data using method of least square without using any built in curve fitting technique. Compare your result with any built in curve fitting technique.
12. Numerical solution of ordinary first-order differential equations using the Euler methods or the fourth order Runge-Kutta method.
13. Using technique of Monte Carlo method obtain the value of π correct to two decimal places.

14. Using Monte Carlo technique calculate the value of the given integral. Compare your result with result obtained by analytical method.
15. Write a program to solve the given system of linear equations by the Gauss elimination method.
16. Find out inverse of a given matrix by using Gauss-Jordan method.
17. Numerical solution of second-order differential equations using the fourth order Runge-Kutta method.
18. Fast Fourier Transform of a given signal.
19. Solution of Heat equation / Diffusion equation using Finite Difference Method.
20. A Duffing oscillator is given by $\ddot{x}+\delta\dot{x}+\beta x+\alpha^3=\gamma\cos(\omega t)$ where δ is damping constant greater than zero. Write a program to study periodic and aperiodic behaviour.
21. Study of path of a Projectile in motion with and without air drag and compare the values.
22. A study of Variation of magnetic field B(T) with critical temperature in superconductivity
23. Generation of output waveform of a Half wave / full wave rectifier.
24. Charging /discharging of a capacitor through an inductor and resistor
25. Variation in phase relation between applied voltage and current of a series L.C.R circuit
26. Phase plot of a pendulum (driven and damped pendulum)
27. Study variation of intensity along a screen due to the interference from Young's double slit experiment. Also study the variation of intensity with variation of distance of the screen from the slit.
28. Study variation of intensity along a screen due to the diffraction due to a grating. Also study the variation of intensity with variation of distance of the screen from the grating.
29. Study the difference equation $X_{n+1} = mX_n (1 - X_n)$ and obtain periodic and aperiodic behavior.
30. Generate a standing wave pattern and study change in pattern by changing its various parameters.

Reference books

1. Computational Physics: An Introduction, R.C. Verma, P.K. Ahluwalia & K.C. Sharma, New Age India, Pvt. Ltd ,2014.
2. An Introduction To Computational Physics, 2nd Edn,Tao Pang Cambridge University Press, 2010
3. Numerical Recipes: The Art of Scientific Computing 3rd Edn, William H. Press Cambridge University Press, 2007.

CHAPTER IV

ELECTIVES - SYLLABUS

This chapter deals with the syllabi of all Elective courses of MSc. Space Science program. The courses from Elective bunches will come in semesters III and IV, as opted by the colleges concerned.

ELECTIVE - BUNCH A – ASTROPHYSICS (Code: 88)

PH880301: SOLAR & ASTROPHYSICS

Credits: 4

Total Hours: 54

Objective of the course: This course aims to inculcate knowledge on celestial coordinate systems, solar physics, stellar evolution and galaxy among students.

UNIT I

The Celestial Co-ordinate systems: (12 hours)

Identification of stars- spherical co-ordinates the Alt azimuth system – Local equatorial system – the universal equatorial system – aspects of sky at a given place- Other systems- Stellar parallax and units of stellar distance.

UNIT II

Sun & Solar Phenomena (6 hrs)

Structure of the Sun: Solar interior, solar atmosphere, photosphere, chromosphere, corona; Small & large scale Solar structures, Sun spots and their properties, Prominences, Solar Flare: classifications, phases & flare theory; Solar cycle, Solar magnetic field.

Solar Wind (6 hrs)

Observed and derived properties of solar wind, Solar wind formation: Fluid theory for static as well as expanding isothermal solar atmosphere, Spatial configuration of magnetic field frozen into solar wind, Termination of solar wind, Heliosphere.

UNIT III

Stellar Physics (8 hrs)

Absolute magnitude and distance modulus, Colour index of a star, Luminosities of stars. Spectral classification of stars, HR diagram, equations of stellar structure, equation of state for stellar interiors, perfect gas, degenerate gas, sources of opacity. Boltzmanns formula, Saha's equation of thermal ionization, Harward system of classification, Luminosity effect of stellar spectra, Importance of ionization theory.

Stellar evolution – Its end stages (8 hrs)

Nuclear reactions, H burning, CNO cycle, energy transport by radiation and convection, Helium burning, neutrinos, solar neutrino experiments, structure of main sequence stars. Qualitative account of pre-main sequence evolution, early post main sequence evolution, turn off and the ages of stellar clusters, advanced evolutionary stages, degenerate stars.

UNIT IV

Our Galaxy, galaxies, hierarchical structure in the Universe (14 hrs)

The Galaxy, structure, stellar populations and the formation of the Galaxy. The ISM -components, Giant Molecular Clouds and star formation. Determination of the rotation curve of the Galaxy, its implications regarding dark matter. Classification of galaxies. Hierarchy of structures (groups clusters super-clusters). Active Galactic Nuclei and quasars.

Text books

1. Astrophysics: Baidyanath Basu
2. Astrophysics: Stars & Galaxies K. D. Abhyankar

References

1. The Physical Universe F. H. Shu
2. The New Cosmology, Albrecht Unsold
3. Introduction to Cosmology – J V Narlikar
4. Theoretical Astrophysics, T. Padmanabhan
5. https://www.springboard.com/blog/astronomy-for-beginners-free-online-courses/
6. https://ocw.mit.edu/courses/physics/8-282j-introduction-to-astronomy-spring-2006/

PH880402: PLASMA PHYSICS

Credits: 3

Total Hours: 90

Objective of the course: This course aims to give an idea on basic plasma physics to students. It includes the motion of a particle, waves and instabilities existing inside plasma. Also intend to develop a fundamental idea on nonlinear phenomena in plasma.

UNIT I

Introduction & Single Particle Motions (22 hours)

Occurrence of Plasmas in Nature - Definition of Plasma - Concept of Temperature - Debye Shielding - The Plasma Parameter - Criteria for Plasmas - Applications of Plasma Physics –Gas discharges, controlled thermonuclear fusion, Application in space physics and Astrophysics, MHD energy conversion and ion propulsion.

Motion in uniform E and B Fields - E x B and Gravitational drifts - Motion in non-uniform B Field - Gradient and Curvature drifts – Magnetic Mirrors – Non uniform E Field - Motion in time varying E Field - Motion in time varying B Field - Summary of Guiding Centre Drifts.

UNIT II

Waves in Plasmas (24 Hours)

Relation of Plasma to Ordinary Electromagnetics – classical treatment of magnetic fields- classical treatment of dielectrics - The Fluid Equation of Motion – convective equilibrium – stress tensor- Concept of collision - Representation of Waves - Group Velocity . Plasma Oscillations - Electron Plasma Waves - Ion Waves - Validity of Plasma Approximation - Comparison of Ion and Electron Waves. Electrostatic Electron Oscillations Perpendicular to B - Electrostatic ion Waves Perpendicular to B - The Lower Hybrid Frequency. Electromagnetic Waves with B, Electromagnetic Waves Perpendicular to B - Cutoffs and Resonances

UNIT III

Plasma Waves, Equilibrium & Stability (20 Hours)

Electromagnetic Waves Parallel to B - Hydromagnetic Waves - Alfven waves, Magnetosonic Waves – Hydro-magnetic Equilibrium – Concept of plasma β, diffusion of magnetic field into plasma - Classification of Instabilities – the Two Stream Instability and the Gravitational Instability – Weibel instability – Concept of Landau damping.

UNIT IV

Nonlinear Plasma Physics (24 Hours)

Parametric Instabilities – Coupled Oscillators, Frequency Matching, Instability Threshold and Growth Rate – Equations of Nonlinear Plasma Physics– Nonlinear Ion Acoustic waves – the Korteweg – deVries equation. The Ponderomotive Force - Nonlinear Electron Plasma waves – the Nonlinear Schrodinger equation – Concepts on Solitons, shocks, double layers.

Text Books:

1. Introduction to Plasma Physics and Controlled Fusion F. F. Chen 2nd edition, Plenum Press.
2. Introduction to Plasma Theory – D. R. Nicholson 1st edition, John Wiley & Sons.

3. Chaos and Structures in Nonlinear Plasmas W. Horton & Y. H. Ichikawa 1st edition, Allied Publishers.

Reference Books:

1. Fundamentals of Plasma Physics – J. A. Bittencourt, Springer
2. Fundamentals of Plasma Physics – Paul M. Bellan, Cambridge.

PH880403: INSTRUMENTATION IN SPACE PHYSICS & ASTROPHYSICS

Credits: 3

Total Hours: 90

Objective of the course: This course provides knowledge on some important instrumentation techniques in space science and astrophysics.

Unit I:

Photoemissive Materials: (24 Hrs)

Theory of Photoemission, Spicer's three step photoemission model; Development of photocathode in X-rays, Ultraviolet, Visible and Infra-red wavelength region; Negative electron affinity (NEA) photocathode, alternative routes to enhanced photocathode performance.

Unit II

Detecting Photons (22 Hrs)

Photomultiplier tubes, Photodiodes, Hybrid photodiodes; Charge-Coupled Device (CCD); Micro channel plates, Sensitivity and dynamic range, Time resolution, Energy resolution and Image resolution of photo-detectors.

UNIT III

Radio waves Detection: (24 Hrs)

Techniques to study Ionosphere: Ionosondes, Insitu measurements, VHF (Scintillation) receivers; VLF receiver, Whistler diagnostics.

Remote Sensing

Concept and Foundations of Remote Sensing: Electromagnetic Radiation (EMR), Interaction of EMR with Atmosphere and Earth surface, Application areas of Remote Sensing.

Characteristics of Remote Sensing Platforms & Sensors: Ground, Air & Space platforms, Return Beam Vidicon, Multi-spectral Scanner.

Microwave Remote Sensing: Microwave sensing, RADAR: SLAR & applications, LIDAR: basic components & applications.

Earth Resource Satellites: Brief description of Landsat and Indian Remote Sensing (IRS) satellites.

UNIT III

Astronomical Techniques: (20 Hrs)

Image formation, Diffraction, Aberrations; Telescopes – Optical and Radio Telescopes, Telescope structures and mountings; X-ray telescopes & detectors; Gamma rays telescopes and detectors.

Reference Books:

1. Photoemissive material: Preparation, properties & uses: A.H. Sommer, Wiley, NewYork.
2. Physics of semiconductor devices: S.M. Sze & K.K. Ng, A John Wiley and Sons, INC Publications.
3. Ionospheric techniques and phenomena: Alain Giraud, A. Giraud & M. Petit, Springer Pub.
4. Space science: Editors: L.K. Harra & K.O. Mason, Imperial College Press; Singapore.
5. Telescopes and Techniques: An Introduction to practical Astronomy: C.R. Kitchin, Springer UK
6. Observational Astrophysics: R.C. Smith, Cambridge University Press.
7. Introduction to Remote Sensing – J. B. Campbell.
8. Manual of Remote Sensing: Vol I & II, Edited by R. N. Colwell, American Society of Photogrammetry.

ELECTIVE - BUNCH B – ATMOSPHERIC SCIENCE (Code: 89)

PH890301: NUMERICAL WEATHER PREDICTION

Credits: 4
Total hours - 54

Unit I

Numerical Weather Prediction (20 Hrs)

Historical Back ground, Finite Difference Schemes for Space and Time, Trucation Error, Linear and non-linear computational instabilities, Staggered Grid, Aliasing, Arakawa Jacobian, Barotropic and Equivalent Barotropic Models, Thermodynamic Energy Equation and Quasigeostrophic Vorticity Equation in Isobaric Coordinates, Diagnostic Omega Equation, Tendency Equation and Potential Vorticity Equation, Primitive Equation Model, Sigma Coordinate System and Primitive Equation Model in Sigma Coordinate system. Introduction of various numerical models

Unit II

Initialisation and Data Assimilation (14 Hrs)

Static, Dynamic, normal mode, Newtonian relaxation. 3d Var and 4d Var Concept of Kalman Filter

Unit III

Parametrization (20 Hrs)

Subgrid scale processes, closure problem, Dry and moist adiabatic adjustment, cumulus parameterization. Shallow and deep convection, Kuo's Cumuluis Parameterization, Arakawa Schubert Parameterization, Grell Scheme, Betts Miller and Kain – Friesch Parametetization Schemes, Parameterization of PBL. Radiation parameterization. Orographic parameterization, Gravity wave drag and its parameterization.

Reference Books

1. An introduction to Dynamic Meteorology by J.R. Holton, Academic Press.
2. Numerical Methods used in Atmospheric Models WMO-GARP Series No.17
3. Numerical Prediction and Dynamic Meteorology G.J. Haltiner and R.T. Williams,
4. Parameterization of subgrid scale processes WMO-GARP, Series No. 8.
5. Numerical Weather Prediction by P.D. Thompson

PH890402: CLOUD PHYSICS AND ATMOSPHERIC ELECTRICITY

Credits: 3
Total hours - 90

Unit I (24 Hrs)

Cloud Morphology, Warm Cloud Microphysics (Nucleation and Condensation, Kelvin equation, Kohler Theory), Growth of cloud droplets by collision and coalescence, Initiation of warm rain. Cold Cloud Microphysics (Nucleation and growth of ice) Bergeron-Findeisen Process. Types of microphysical processes and categories in clouds. Weather modification (Artificial and inadvertent).

Unit II (24 Hrs)

Atmospheric electricity in fair weather (Ions and Atmospheric conductivity, Space charges), Electric field, Air-Earth currents, Precipitation currents and Point discharge currents. Global Electric Circuit (Classical concept, validity and limitations).

The electrical structure of thunderstorms, Cloud electrification mechanisms, Physics of lightning, lightning and nitrogen fixation.

Unit III (18 Hrs)

Fog and Boundary layer clouds, Middle level clouds, Cumulus and Cumulonimbus clouds, Thunderstorms and Tornadoes, Meso-scale convective systems, Clouds in Hurricanes and cyclones, Orographic Clouds, Frontal clouds, Polar Stratospheric Clouds, High Clouds and Contrails, Lightning in other Planets of Solar System.

Unit IV (24)

Brief Introduction of Plasma physics, Sun-Composition and Structure, Solar radiation, Solar atmosphere, Sunspots and solar rotation, Solar Cycle, Solar wind, Solar Flares and Coronal Mass Ejections.

Earth’s atmosphere-ionosphere and magnetosphere. Propagation of CMEs in the IP medium, Interaction of solar wind with earth's magnetosphere, magnetic reconnection, geomagnetic storms. Implications of Space weather effects

Books

1. A Short course in cloud physics” R.R. Rogers,
2. Atmospheric Sciences: An introductory Survey by J.M. Wallace and P.V. Hobbs, Academic Press.
3. Atmospheric Electrodynamics” H.Volland, Springer Verlag,
4. Physics of the Cloud by B.J. Mason
5. Microphysics of cloud and Precipitation by Pruppacher and Klett
6. Atmospheric Electricity by J.A. Chalmers
7. Earth’s Electrical Environment- National Academy Press
8. Lightning by M.A. Uman
9. Cloud Dynamics by R.A. Houze
10. Clouds Rain and Rainmaking by B.J. Mason
11. Electrical Nature of Storms by D. McGorman and W.D. Rust

12. Space Weather: Physics and Effects, By Volker Bothmer and I.A. Dagliz, Springer.
13. Solar Terrestrial Environment: Introduction to Geospace, By J.K. Hargereaves,Cambridge University Press.

PH890403: SATELLITE METEOROLOGY

Credits: 3
Total Hours: 90

Unit I (24 Hrs)

Remote sensing principles, Application in meteorology. Signal Sensor, A platform,Signature for Interpretation. Satellite orbits and attitude: principles of satellite motion, Kepler's laws, Sub satellitepoint, Apogee, perigee, node anti node**,** Electromagnetic spectrum,Radiation laws.Spatial Resolution Temporal Resolution ,Spectral Resolution,Radiometric Resolution.

Orbital mechanics orbital elements, satellite attitude. Types of orbits- earth- and sun-synchronous, polar orbiting and geostationary satellites.

Unit II (22 Hrs)

Concept of pitch roll and yaw. Visible, infrared, and microwave channels; Scanning mechanism, IFOV and contrast enhancement in an image.

Identification of cloud types and patterns in satellite images, synoptic systems, estimation of SST, cloud top temperatures, winds and rainfall: temperature and humidity soundings.

Hardware details of INSAT Meteorological Data Processing System (IMDPS) including Earth Station. Current and future meteorological satellites of the world. Payloads on Meteorological Satellites, NOAA, INSAT -3D, Meghatropiques etc.

Unit III (22 Hrs)

Quantitative product derivation from satellite data: Sea surface temperature, outgoing longwave radiation, cloud motion vectors, computation of NDVI. Algorithm for vertical temperature and humidity profiles. Microwave retrievals: TRMM satellite, Global Precipitation Mission, Global Precipitation Climatology Project. D'vorak's technique for tropical cyclone intensity estimation. Ozone and aerosol estimation using satellite radiance

Unit IV (22 Hrs)

Radar principles, Classification of RADARS-Weather and Atmospheric Radar, Radar Hardware, History of radar in atmospheric investigation,Radar Equation for Point Targets, Distributed Targets.

Derivation of Radar parameters-Doppler Velocity Measurements, Spectrum Width and turbulence, Meteorological Targets, Meteorological Uses of Weather Radar, Signal Processing of Radar returns and their applications.

Reference Books:

1. Theory of Satellite Orbit in the Atmosphere by King Hele
2. Weather Satellite by L.F. Hubert
3. Meteorological Satellite by W.K. Widger
4. A guide to Earth Satellite by D. Fishlock
5. Advances in Satellite Meteorology by VinnichenkoGoralik
6. Satellite meteorology by Henri W. Brandli
7. Satellite Meteorology - WMO Technical Notes No. 124 and 153.
8. Satellite Meteorology, by R.R. Kelkar
9. Radar Meteorology by L.J. Batton
10. Radar Observation of the Atmosphere By Battan (1973),