ST. ALBERT'S COLLEGE ERNAKULAM
(AUTONOMOUS)
Affiliated to Mahatma Gandhi University, Kottayam, Kerala

SYLLABUS FOR POSTGRADUATE PROGRAMME

MASTER OF SCIENCE IN
SPACE SCIENCE AND TECHNOLOGY

(WITH EFFECT FROM 2011 ADMISSION)

BOARD OF STUDIES

(As per UGC Regulations 2018)

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7.	Dr. Ninan Sajith Philip	Associate Professor, Department of Physics, St. Thomas College,Kozhencherri-689641..	MSc, PhD.
8	Dr. Tripti S. Warrier	Assistant Professor, Department of Electronics,CUSAT, Kalamassery.	B Tech, M Tech, PhD.
c) Two Subject Experts: *(From outside the Parent University to be nominated by the Academic Council)*			
1	Dr. Anand Narayanan	Associate Professor , Department of Earth and Space Science , Indian Institute of Space Science and Technology, TVM	M.Sc., Ph.D

2	Dr. M. K. Jayaraj	Syndicate member, and Professor Department of Physics , CUSAT ,Kalamassery	M.Sc , Ph.D
d) Nominee of Vice Chancellor: (*one expert to be nominated by the Vice-Chancellor from a panel of six experts recommended by the Principal)*			
1	Dr.Annieta Philip	Associate Professor , Department of Physics , Cochin College	M.Sc , M.Phil , Ph.D
2	Dr.Issac Paul	Associate Professor, Department of Physics , S.B.CollegeChanganassery	M.Sc , Ph.D
3	Dr. S Antony	Associate Professor, School of Pure and Applied Physics, MG. University Kottayam	M.Sc ,Ph.D
4	Dr. Gishamol Mathew	Assistant Professor , Maharajas College Ernakulam	M.Sc , Ph.D
5	Dr. K. P. Vijayakumar	Professor Emeritus, Department of Physics, CUSAT	M.Sc , Ph.D
6	Dr.Siby Mathew	Associate Professor , Department of Physics , S.H. College Thevara	M.ScPh.D
e) Placement Representative: *(One representative from industry/corporate sector/allied area relating to placement)*			
1	Mr G. Sivaramakrishnan	Consultant	Konark Systems Pvt Ltd Kaloor, Ernakulam, Kerala
2	Rev.Dr.GeorgePeter Pittappillil	Director	Mithradham
f) Meritorious alumnus: *(One postgraduate meritorious alumnus to be nominated by the Principal)*			
1	Dr.Sasikumar	Principal , Govt.College Thalasseri	M.Sc , Ph.D
g) The Chairman, Board of Studies, **may** *with the approval of the Principal of the college*, **co-opt:**			
a) Co-opted Special Experts from outside (*Experts from outside the college whenever special courses of studies are to be formulated)***:**			
1	Dr. Joe Jacob	Associate Professor and HoD Department of Physics, SB College Changanserri	M.Sc , Ph.D
2	Dr. L. Godfrey	Emeritus professor, Dept. of Physics, CUSAT	M.Sc , Ph.D
3			
4			
5			
b) Other members of staff of the same faculty:			

1	Sri. Shaji Joseph	Associate Professor	M.Sc
2	Sr. Lawrel Gregory	Associate Professor	M.Sc
3	Sri. S. Charles	Associate Professor	M.Sc
4	Sri. Justin Paiva	Associate Professor	M.Sc, M.Phil
5	Sri. Augustine Sumesh C J	Assistant Professor	M.Sc, B.Ed

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CONTENTS

PREFACE

As envisaged in the recent regulations of Autonomous colleges in India by University Grants Commission, autonomous colleges enjoy the academic freedom to enrich the curriculum by incorporating recent trends and needs. Curriculum and syllabus of each academic program has to be revised periodically to impart major objectives like global competency, skill component, values and regional relevance. Academicians and scholars in the respective area of knowledge have to express a missionary zeal for this great purpose.

In 2016, when St. Albert's College was granted autonomy, we adopted the curriculum and syllabus followed by the Mahatma Gandhi University, Kottayam for the year 2016. In 2017, when the Mahatma Gandhi University made a comprehensive revision of their curriculum and syllabus, it was adopted by the college as it was a better curriculum that met the needs and current demands of the culture, the society, and the expectations of the population being served. However the Syllabus revision committee of the department studied the present curriculum in detail and proposed some reasonable changes for further enrichment which may be implemented from 2019 admission onwards.

The present M.Sc Space Science And Technology is a two year program shall be conducted in the semester pattern. There shall be four semesters with two semesters in each year. Each semester shall have 90 instructional days with five hours of instruction each day under the five day system. End semester examination shall be held outside the 90 regular instructional days.

Chapter – I is dedicated to the General Scheme of the Syllabi. The M.Sc. programme in Space science and technology with the course structures in all four semesters are also given in this chapter.

Evaluation is discussed in Chapter – II. The pattern of question papers of theory and practicals and the respective internal and external evaluation schemes are discussed here.

In Chapter – III, the syllabi of M.Sc Space science and Technology programme is given. Chapter – IV is dedicated for the gist of the syllabus revision.

GRADUATE PROGRAMME OUTCOME

Deep Knowledge in the Discipline: To develop a thorough knowledge about the subject and its allied realms by conscious and continuous process of learning and get informed about the cutting edge research in the frontier areas of the subject.

Critical Thinking and Problem Solving Skills: To develop an informed and analytical approach to learning and demonstrate an in-depth knowledge of the subject and to give his/her opinion supported by logical reasoning and problem solving skills.

Self-Awareness and Emotional Intelligence: To develop a proper idea about one's own capabilities and potentials and to nurture those attributes towards holistic personality development.

Teamwork and Effective Communication: To demonstrate proficiency in communicating competently in groups and organizations, competence in interpersonal communication and to possess skills to effectively deliver formal and informal presentations to a variety of audiences in multiple contexts.

Leadership Qualities: To build essential features of a true leader and to cultivate the character and courage to shoulder responsibilities.

Social Interaction and Ethical Standards: To foster the social skills and developing peer interaction and enabling them to make all people feel valued and to respect their differences by being responsible citizens for creating a socially inclusive society. To recognize values such as justice, trust, equity, fairness, kindness and develop a commitment to meeting and upholding standards of ethical behaviour in all walks of life and comprehending the moral dimensions of decisions and actions.

Environmental Consciousness: To discern the issues of environmental contexts and engages in promoting values and attitudes that claim coexistence and sustainable living with reduced, minimal, or no harm upon ecosystems.

Lifelong Learning: To develop a passion to be an independent lifelong learner by imbibing real-time changes in the socio-technological context, promoting continuous development and improvement of the knowledge and skills needed for employment and personal fulfilment.

PROGRAMME SPECIFIC OUTCOME

MSc Space science and Technology is a master's programme specially designed with the guidance of Indian Space Research Organization under University Grants Commission innovative program with the aim of developing research interest in Atmospheric and Astronomical disciplines among students and thereby facilitating them to give back to the society through their research. The major outcomes envisioned through this program are,

To train the students to engage research under inter disciplinary domains- the course is designed in a way so as to impart sound theoretical knowledge in the realms of Physical, Astronomical and Atmospheric sciences along with contemporary practical ,computational and analytical methods.

Enable the students to work under demanding and rigorous nature of research- the course allows the students to carry out their master's thesis work at leading scientific institutions around the country. The project is carried out in three months time and thus preparing them in a time bound manner.

CHAPTER – I

1. GENERAL SCHEME OF THE SYLLABI

1.1 Theory courses

There are seventeen theory courses spread equally in all four semesters in the M.Sc. Programme. Distribution of theory courses is as follows. There are seventeen courses common to all students. Semester I, Semester II and semester III will have **five** courses each out of which four will be of 90 hours of teaching and one will be of 54 hours of teaching. And Semester IV will have **two** courses each. Paper PSP4CRT0119 and Paper PSP4CRTO2119, each with a syllabus for 90 hours of teaching. Paper PSP4CRT02 will be an elective paper. Students can choose the elective from two papers given.

1.2 Practicals:

All four semesters will have a course on practicals. In Semesters I, II have computer practicals in different programming languages. In semester III has plotting practical. The Semester IV has laboratory practical on Plasma and Astronomy and Astrophysics . A minimum of 7 programs and 15 programs a should be done in Semester I and II respectively and recorded. In Semester III at least 12 problems should be done. The practical examinations will be conducted on each semester and one examiner appointed as external examiner except in semester IV, there would be of two examiners.

1.3 Project:

The project of the PG program should be very relevant and innovative in nature. The type of project can be decided by the student and the guide (a faculty of the external institution). The project work should be taken up seriously by the student and the guide. The project should be aimed to motivate the inquisitive and research aptitude of the students. The students may be encouraged to present the results of the project in seminars/symposia. The conduct of the project may be started at the beginning of Semester III, with its evaluation scheduled at the end of Semester IV along with the practical examination as being practiced in the present syllabus. The project is evaluated by the external examiners. The project guide or a faculty member deputed by the head of the department may be present at the time of project valuation. This is to facilitate the proper assessment of the project.

1.4 Viva Voce:

A viva voce examination will be conducted by the two external examiners at the time of evaluation of the project. The components of viva consists of subject of special interest, fundamentals, topics covering all semesters and awareness of current and advanced topics with separate marks.

1.5 Course Code:

The courses in the programme are coded according to the following criteria. The first letter 'P' of the code indicates PG, the second two letters indicate the name of programme, ie. SP stands for Space science. Next digit indicate the semester. ie., 1 for 1 st semester, next letters CRT indicate core theory(CRP-Core Practical, CRV- Core Viva, CPR- Core Project), next two digits 01, 02 etc run for order of courses. (eg: 01 for first paper,02 for second paper), last two digits indicate year of syllabus(19 for 2019)

1.6 Programme design

The detailed structure of the courses common to all students of the programme is given in Table 1.1

Sem	Name of the course with course code	No.of Hrs/week	Total Hrs per sem
I	PSP1CRTO1 Fundamentals of atmospheric and Space sciences	5	90
I	PSP1CRTO2Classical mechanics	5	90
I	PSP1CRTO3Quantum mechanics	5	90
I	PSP1CRTO4Mathematical and statistical methods	5	90
I	PSP1CRTO5Numerical methods and computer programming	3	54
I	PSP1CTP01Computer programming I	2	36
II	PSP2CRTO1Fundamentals of earth sciences and Remote sensing	5	90
II	PSP2CRTO2Statistical mechanics	5	90
II	PSP2CRTO3Electrodymanics	5	90
II	PSP2CRTO4Introduction to plasma physics and space physics	5	90

II	PSP2CRTO5Advanced computer programming	3	54
II	PSP2CRPO1Computer programming II	2	36
III	PSP3CRTO1Atmospheric dynamics	5	90
III	PSP3CRTO2Climatology-Tropical and Global	5	90
III	PSP3CRTO3Synoptic meteorology and Satellite meteorology	5	90
III	PSP3CRTO4Astronomy and Astrophysics	5	90
III	PSP3CRTO5Atmospheric chemistry and Atmospheric Electricity	3	54
III	PSP3CRPO6Atmospheric sciences	2	36
IV	PSP4CRTO1Space plasma	5	90
IV	PSP4CRTO2Elective I- Solar physics	5	90
IV	PSP4CRTO2Elective II- Space dynamics	5	90
IV	PSP4CRPO1Experiments for Astronomy and Astrophysics	6	108
IV	PSP4CRPO2Laboratory for plasma	2	36
IV	PSP4CPRO1Project/Dissertation	Nil	Nil
IV	PSP4CRVO1Course Viva	Nil	Nil

Year	Semester	Paper	Paper Code	Teaching hours/ week		Paper for examination			Maximum marks awarded per paper			Semester Total
				Theory	Practical	Theory	Practical	Others	Internal	External	Total	
First Year	I	Paper I Paper II Paper III Paper IV Paper V Paper I (Lab)	PSP1CRT0119 PSP1CRT0219 PSP1CRT0319 PSP1CRT0419 PSP1CRT0519 PSP1CRP0119	5 5 5 5 3	2	PSP1CRT0119 PSP1CRT0219 PSP1CRT0319 PSP1CRT0419 PSP1CRT0519	PSP1CRP01		25 25 25 25 15 10	75 75 75 75 45 30	100 100 100 100 60 40	500
	II	Paper VI Paper VII Paper VIII Paper IX Paper X Paper II (Lab)	PSP2CRT0119 PSP2CRT0219 PSP2CRT0319 PSP2CRT0419 PSP2CRT0519 PSP2CRP0119	5 5 5 5 3	2	PSP2CRT0119 PSP2CRT0219 PSP2CRT0319 PSP2CRT0419 PSP2CRT0519	PSP2CRP01		25 25 25 25 15 10	75 75 75 75 45 30	100 100 100 100 60 40	500
Second Year	III	Paper XI Paper XII Paper XIII Paper	PSP3CRT0119 PSP3CRT0219 PSP3CRT0319 PSP3CRT0419 PSP3CRT0519 PSP3CRP0619	5 5 5 5 3	2	PSP3CRT0119 PSP3CRT0219 PSP3CRT0319 PSP3CRT0419 PSP3CRT0519	PSP3CRP06		25 25 25 25 15 10	75 75 75 75 45 30	100 100 100 100 60 40	500

		XIV Paper XV Paper III (Lab)										
	IV	Paper XVI Paper XVII Paper IV (Lab) Paper V (Lab) Project Viva voce	PSP4CRT0119 PSP4CRT0219 PSP4CRP0119 PSP4CRP0219 PSP4CPR0119 PSP4CRV0119	5 5 7	6 2	PSP4CRT0119 PSP4CRT0219	PSP4CRP0119 PSP4CRP0219	PSP4CPR0119 PSP4CRV0119	25 25 30 10 35 -	75 75 90 30 105 100	100 100 120 40 140 100	600
		Grand Total										2100

1.7 Programme structure –Table 1.2

CHAPTER – II

2. EVALUATION

2.1 Scheme of evaluation:

For each theory paper 25% marks will be set apart for continuous internal evaluation. External evaluation will be 75% marks. The same will follow for the project work also. For viva-voce there will only be external evaluation. A team of external examiners will evaluate the project at the end of the fourth semester. A comprehensive viva voce will also be conducted by the same team at the end of the fourth semester.

The 25% marks for continuous internal evaluation will be distributed as follows:

Theory Paper:

1. Attendance : 20%
2. Assignment (1) : 20%
3. Test paper (2) : 40%
4. Seminar : 20%

Practical paper:

1. Attendance : 20%
2. Record : 40%
3. Test paper (2) : 40%

Project:

1. Test paper/Oral test : 15 marks
2. Seminar (1) : 15 marks
3. Punctuality : 5 marks

Total : 35 marks

2.2 Question Paper Pattern for Theory Courses.

Maximum time : 3 Hours

Maximum mark: 75

The question paper consists of three parts namely part A, part B and part C. Part A consists of 9 questions of 2 marks of which 6 questions have to be answered by students. A maximum score of 12 can be obtained from part A. Part B consists of 5 questions of 5 marks of which 3 questions are to be answered. A maximum of 15 marks will be awarded. Part C consists of 8 questions of 12 marks each in 4 pairs and student is expected to answer one question from each pair. A maximum of 48 marks can be awarded.

For Semester1, Semester2, and Semester3 paper 5 is of maximum 45 marks and 2 hours time. The question paper consists of three parts namely part A, part B and part C. Part A consists of 6 questions of 2 marks each of which 4 questions have to be answered by students. A maximum score of 8 can be obtained from part A. Part B consists of 4 questions of 5 marks each,of which 2 questions are to be answered. A maximum of 10 marks will be awarded. Part C consists of 6 questions of 9 marks each in 3 pairs and student is expected to answer one question from each pair. A maximum of 27 marks can be awarded.

2.3 Attendance, Seminar , Project

The same marks will be awarded for all papers on the basis of the average attendance of the student concerned. The weightage for awarding marks for attendance shall be as follows:

Attendance Marks

Below 75% Nil

75% above but below 80% 40% of the total marks allotted for attendance

80% above but below 85% 60% of the total marks allotted for attendance

85% above but below 90% 80% of the total marks allotted for attendance

90% and above Full marks allotted for attendance

d. Attendance shall be marked in every period and is consolidated at the college office.

e. Test paper: A minimum of two tests for each paper shall be conducted (except in the case of project)

of which the best shall count for internal evaluation.

f. Seminar: One seminar for each paper marks to be awarded on the basis of the script (3 marks) and presentation (2 marks).

g. Internal for project: There will be a test paper / oral test and a seminar, the former to be held in the

second semester and the latter in the third semester. The seminar will carry a maximum of 15 marks (10 marks for script and 5 for presentation). Only those who present in the stipulated time and submit the project report two months before the completion of the final semester will qualify the marks set apart for punctuality, which will be distributed as follows;

Presentation of seminar paper in the stipulated time: 2 marks

Submission of the project report in the stipulated time: 3 marks

2.4 General Instructions

(i) The assignments/ seminars / test papers are to be conducted at regular intervals. The time for conduct of two test papers will be notified by the university from time to time. These should be marked and promptly returned to the students.

(ii) One teacher appointed by the Head of the Department will act as a coordinator for consolidating grade sheet for internal evaluation in the department in the format supplied by the University. The consolidated grade sheets are to be published in the department notice board, one week before the closing of the classes for end semester examinations. The grade sheet should be signed by the coordinator and counter signed by the Head of the Department and the college Principal.

(iii) The consolidated grades in specific format supplied by the university are to be kept in the college for future references. The consolidated grades in each course should be uploaded to the University Portal at the end of each semester as directed by the University.

(iv) A candidate who fails to register for the examination in a particular semester is not eligible to continue in the subsequent semester.

(v) Grievance Redress Mechanism for Internal evaluation: There will be provision for grievance redress at four levels, viz,

a) at the level of teacher concerned,

b) at the level of departmental committee consisting of Head of the Department, Coordinator and teacher concerned,

c) at the level of college committee consisting of the Principal, Head of the Department and one member of the college council, nominated by the principal each year,

d) at the university level committee consisting of Pro-Vice Chancellor / Dean of the Faculty, the controller of examinations and the Convener of the Standing Committee on Academic Affairs of the Syndicate. College level complaints should be filed within one week of the publication of results and decisions taken within two the next two weeks. University level complaints will be made within the time stipulated by the University and decisions will be taken within one month of the last date fixed for filing complaints.

2.5 Practical, Project and Viva Voce Examinations

Practical Examination: All practical examinations are conducted at the end of Semester. The practical examinations are conducted immediately after theory examinations . Practical examinations in Semester I and II and IV will be of three hours duration. And in Semester III examination has five hours duration .Two examiners in Semester IV, and one examiner in Semester I,II and III from the panel of examiners of the institution will be deputed to each of the examination for the fair and transparent conduct of examinations. Practical examination is conducted in batches having a maximum of eight students. The board enjoys the right to decide on the components of practical and the respective weights.

Project Evaluation: The project is evaluated by the two external examiners deputed from the board of practical examination. The dissertation of the project is examined along with the oral presentation of the project by the candidate.. The supervising guide or the faculty appointed by the head of the department may be allowed to be present at the time of project evaluation. This is only to facilitate proper evaluation of the roject. The different mark for assessment of different components is shown in Table 1.3.

Components	Maximum mark
Quality	10
Presentation	30
Experimental and data collection	45
Result and dissertation layout	20

Viva Voce Examination: Viva voce examination is conducted only by the two external examiners of the board of practical examinations. The viva voce examination is given a mark of 100 . The different mark for assessment of different components is shown in Table 2.6.

Components	Maximum mark
Bsc/+2 Level	20
Msc syllabus based	40
Subject of interest	20
Advanced level	20

CHAPTER III

SYLLABUS

SEMESTER I

Paper – I: FUNDAMENTALS OF ATMOSPHERIC AND SPACE SCIENCES
Paper Code: SST 101 (90 Hrs)

Module 1 (20 Hrs)

Elementary concepts of atmospheric sciences: atmosphere and its composition, pressure and its variation with height, diurnal variation of surface pressure, earth-sun relationship, variation of temperature with height, diurnal variation of surface temperature, definition of wind, squall, gustiness, gale, Beaufort scale, land and sea breeze, katabatic and anabatic winds, Buys-Ballot's law, geostrophic wind, visibility, causes of poor visibility, haze, mist, fog, tropical depression and storm, basic ideas of general circulation (without mathematical derivations).
Remote sensing – basic principles. Sensors and systems: visible, infrared, water vapour and microwave sensors, sensor characteristics, sensor materials, passive and active sensors, scanning radiometers, spectral signatures.

Module 2 (20 Hrs)

Laws of thermodynamics: Maxwell's equation, Gibbs' equation, free energy, atmospheric composition, equation of state for dry and moist air, adiabatic and isothermal processes, humidity parameters, thermodynamic laws, entropy, potential temperature, pseudo-adiabatic process, equivalent temperature, equivalent potential temperature, Claussius-Clapeyron equation, stability and instability.

Module 3 (20 Hrs)

Thermal structure of the troposphere, stratosphere, mesosphere and ionosphere, D, E, F-1 and F-2 regions, radio wave propagation, effect of earth's curvature, stratospheric circulation, stratospheric warming, quasi-biennial oscillation, ozone, temporal and spatial variations of ozone, Umkehr effect, ozone depletion and its impact.

Module 4 (15 Hrs)

Radiation: sun and atmosphere, electromagnetic spectrum, attenuation, absorption, reflection, scattering, emissivity, black body, Planck’s law, Stefan-Boltzmann law, Wien’s displacement law. Radiative transfer, forward and inverse problems, optical depth, rotational, vibrational and mixed spectra, emissivity and polarization, Beer’s law, thermal radiation, spectral windows.

Module 5 (15 Hrs)

Solar and planetary system - Kepler’s laws, orbital elements. Satellite orbits and altitude: principles of satellite motion, satellite altitude and its control, types of orbits, polar and geostationary, earth- and sun-synchronous, orbit optimization, viewing geometry, launch vehicles and spacecrafts.

Text Books:

1. *An Introduction to Meteorology*, S. Petterssen
2. *Introduction to Theoretical Meteorology*, S. Hess
3. *Atmospheric Physics*, J. V. Iribrine and H. R. Cho
4. *Digital Image Processing*, R. C. Gonzales and R. E. Woods, 2nd Ed, Pearson India, 2002
5. *Lecture Notes on Satellite Meteorology*, Vol 1 and 2, SAC, Ahmedabad
6. *Fundamentals of Remote Sensing*, George Joseph, 2003
7. *Processing Remote Sensing Data*, M. C. Girgard and C. Girgard, Oxford-IBH, 1999
8. *Theory of Satellite Orbits in an Atmosphere*, King-Hele Desmond, Butterworths, 1964

Reference Books

1. *Elementary Meteorology*, S. Petterssen
2. *Atmospheric Science - An Introductory Survey*, J. M. Wallace and P. V. Hobbs
3. *Thermodynamics*, P. C. Rakshit
4. *Thermodynamics*, E. Fermi
5. *The Upper Atmosphere - the Meteorology and Physics*, R. A. Craig
6. *An Introduction to Atmospheric Dynamics*, A. A. Tsonis
7. *Satellite Meteorology*, S. Q. Kidder and T. H. Von der Haar, Academic Press, 1995
8. *Remote Sensing and Image Interpretation*, T. M. Lillesand and R. W. Kieffer, John Wiley, 2002
9. *Fundamentals of Space Systems*, V. L. Pisacane and R. C. Moore, Oxford University Press, 1994
10. *Quantitative Remote Sensing of Land Surfaces*, Shunlin Liang, Wiley Interscience, 2004
11. *Scale in Remote Sensing and GIS*, D. A. Quattrachi and M. F. Goodchild
12. *Uncertainty in Remote Sensing and GIS*, Ed: G. M. Foddy and P. M. Atkinson

Paper – II: CLASSICAL MECHANICS
Paper Code: SST 102 (90 Hrs)

Module 1 **(15 Hrs)**

Mathematical preliminaries, Newtonian mechanics of single and many-particle systems, conservation laws, work energy theorem, open systems with variable mass.
Constraints, their classification, D'Alembert's principle, generalized coordinates.

Module 2 **(20 Hrs)**

Lagrange's equations, gyroscopic forces, dissipative systems, Jacobi integral, gauge invariance, moments, integrals of motion, symmetries of space and time with conservation laws, Galilean transformation, impulsive forces.
Rotating and translating frames, inertial forces, terrestrial and astronomical applications of Coriolis force.

Module 3 **(15 Hrs)**

Central force, definition and characteristics, two-body problem, closure and stability of circular orbits, general analysis of orbits, Kepler's laws and equation, artificial satellites, scattering, relationship between CM and Lab frames, Rutherford scattering.

Module 4 **(15 Hrs)**

Legendre transformation, Hamilton's equations, phase portraits of some simple systems.
Principle of least action, Derivation of equations of motion, variation of end points, Hamilton's principal and characteristic functions, Hamilton-Jacobi equation.

Module 5 **(25 Hrs)**

Canonical transformations, generating functions, properties, group property, examples, infinitesimal generators, Poisson bracket, Poisson's theorems, angular momentum, PBs, small oscillations, normal modes and coordinates, case study of a coupled system of oscillators, rigid bodies, Euler's and Chasel's theorems, moment of inertia, MI tensor and ellipsoid, Euler equation for rotating rigid body and its solutions, Eulerian angles, symmetric top, introduction to classical scalar fields (optional).

Module 6

Classification of dynamical systems, conservative systems, integrable systems, non-linear perturbation, Hamiltonian chaos, dissipative systems, continuous systems, duffing oscillator, discrete systems, logistic map, fixed points, period doubling, limits cycles, chaotic attractors, Lyapunov characteristic exponent.

Module 7

Fluid dynamics: definition, Lagrangian and Eulerian systems, streamlines and trajectories, conservation equations of mass, momentum and energy, velocity potential, stream function, momentum equation, viscosity, stress tensors and their relation with strain function, Navier-Stokes' theorem**.**

Text Books:

1. *Classical Mechanics*, N. C. Rana and P. S. Joag, Tata McGraw Hill, 1991
2. *Classical Mechanics*, H. Goldstein, Addison Wesley, 2nd Ed, 1980
3. *Mechanics,* A. Sommerfeld, Academic Press, 1952
4. *Introduction to Dynamics,* I. Percival and S. Richards, Cambridge University Press, 1982
5. *Classical Dynamics of Particles and Systems*, Marrion and Thornton
6. *Chaos and Nonlinear Dynamics: An Introduction for Scientists and Engineers*, Robert Hilborn
7. *Mathematical methods in physics:* Arfken

Reference Books

1. *Calculus of Variations,* M. Gel'fand and S. V. Fomin
2. *Mathematical Methods of Classical Mechanics,* V. I. Arnold, Springer-Verlag
3. *New Foundations of Classical Mechanics*, D. Hestenes, Kluwer Scientific
4. *Classical Mechanics*, Jose and Saletan, Cambridge University Press, 1999
5. *Mechanics*, F. Scheck, 3rd Ed, Springer-Verlag
6. *Mechanics of Atom*, Max Born, Fredrik Unger Publishing
7. *Problems of Atomic Dynamics,* Max Born, Fredrik Unger Publishing
8. *Chaos and Integrability in Nonlinear Dynamics: An Introduction*, Michael Tabor
9. *Fluid Dynamics*, William F. Hughes and John A. Brighton, Schaum Publishing

10. *Fluid Mechanics*, Pijush Kundu, Academic Press
11. *Fluid Mechanics*, David Pneuli and Chaim Goodfinger, Cambridge University Press
12. *An Introduction to Fluid Dynamics*, G K Batchelor, Oxford University Press

Paper – III: QUANTUM MECHANICS
Paper Code: SST 103 (90 Hrs)

Module 1 **(20 Hrs)**

Revision, inadequacy of classical concepts, wave-particle duality, thought experiments, uncertainty relations.
Schrödinger equation, continuity equation, Ehrenfest's theorem, solutions of Schrödinger equation, admissible wave functions, stationary states.
Simple one-dimensional problems, harmonic oscillator and its stationary states using Schrödinger equation, one-dimensional wells and barriers.

Module 2 **(20 Hrs)**

Obtaining uncertainty relation of x and p from commutation relation, states with minimum uncertainty product.
General formalism of wave mechanics, representation of states and dynamic variables, observables, self-adjoint operators, completeness of eigen functions, Dirac delta function, commutability and
compatibility, bra and ket notation, matrix representation of an operator, change of basis, unitary transformations.

Module 3 **(20 Hrs)**

Simple harmonic oscillator by operator method.
Angular momentum in quantum mechanics, Pauli theory of spins, addition of angular momenta, computation of Clebsch-Gordan coefficients in simple cases.
Central forces, hydrogen atom.

Module 4 **(20 Hrs)**

Evolution of system with time, constants of motion, Heisenberg, Schrödinger and interaction pictures.
Time-independent perturbation theory, non-degenerate and degenerate cases, applications such as the Stark effect.

Module 5 **(10 Hrs)**

WKB Approximation, Variational method, helium atom, van der Waal's interaction.

Text Books:

1. *Modern Quantum Mechanics* by J.J. Sakurai
2. *Quantum Mechanics*, G Aruldhas

Reference Books:

1. *Quantum Mechanics*, L. I. Schiff, McGraw Hill.
2. *Introduction to Quantum Mechanics*, L. Pauling and E. B. Wilson, McGraw Hill

3. *Quantum Mechanics*, A. Messiah, Vol I & II.
4. *Quantum Mechanics*, L. D. Landau and E. M. Lisfshitz, Addison Wesley

Paper – IV: MATHEMATICAL AND STATISTICAL METHODS - I
Paper Code: SST 104 (90 Hrs)

Module 1 **(15 Hrs)**

Properties of matrices: Vector spaces, linear dependence and independence, basic properties, basis and rank of a matrix, symmetric and skew symmetric, Hermitian and Skew Hermitian, orthogonal and unitary matrices, homogeneous and non-homogeneous linear simultaneous equations and their consistency, Eigen- values and Eigen-vectors, Cayley-Hamilton theorem and its applications**,** various techniques for computation of inverse of matrices to find solutions of non-homogeneous equation, Eigen-values and Eigen-vectors of symmetric as well as non- symmetric matrices and their applications.

Module 2 **(25 Hrs)**

Complex analysis and special functions: differentiable and analytic functions, singularity, Taylor's series, Laurent series, calculus of residue, contour integration, Legendre polynomial, Hermite polynomial, Laguerre polynomial, introduction to Bessel functions.

Module 3 **(15 Hrs)**

Probability and statistics: theory of probability and probability distribution, binomial distribution and random walk, Poisson and Gaussian distribution and gamma distribution, t-and chi-square distribution, measures of central tendency and dispersion, moments.
Statistics: scatter diagram, least squares method, regression equation, coefficients of correlation and their significance, partial and multiple correlations and their applications, tests of significance,
Students'- t, chi- square tests, ANOVA.

Module 4 **(20 Hrs)**

Laplace Transforms and Integral Transforms: Transforms of elementary Functions, Inverse Transforms, Shifting Property, Convolution Theorem, Unit Step functions, Fourier integral Theorem, Properties of Fourier transforms, Parseval's Identity, Relation between Fourier and Laplace Transforms. Application to Boundary Value Problems.

Module 5 **(15 Hrs)**

Vector Calculus: Scalar and Vector point functions, Del, Gradient, Divergence and Curl, Integration of vectors, Line Integral, Surface Integral and Volume integral, Divergence Theorem, Green's Theorem and Stoke's Theorem, Applications.

Text Books:

1. *Mathematical Methods in Physics*, Arfken

Reference books

1. *Theory of Differential Equations*, Andrew Russell Forsyth, Dover
2. *Partial Differential Equations in Physics*, Arnold Sommerfield, Academic Press
3. *A Book of Splines*, Arthur Sard and Sol Weintrub, John Wiley
4. *Vector Calculus*, Peter Bexandall an Hans Liebeck, Clarendon
5. *Vector Space and Matrices*, Robert M. Thrall and Leonard Tornhein, John Wiley
6. *Theory of Matrices*, F. R. Gantmacher, Chelsea
7. *Principle of Random Walk*, Franks Spitzer, Van Nostrand
8. *Mathematics of Statistics*, Kenney and Keeping, Van Nostrand
9. *Fundamentals of Mathematical Statistics*, C. Gupta, and V K Kapoor, S. Chand Publication
10. *Mathematical Statistics*, J N Kapoor and H C Saxena, S. Chand Publication
11. *Fourier Series*, Georgi P. Tolstov and Richard A. Silverman, Prentice-Hall
12. *Survey of Applicable Mathematics*, Karel Rektory, Ilifee Books
13. *Methods of Mathematical Physics*, Vol I & II, R. Courant and D. Hilbert, Wiley Eastern
14. *Advanced Engineering Mathematics* , Erwin Kreyszig, Wiley Eastern
15. *Applied Mathematics for Engineers and Physicists*, Pipes and Harvill, McGraw Hill
16. *Analysis of Variance and Regression,* Ruth M. Mickey, Olive Jean Dunn, Virginia A. Clark, Wiley Interscience
17. *Vector Analysis and Introduction to Tensor Analysis*, Murray R Spiegel, Schaum Publishing
18. *Theory and Problems of Statistics*, Murray R Spiegel, Schaum Outline Series, McGraw Hill
19. *Theory and Problems of Matrices*, Frank Ayres, Jr, Schaum Publishing
20. *Theory and Problems of Probability*, S. Lipschutz, Schaum Outline Series, McGraw Hill
21. *Theory and Problems of Fourier Analysis with Application to Boundary Value Problems,* Murray R. Spiegel, Schaum Outline Series, McGraw Hill
22. *The Fourier Transform and its Applications*, Ronald N. Bracewell, McGraw Hill

Paper V: NUMERICAL METHODS AND COMPUTER PROGRAMMING
Paper Code: SST 105 (54 Hrs)

Module 1 **(12 Hrs)**

Finding roots of Algebraic and Transcendental Equations by Bisection, Regula Falsi and Newton – Raphson's methods, Finite difference schemes, Interpolation: Newton's Forward and Backward Difference, Sterling's interpolation and Lagrange's Interpolation and Extrapolation.

Module 2 **(12Hrs)**

Numerical Integration: Trapezoidal rule, Simpson's 1/3 and 3/8 rule. Gaussian quadrature. Numerical solutions of Simultaneous Algebraic Equations.
Generation of random number, Monte-Carlo technique.

Module 3 **(10 Hrs)**

FORTRAN fundamentals: integer constant, floating point constant, variables, arithmetic operator, relational operator, FORTRAN arithmetic and expression, input/output and format statements, declaration and initialization, branching and looping, Arithmetic IF, Logical IF, Unconditional GO TO, Computed GO TO, DO statement, Nesting of DO Loops, Dimension Statement, arrays, multi- dimensional arrays, functions, sub-programs and subroutines. Basics of file handling and data manipulation.

Module 4 **(10 Hrs)**

Concept of finite element method, solution of ordinary differential equation, Euler method, Taylor series, Runge Kutta method, solution of partial differential equations, elliptic equations.

Module 5 **(10Hrs)**

Approximation of function by cubic spline, harmonic analysis, spectral analysis, use of filters.

Text Books:

1. *Introductory Methods of Numerical Analysis*, S. S. Shastry, Prentice Hall India
2. *Computer-Oriented Numerical Methods*, V. Rajaraman, Prentice Hall India
3. *Fortran 77 Elemetst of Programming Style*, Willam M Fuori, Stephen Gaughran, Louis Gioia and Michael Fuori, CBS Publishers

Reference Books

1. *Numerical Methods for Scientific and Engineering Computation*, M. K. Jain, S. P. K
2. Iyenger and R. K. Jain, Wiley Eastern
3. *Numerical Analysis and Algorithms*, Pradip Neogy, Tata McGraw Hill
4. *New Methods for Solving Elliptical Equations*, I. N. Vekua, North Holland and John Wiley
5. *Numerical Methods in Engineering*, Salvadori and Baron, Prentice Hall India
6. *Numerical Analysis*, Kaiser Kunz, McGraw Hill
7. *Numerical Analysis*, F.B. Hilderbrand, Tata McGraw Hill
8. *Finite Difference and Differential Equations*, Murray R. Spiegel, Schaum Outline Series,
9. McGraw Hill
10. *Numerical Analysis*, Francis Scheid, Schaum Outline Series, McGraw Hill

Module 3

Reference Books

1. *Computer Studies – A First Course*, John Shelley and Roger Hunt, A. H. Wheeler Publishing
2. *Fundamentals of Computers*, V. Rajaraman, Prentice Hall International Eastern Economy Edition
3. *Understanding Fortran 77 with Structured Problem Solving*, Michel Boillot, Jaico Publishing House
4. *Fortran 77/ 90*, V. Rajaraman, Prentice Hall International Eastern Economy Edition

Paper I (Lab) – COMPUTER PROGRAMMING – I
Paper Code: SST 106

FORTRAN Lab: **(36 Hrs)**

1. Solution of algebraic equation by Bisection Method
2. Solution of algebraic equation by False Position method
3. Solution of algebraic and transcendental equation by Newton- Raphson's method
4. Numerical Integration by Trapezoidal Rule
5. Numerical Integration by Simpson's 1/3 and 3/8 Rule
6. Generation of Random Numbers by multiplicative congruence method
7. Numerical Integration by Monte Carlo technique

Reference Books:

1. *Computer Studies – A First Course*, John Shelley and Roger Hunt, A. H. Wheeler Publishing
2. *Fundamentals of Computers*, V. Rajaraman, Prentice Hall International Eastern Economy Edition
3. *Fortran 77 Elemetst of Programming Style*, Willam M Fuori, Stephen Gaughran, Louis Gioia and Michael Fuori, CBS Publishers
4. *Understanding Fortran 77 with Structured Problem Solving*, Michel Boillot, Jaico Publishing House
5. *Fortran 77/ 90*, V. Rajaraman, Prentice Hall International Eastern Economy Edition

SEMESTER II

Paper – VI: FUNDAMENTALS OF EARTH SCIENCES AND REMOTE SENSING
Paper Code: SST 201(90 Hrs)

Module 1 **(35 Hrs)**

Earth as a planet of the solar system: its origin and internal structure, physical and chemical characteristics of the internal zones, crustal types, Archaean shields and Cratons, heat flow and temperature gradient.

Types of rocks, major constituent minerals and their (chemical) composition, stability of minerals, climatic belts, effect of climate on processes of weathering and erosion, sediment cycle, radioactive minerals and dating methods, palaeoclimate, quaternary ice age, factors affecting sea level, sea level changes, with reference to India.

Geomagnetism, magneto-stratigraphy, palaeomagnetism, convection current, geodynamics, continental drift, sea floor spreading, plate tectonics, drift of the Indian subcontinent; belts of compressional and tensional stresses, seismicity and volcanism, subduction zone, Benioff zone and island arcs, polar wandering, permanence of continents and ocean basins.

Internal structure, constitution and magnetism of planetary bodies.

Module 2 **(35 Hrs)**

Satellite data processing: satellite data acquisition, satellite communications, data collection platforms, earth station, image processing, geometric and radiometric corrections, image navigation, registration, image enhancement techniques, noise removal methods, histogram methods, density slicing, image classification.
Applications of remote sensing in earth resources management, agriculture, forestry, water resources and disaster mitigation

Module 3 **(20 Hrs)**

Remote sensing:
Radars – principle, atmospheric applications, radar equation, range, resolution, anomalous propagation, radar cross-section, Z-R relationships, Doppler radar, interpretation of Doppler radar data, polarimetry.
Soundings – principle, sodar, lidar, wind profiler, radio-acoustic sounding systems, MST radar, radiosondes, GPS sondes.
Practicals – hands-on experience with sodar, lidar, WP-RASS.

Books:
Module 1
Text Books

1. *Earthquakes*, Bolt B.A., W. H. Freeman and Company, New York.
2. *Manual of Geology (Vol. I and II)*, Dana J.D., Akashdeep Publishing House.

3. *A text book of general & engineering Geology*, Arora D.S., Mohindra Capital Publishers.

Reference Books

1. *Planet Earth- Cosmology, geology and the evolution of life and environment*, A.
2. Emilianic, Cambridge University Press.
3. *Encyclopedic Dictionary of Applied Geophysics*, Sheriff R.E., Society of exploration geophysics, USA.
4. *Isostasy and Flexure of lithosphere*, Watts A.B., Cambridge University Press.

Modules 2, 3

Text Books

1. *Digital Image Processing*, R. C. Gonzales and R. E. Woods, 2nd Ed, Pearson India, 2002
2. *Lecture Notes on Satellite Meteorology*, Vol 1 and 2, SAC, Ahmedabad
3. *Remote Sensing and Image Interpretation*, T. M. Lillesand and R. W. Kieffer, John Wiley, 2002
4. *Fundamentals of Remote Sensing*, George Joseph, 2003
5. *Quantitative Remote Sensing of Land Surfaces*, Shunlin Liang, Wiley Interscience, 2004
6. *Theory of Satellite Orbits in an Atmosphere,* King-Hele Desmond, Butterworths, 1964
7. *Radar metereology, Dr. M. S. Raghavan, Academic Press*

Reference Books

1. *Satellite Meteorology*, S. Q. Kidder and T. H. Von der Haar, Academic Press, 1995
2. *Fundamentals of Space Systems,* V. L. Pisacane and R. C. Moore, Oxford University Press, 1994
3. *Processing Remote Sensing Data*, M. C. Girgard and C. Girgard, Oxford-IBH, 1999
4. *Scale in Remote Sensing and GIS,* D. A. Quattrachi and M. F. Goodchild
5. *Uncertainty in Remote Sensing and GIS,* Ed: G. M. Foddy and P. M. Atkinson

Paper – VII: STATISTICAL MECHANICS
Paper Code: SST 202 (90 Hrs)

Module 1 **(20 Hrs)**

Elementary probability theory: preliminary concepts, random walk problem, binomial distribution, mean values, standard deviation, various moments, Gaussian distribution, Poisson distribution, mean values, probability density, probability for continuous variables (brief).

Laws of thermodynamics and their consequences (brief).

Problem of kinetic theory: phase space, Gibbsian ensemble, Liouville's theorem and its consequences, Boltzmann equation.

Module 2 **(20 Hrs)**

Statistical description of system of particles: state of a system, microstates, ensembles, basic postulates, behaviour of density of states, density of state for ideal gas in classical limit, thermal and mechanical interactions, quasi-static process.

Statistical thermodynamics: irreversibility and attainment of equilibrium, reversible and irreversible processes, thermal interaction between macroscopic systems, approach to thermal equilibrium, dependence of d.o.s. on external parameters, statistical calculation of thermodynamic variables.

Module 3 **(20 Hrs)**

Classical statistical mechanics: microcanonical ensembles and their equivalence, canonical and grand canonical ensembles, partition functions, thermodynamic variables in terms of partition function and grand partition function, ideal gas, Gibbs paradox, validity of classical approximation, equipartition theorem, MB gas velocity and speed distribution, chemical potential, free energy and connection with thermodynamic variables, 1^{st} and 2^{nd} order phase transition, phase equilibria.

Module 4 **(15 hrs)**

Formulation of quantum statistics: density matrix, ensembles in quantum statistical mechanics, simple application of density matrix.

Theory of simple gases: Maxwell, Boltzmann, Bose-Einstein, Fermi-Dirac gases, statistics of occupation numbers, evaluation of partition functions, ideal gases in the classical limit.

Module 5 **(15 Hrs)**

Ideal Bose system: thermodynamic behavior of an ideal Bose gas, Bose-Einstein condensation.

Thermodynamics of black body radiation: Stefan-Boltzmann law, Wien's displacement law,

specific
heat of solids (Einstein and Debye methods).

Books:
Text Books

1. *Statistical Mechanics*, R. K. Pathria, Pergamon Press
2. *Statistical Mechanics*, K Huang, 2nd Ed, John Wiley
3. *Fundamentals of Statistical Mechanics*, B. B. Laud, New Age

Paper – VIII: ELECTRODYNAMICS
Paper Code: SST 203 (90 Hrs)

Module 1

Review of :- Electrostatic fields in matter – Polarisation – Dielectrics – Induced dipoles – Electric displacement – Gauss's Law in the presence of dielectric – Linear dielectrics – Susceptibility – Polarisability.

Maxwells's equations boundary conditions – Potential formulation of electro dynamics – Scalar and vector potentials – Gauge transformations – Coulomb Gauge – Lorentz Gauge – Lorentz force law in potential form –

Energy and momentum in electrodynamics – Newton's third law – Poynting's Theorem – Maxwell's Stress Tensor – conservation of momentum.

Module 2

Wave equations – Boundary conditions – Plane waves in vacuum – Energy and momentum of electromagnetic waves – Propagation through linear media – Reflection and transmission of electromagnetic waves in non conducting media – Electromagnetic waves in conductors.

Lorentz transformation of electromagnetic fields – Electromagnetic field tensor – Electrodynamics in tensor notation – Potential formulations of relativistic electrodynamics.

Module 3

Retarded potential – Electric dipole radiation – Magnetic dipole radiation- Radiation from an arbitrary distribution of charges and currents – radiation from a point charge – Lienard-Wiechert potential – point charge in motion – power radiated by a point charge.

Module 4

Waves between parallel conducting planes – TE and TM waves – TEM waves – Rectangular wave guides – TM and TE waves – impossibility of TEM waves in guides.

Radiation resistance of a short dipole – radiation from a quarter wave monopole – Directivity, gain and effective aperture – Antenna arrays – Array of two driven /2 elements – broad side and end fire cases.

Basic ideas of Yagi-Uda antenna, horn antennas and parabolic reflector Antennae.

Text Books:

1. *Introduction to Electrodynamics* – D.J. Griffiths
2. *Electromagnetic Waves and Radiating Systems* – E.C. Jordan & K.G. Balmain

Reference Books:

1. *Antennas – J.D. Kraus* – Mc-Graw Hill.
2. *Electronic Communication Systems* – Kennedy G & Davis B – TMH 1999.
3. *The Feynman Lecturers in Physics* – Vol.2 – R.P. Feynman, R.B. Leighton & M Sands – Narosa 1998.
4. *Introduction to Classical Electrodynamics* – Y K Lim – World Scientific – 1986.

5. *Classical Electrodynamics* – J.D. Jackson – Wiley Eastern Ltd.
6. *Electromagnetic Waves and Fields* – VV Sarwate – Wiley Eastern Ltd.
7. *Antenna and Wave Propagation* – K.D. Prasad – Pragathi.

Paper – IX: INTRODUCTION TO PLASMA PHYSICS AND SPACE PHYSICS
Paper Code: SST 204 (90 Hrs)

Module 1

Basic Plasma Physics – occurrence of plasma in nature, definition of plasma, Debye shielding, applications of plasma physics. Single particle motion, uniform E and B fields, Grad B drifts, curvature drifts, magnetic mirrors, time varying B fields, adiabatic invariance, equation of motion, equation of continuity, equation of state, representation of plasma waves, plasma oscillations, comparison of ion and electron waves, electrostatic ion waves perpendicular to B, the lower hybrid wave.

Module 2

Introduction to ionosphere
The ionospheric layers D,E,F, and their formation, effect of radiation on earth's ionosphere, the equatorial F2 layer, the topside ionosphere, the basic theory of photionisation, Chapman's production function and Chapman layer, the generalized production function,

Module 3

Introduction to Magnetosphere- magnetic field configuration of the earth magnetosphere, plasma in the earth middle and inner magnetosphere, electric fields, ionospheric-magnetospheric coupling, ionospheric currents. Bow shock; magnetopause, magneto tail and magnetic reconnection, geomagnetic tail – morphology in these regions. Reconnection at the magnetopause, magnetospheres of other planets

Module 4

Ionosopheric measurements – vertical incidence sounding, ground based radio investigation of the lower ionosphere, propogation experiments using rockets and satellites, coherent, incoherent and partial reflection radars, ionospheric scintillations.

Module 5
Basic ideas of Turbulence – physical nature, practical consequences – energy loss, drag and dispersion, statistical tools, Gaussian statistics and central limit theorem, turbulent mass flow and fluctuations – steadiness homogeneity isotropy etc. Space and time scales of turbulence – velocity correlation and spatial characteristics, time correlation and Time Scale – Basic theory and examples, mean flow, turbulence energetics, simple examples of turbulence flows.

Text Books:
1. *Introduction to Plasma physics and controlled fusion* F. F. Chen, Plenum Press
2. *Introduction to ionospheric physic,* H. Rishbeth and H. Garriot, Academic press
3. *An introduction to turbulence flow*, Jean Mathieu and Julian Scott, Cambridge University Press

Paper – X: ADVANCED COMPUTER PROGRAMMING
Paper Code: SST 205 (54 Hrs)

Module 1 **(18 Hrs)**

Fundamentals of C: data type, integers, float, double, character constant and variable, array and array declaration, expression statement, symbolic constant, arithmetic operator, relational operator, assigned operator, library function, data input and output, unformatted input /output statement, entering data input, writing data output, control statement, while statement, IF statement, IF ELSE statement, Switch statement, structures, arrays and pointers, pointer arrays, linked lists, stacks, queues, regression and trace. Error handling. Introduction to C-graphics

Module 2 **(18 Hrs)**
Introduction to MATLAB

Module 3 **(18 Hrs)**
IDL (with emphasis on file manipulation, data handling and graphic utilities)

Text Books
1. *Getting Started with MATLAB 7 – A quick introduction for Scientists and Engineers*, Rudraprathab, Oxford University Press.
2. *An Introduction to Programming with IDL: Interactive Data Language*, Kenneth P. Bowman
3. *Programming with C*, Byron S. Gottfried, Tata McGraw Hill
4. *Mastering "C"*, Bolon, BPB Publication

Reference books
1. *The "C" Programming Language*, Brian W. Kernighan and Dennis M. Ritchie, Prentice Hall India
2. *C Programming for Unix*, John J. Valley, Prentice Hall India
3. *Theory and Problems of Programming with C*, Byron S. Gottfried, Schaum Outline Series International

Paper I (Lab) – COMPUTER PROGRAMMING – II
Paper Code: SST 206 (36 Hrs)

C Lab:
1. Fitting of straight lines by least square method
2. Computation of Correlation Coefficients
3. Problems related to test of significance
4. Solution of simultaneous non-homogeneous equations
5. Computation of solution of ordinary differential equations by Runge-Kutta Method
6. Computation of Harmonic Analysis of a given time series.
7. Solution of Laplace's Equation
8. C-programming – projectile motion, stationary waves, satellite motion
9. MATLAB
10. GRADS

Reference Books:

1. *Programming with C*, Byron S. Gottfried, Tata McGraw Hill
2. *The "C" Programming Language*, Brian W. Kernighan and Dennis M. Ritchie, Prentice Hall India
3. *Mastering "C"*, Bolon, BPB Publication
4. *C Programming for Unix*, John J. Valley, Prentice Hall India
5. *Theory and Problems of Programming with C*, Byron S. Gottfried, Schaum Outline Series International

SEMESTER III

Paper – XI: ATMOSPHERIC DYNAMICS
Paper Code: SST 301 (90 Hrs)

Module 1 **(15 Hrs)**

Basic equations: inertial and non-inertial frame, pressure gradient force, gravitational force, viscous force, equation of motion in rotating coordinates, equation of motion in tangential local coordinate system, spherical coordinate system, isobaric coordinate system, scale analysis of the equation of the motion, thermodynamic energy equation and equation of continuity, vertical velocity.

Module 2 **(15 Hrs)**

Classification of flow: natural coordinate system and the horizontal momentum equation in natural coordinates, inertial flow, Eulerian flow, cyclostrophic flow, geostrophic flow, gradient flow. Trajectory and streamline, Blaton's equation, geopotential, thermal wind, cold and warm air advection, hodograph, barotropic and baroclinic atmosphere.

Module 3 **(15 Hrs)**

Circulation and vorticity: Kelvin's circulation theorem, Bjerknes' circulation theorem, Stoke's theorem, divergence and outflow, absolute and relative vorticity, solenoidal vector, sea and land breeze.

Module 4 **(15 Hrs)**

Vorticity and divergence equations: vorticity equation, cartesian and isobaric coordinates, divergence and vorticity in natural coordinates, conservation of absolute vorticity, potential vorticity, scale analysis of vorticity equation, dynamics of lee side trough, geostrophic vorticity and divergence, divergence equation, balance equation, stream function and velocity potential, Helmoltz theorem, geostrophic, quasi-geostrophic approximation.

Module 5 **(15 Hrs)**

Perturbation theory and atmospheric waves: phase velocity and group velocity, dispersion, acoustic waves, inertial waves, Rossby waves, concept of instability.

Module 6 **(15 Hrs)**

Atmospheric boundary layer and turbulence: viscous flow and turbulent flow, Navier-Stokes' theorem, general properties of boundary layer and classification, Reynold’s number, Froud number, Rossby number, Richardson number, Boussinesq approximation.

Books:
Text Books

1. *Dynamic and Physical Meteorology*, S. L. Haltiner and F. L. Martin
2. *Introduction to Theoretical Meteorology*, S. Hess
3. *Introduction to Dynamic Meteorology*, J. R. Holton, (1st, 2nd and 3rd Editions)
4. *Atmospheric Boundary Layer*, W.M.O. Technical Notes

Reference Books

1. *Atmospheric Science – An Introductory Survey*, J. M. Wallace and P. V. Hobbs
2. *Numerical Analysis and Prediction*, P. D. Thomson
3. *W. M. O. Compendium of Meteorology: Dynamic Meteorology*, Aksel Wiin-Nielsen
4. *The Physics of Atmosphere*, John Houghton

Paper – XII: CLIMATOLOGY – TROPICAL AND GLOBAL
Paper Code: SST 302 (90 Hrs)

Module 1 **(20 hrs)**

Climatology
Climatology: basics, definition of climate, physical factors of climate, earth-sun relationship, ecliptic and equatorial plane, rotation and evolution of the earth, seasons, climatic controls, elementary ideas about general circulation of the atmosphere.
Physical climatology: solar radiation, terrestrial radiation, heat, energy and water balance, evaporation and evapotranspiration.
Climatic classification: methods of Koppen, Thornthwaite and Penman
Micrometeorology: influence of ground surface on the microclimate, factors affecting soil temperature, vertical profile of temperature, humidity and wind in the lowest layer.

Module 2 (Tropical climatology) **(30 Hrs)**

Indian climatology: pressure, wind, temperature and rainfall distribution during the four seasons.
Winter: western disturbances, fog, thunderstorm, hail, cold waves, subtropical jet stream, north-east monsoon, interaction of low and high latitude disturbances, easterly waves.
Pre-monsoon: cyclonic storms, tracks, and frequencies, western disturbances, fog, dust-storms, thunderstorms, nor'westers, heat waves, pre-monsoon thunderstorms, dust-raising winds, equatorial troughs.

Monsoon: onset and advance of monsoon, activity of monsoon, rainfall, break monsoon, strong and weak monsoon, monsoon trough, Tibetan anti-cyclone, off-shore vortices and trough, low level jet, Mascarene high, monsoon depression, mid-tropospheric cyclone, floods and draughts, tropical easterly jet stream, westerly disturbances and their influence on monsoonal circulation, withdrawal of monsoon. Post monsoon: cyclonic storm- tracks, frequency, northeast monsoon circulation and rainfall.
Tropical Meteorology: Hadley cell, trade winds, equatorial trough, monsoon areas of the world, monsoon over Asia, Australia and Africa. Tropical convection, tropical precipitation and its spatial and temporal variation.
ITCZ, easterly waves, El-nino, southern oscillation, monsoons, convective systems, tropical cyclones, Gray's parameter, CISK, waves in equatorial atmosphere

Module 3 (Global climate) (20 Hrs)

Surface temperature, pressure, wind, cloudiness and rainfall distribution and variation with latitude in January and July, upper air climatology during winter and summer.
Climate of the continents: Asia, Africa, Australia, Europe, North America and South America, Arctic and Antarctic. Climatic change scenario and impact

Module 4 (Cloud Physics) (20 Hrs)

Cloud morphology, atmospheric aerosols, cloud condensation nuclei. Warm cloud microphysics, cold cloud microphysics.
Shallow layer clouds, cumulus clouds, thunderstorms, meso-scale convective systems.
Weather modification experiments.

Books:

Text Books

1. *Monsoons*: P. K. Das, NBT
2. *Southwest Monsoon (IMD Met Monograph)*: Y. P. Rao
3. *World Survey of Climate*, Vol I to XV, Ed: Landsberg
4. *Physical Climatology*, W. D. Sellers
5. *An Introduction to Climate*, G. T. Trewartha
6. *Tropical Meteorology*, Herbert Riehl
7. *Tropical Meteorology*, Vol I and II, G. C. Asnani
8. *Climate of South Asia*, G.B. Pant and Rupa Kumar
9. *Cloud Physics*, R. R. Rogers
10. *The Physics of Clouds*, B. J. Mason

Books

1. *Atmospheric Circulation Systems*: E. Palmen and Newton
2. *Monsoons (WMO lectures)*, P. K. Das
3. *World Climatology*, John G. Lockwood
4. *Climate of the Continents*, W. C. Kendrew
5. *Foundation of Climatology*, E. T. Stringer

6. *Weather Forecasting*, A. A. Ramsastry
7. *Tropical Climatology*, Nieuwolt
8. *Cloud Dynamics*, Robert A. Houze
9. *Atmospheric Sciences: Introductory Survey*, J. M. Wallace and P. V. Hobbs
10. *Microphysics of Clouds and Precipitation*, H. R. Pruppacher and J. D. Klett
11. *A Short Course in Cloud Physics*, M. K. Yau.

Paper – XIII: SYNOPTIC METEOROLOGY AND SATELLITE METEOROLOGY
Paper Code: SST 303 (90 Hrs)

Module 1 **(35 Hrs)**

Introduction to synoptic meteorology, scales of weather systems, network of observatories, synoptic observations, surface, upper air and special observations, satellite, radar data etc., representation and analysis of fields of meteorological elements.

Extra-tropical meteorology: air masses, characteristics, prediction and modification, fronts and frontolysis, slope and fronts, Margule's formula, structure of fronts and polar-front theory, cyclones and anti-cyclones, frontal and baroclinic models, structure and development theories, jet stream and tropopause, long waves, cut-off lows and highs, blocking highs.

Jet stream: polar front jet, sub-tropical jet, tropical easterly jet, polar night jet, characteristic features of various jet streams, theories of formation, weather development, cloud and clear air turbulence (CAT).

Module 2 **(35 Hrs)**

Principles of satellite image interpretation: identifying cloud types and patterns in satellite images, comparison of visible, infrared, water vapour and microwave imagery, monitoring development of weather phenomena and tracking movement of weather systems.
Monsoons: large-scale circulation, onset and advance of south-west monsoon, monsoon trough, active, weak and break monsoon conditions, monsoon depressions, tropical easterly jet, north-east monsoon.
Mesoscale systems: MCCs, orographic systems, dust storms.
Extra-tropical systems: sub-tropical and polar jets, long and short waves, clod and warm fronts, cyclogenesis, types of extra-tropical cyclones, western disturbances.
Tropical disturbances: inter-tropical convergence zone, easterly waves, tropical cyclones, formation,
structure, intensification, movement, recurvature.
Practicals: identification of clouds and cloud associations, upper air troughs/ridges, fronts, western disturbances, fog, in satellite images

Module 3 **(20 Hrs)**

Quantitative product derivation from satellite data: rainfall, sea surface temperature, outgoing longwave radiation, cloud motion winds, vertical temperature profiles.
Microwave retrievals: scatterometer, TRMM satellite, Global Precipitation Mission, Global Precipitation Climatology Project

Practicals: phases of south-west monsoon, D'vorak's technique for tropical cyclone intensity estimation, local severe storms, SST analysis.

Books
Module 1
Text Books

1. *Atmospheric Circulation Systems*: E. Palmen and Newton
2. *Monsoons*: P. K. Das, NBT
3. *Southwest Monsoon (IMD Met Monograph)*: Y. P. Rao
4. *World Survey of Climate*, Vol I to XV, Ed: Landsberg
5. *Physical Climatology*, W. D. Sellers
6. *An Introduction to Climate*, G. T. Trewartha
7. *Tropical Meteorology*, Herbert Riehl
8. *Tropical Meteorology*, Vol I and II, G. C. Asnani
9. *Tropical Climatology*, Nieuwolt
10. *Climate of South Asia*, G.B. Pant and Rupa Kumar

Reference Books

1. *Monsoons (WMO lectures)*, P. K. Das
2. *World Climatology*, John G. Lockwood
3. *Climate of the Continents*, W. C. Kendrew
4. *Foundation of Climatology*, E. T. Stringer
5. *Weather Forecasting*, A. A. Ramsastry

Modules 2 and 3
Text Books

1. *Lecture Notes on Satellite Meteorology*, Vol 1 and 2, SAC, Ahmedabad
2. *Satellite Meteorology*, S. Q. Kidder and T. H. Von der Haar, Academic Press, 1995
3. *satellite meteorology, Dr. R. R Kelkar, academic Press*

Reference Books

1. *Images in Weather Forecasting*, M. J. Bader, G. S. Forbes, J. R. Grant, R. B. E. Lilly and A. J. Waters, Cambridge University Press, 1995
2. *Quantitative Meteorological Data from Satellites*, WMO Technical Note No. 166

Paper – XIV: ASTRONOMY AND ASTROPHYSICS
Paper Code: SST 304 (90 Hrs)

Module 1 **(25 Hrs)**

Overview of the universe:
Qualitative description of interesting astro objects (from planets to large scale structure), length, mass and time scales, physical conditions in different objects, evolution of structures in the universe, red shift.

Radiation in different bands, astronomical jargon, astronomical measurements in different bands, current sensitivities and resolution available.

Physics of astrophysics:
Gravity: Newtonian gravity and basic potential theory, simple orbits, Kepler's laws, precession, flat rotation curve of galaxies and implications for dark matter, virial theorem and simple applications, role of gravity in different astrophysical systems.

Radiative processes: overview of radiation theory and Larmor formula, different radiative processes, Thomson and Compton scattering, Bremsstrahlung, synchrotron (detailed derivations are not expected), radiative equilibrium, Planck spectrum and properties, line widths and transition rates in QT of radiation, contribution of radiative processes in different wavebands and astrophysical systems (qualitative description), distribution function for photons and its moments, elementary notion of radiation transport through a slab, concept of opacities.
Gas dynamics: equations of fluid dynamics, equation of state in different regimes (including degenerate systems), models for different systems in equilibrium, application to white dwarfs and neutron stars, simple fluid flows including supersonic flow, example of SN explosions and its different phases.

Module 2 **(10 Hrs)**
Stellar physics: basic equations of stellar structure, stellar energy sources, qualitative description of numerical solutions for stars of different mass, homologous stellar models, stellar evolution, evolution in the HR-Diagram.
Module 3 **(10 Hrs)**
Galactic physics: Milky Way galaxy, spiral and elliptical galaxies, galaxies as self gravitating systems, spiral structure, super-massive black holes, active galactic nuclei.

Module 4 **(25Hrs)**

General relativity:
Principles of relativity: overview of special relativity, spacetime diagrams, Lorentz metric, light cones, electrodynamics in 4-dimensional language, introduction to general relativity, equivalence principle, gravitation as a manifestation of the curvature of space-time.
Geometrical framework of general relativity: curved spaces, tensor algebra, metric, affine connection, covariant derivatives, physics in curved space-time, curvature - Riemann tensor, Bianchi identities,
action principle, Einstein's field equations, energy momentum tensors, energy momentum tensor for a perfect fluid, connection with Newton's theory.
Solutions to Einstein's equations and their properties: spherical symmetry, derivation of the
Schwarzschild solution, test particle orbits for massive and mass less particles, the three classical tests of general relativity, black holes, event horizon, one-way membranes, gravitational waves.

Module 5 **(20 Hrs)**

Cosmology:
Cosmological models: cosmological principle, Robertson-Walker metric, cosmological red shift, Hubble's law, observable quantities, luminosity and angular diameter distances, dynamics of

Friedmann-Robertson-Walker models, solutions of Einstein's equations for closed, open and flat universes.
Physical cosmology and the early universe: thermal history of the universe, temperature red shift relation, distribution functions in the early universe, relativistic and non-relativistic limits, decoupling of neutrinos and the relic neutrino background, nucleosynthesis, decoupling of matter and radiation, cosmic microwave background radiation, inflation, origin and growth of density perturbations.

Books:

1. *Modern Astrophyiscs*, B. W. Carroll and D. A. Ostlie, Addison -Wesley
2. *The Physics of Astrophysics*, Vol. I and II, F. Shu, University Science Books
3. *The Physical Universe*, F. Shu, University Science Books
4. *Theoretical Astrophysics*, Vol. I, II and III, T. Padmanabhan, Cambridge University Press
5. *The Physics of Fluids and Plasmas*, Arnab Rai Choudhuri, Cambridge University Press
6. *Astrophysical Concepts*, M. Harwitt, Springer-Verlag
7. *Galactic Astronomy*, J. Binney and M. Merrifeld, Princeton University Press
8. *Galactic Dynamics*, J. Binney and S. Tremaine, Princeton University Press
9. *Quasars and Active Galactic Nuclei*, A. K. Kembhavi and J. V. Narlikar, Cambridge University Press
10. *An Introduction to Active Galactic Nucleii*, B. M. Peterson

Modules 4 and 5

Books

1. *General Relativity and Cosmology*, J. V. Narlikar, Macmillan India
2. *Introduction to Cosmology*, J. V. Narlikar, Cambridge University Press
3. *Structure Formation in the Universe*, T. Padmanabhan, Cambridge University Press
4. *Classical Theory of Fields*, Vol. 2, L. D. Landau and E. M. Lifshitz, Oxford-Pergamon Press
5. *First Course in General Relativity*, B. F. Schutz, Cambridge University Press

Paper – XV: ATMOSPHERIC CHEMISTRY AND ATMOSPHERIC ELECTRICITY
Paper Code: SST 305 (54 Hrs)

Module 1 **(36 hrs)**

Evolution of the earth's atmosphere: primitive atmosphere, prebiotic atmosphere and origins of life, rise of oxygen and ozone, oxygen and carbon budgets, other atmospheric constituents.
Half-life, residence time and renewal time of chemicals in the atmosphere, spatial and temporal scales of variability.
Present chemical composition of the atmosphere, units for chemical abundance, composition of air close to the earth's surface, change in the atmospheric composition with height.
Sources, transformations, transport, sinks of chemicals in the atmosphere: transformations by homogeneous transformation, transformations by other processes, transport and distribution of chemicals, sinks of chemicals.
Tropospheric chemical cycles: carbon cycle, nitrogen cycle, sulphur cycle.
Air pollution: sources of anthropogenic pollutants, some atmospheric effects of air pollution.
Stratospheric chemistry: unperturbed stratospheric ozone, anthropogenic perturbations to stratospheric ozone, stratospheric aerosols, sulphur in the stratosphere.

Module 2 **(18 Hrs)**

Ions and electrical conductivity, fair weather electricity, electrical currents in the atmosphere.
Electrical structure of storms, cloud electrification, laboratory experiments.
Lightning discharges, lightning electric fields, lightning location systems.
Upward lightning and sprites, global electric circuit.
Nitrogen fixation.

Books

1. *Introduction to Atmospheric Chemistry*, P. V. Hobbs
2. Chemistry of the Upper and Lower Atmosphere, Barbara J. Finlayson-Pitts, Jr. and James N. Pitts
3. *Chemistry of Atmospheres*, Richard P. Wayne.
4. *Atmospheric Chemistry and Physics: From Air Pollution to Climate Change*, John H. Seinfeld and Spyros N. Pandis
5. *Basic Physical Chemistry for Atmospheric Sciences*, P.V. Hobbs

Module 2

1. *Lightning*, M. A. Uman
2. *Atmospheric Electricity*, J. A. Chalmers
3. *Atmospheric Electrodynamics*, H. Volland
4. *Lightning: Physics and Effects*, Vladimir A. Rakov and M. A. Uman
5. *The Electrical Nature of Storms*, McGorman and Rust
6. *The Earth's Electrical Environment*, National Academy Press, USA
7. *CRC Handbook on Atmospherics*, Ed. H. Volland

Paper II (Lab) ATMOSPHERIC SCIENCES
Paper code: SST 306 (36 Hrs)

Module 1

1. Plotting and analysis of T- grams, estimation of LCL, CCL, LFC, EL, height of the base and top of the cloud and perceptible water.
2. Study of the instability of the atmosphere and forecasting of thunderstorms using T- grams.
3. Analysis of vertical section and vertical time section.
4. Analysis of surface and upper air/ pilot charts of typical synoptic situation: western disturbances
5. Analysis of surface and upper air/ pilot charts of typical synoptic situation: monsoon situation
6. Analysis of surface and upper air/ pilot charts of typical synoptic situation: tropical cyclone

Module 2

1. Computation of CAPE and CINE with radiosonde data.
2. Computation of divergence and vorticity by finite difference technique.
3. Computation of vertical velocity using equation of continuity.
4. Computation of geostrophic wind.
5. Computation of geostrophic vorticity.

6. Computation of stream function and velocity potential
7. Interpretation of satellite data – synoptic weather conditions
8. Satellite data for cyclone – centre and intensity

Books:

1. *Principle of Meteorological Analysis*, W. J. Saucier
2. *An Introduction to Numerical Weather Prediction Techniques*, T. N. Krishnamurti

SEMESTER IV

Paper XVI: SPACE PLASMA
Paper code: 401 (90 Hrs)

Module 1 **(25 Hrs)**

Plasma waves and instabilities – electromagnetic waves parallel to the external magnetic field,

Module 2 (waves in space plasma) **(15 Hrs)**

Oscillations in acoustic wave radiation from plasma, plasma state, fluid picture, hydromantic waves and pulsations**.**
Wave-particle interaction, plasma instabilities, linear versus nonlinear processes in plasma.
Hydromagnetic waves, geomagnetic pulsations, VLF and whistler phenomena.

Module 3 (Ionosphere and Earth's main field) **(15 Hrs)**

Ionospheric storms – causative mechanisms, neutral wind – Ionosphere coupling, EXB drift, TIDs, Models like IRI and FLIP
Geomagnetic and magnetic coordinates, poles, measurement of geomagnetic field components, micro-pulsation indices, variations of geomagnetic field, quiet and disturbed variations, geomagnetic storms, equatorial and auroral phenomena.

Module 4 (Instrumentation for earth's environment) **(10 Hrs)**

Detection of radio wave propagation in the ionosphere, ionosondes, whistlers, electric field measurements, magnetic field of earth, types of magnetometers like proton precession, fluxgate and rubidium vapour magnetometers, all-sky camera and photometers for aurora, particle detectors for cosmic rays. GPS – working and application

Module 5 (Applications of space plasma) **(20 Hrs)**

Solar wind: observational evidence for the solar atmosphere, model of solar winds, interaction in the interplanetary medium and with the planets.

Magnetosphere: interaction of solar wind with the geomagnetic field and formation of the magnetospheric tail, storm and sub-storm phenomena.
Van Allen radiation belts, trajectory of charged particles and invariants of motion, energy and momentum spectra of trapped radiations, sources and sinks of trapped radiation.

Module 6 (Plasma outside solar system) **(10 Hrs)**

Cosmic rays: solar and galactic cosmic rays, phenomenology and interpretation.
Dynamo theory, earth and planetary magnetic fields, comparative planetary magnetosphere, stellar magnetic fields, pulsar's magnetic field.

Module 7 (Instrumentation for interplanetary space) **(10 Hrs)**

Balloon, rocket and satellite based systems for measurements of particles, fields and bodies in the interplanetary space interacting with plasmas like solar wind and cosmic rays.

Books

Modules 1, 2, 3.

Text Books

1. *An Introduction to Ionosphere and Magnetosphere*, J. A. Raticliffe
2. *Solar System Astrophysics,* J. C. Brandft and P. W. Hodge
3. *Introduction to Experimental Physics,* W. B. Fretter
4. *Physics of Geomagnetic Phenomena*, Vol. I and II, S. Matsushita and W. H. Campbell, Academic Press
5. *Introduction to Ionospheric Physics,* H. Risbeth and H. Garriot, Academic Press

Reference Books

1. *Plasma Diagnostic Techniques,* R. H. Huddlestone and S. L. Leonard
2. *High Vacuum Techniques,* J. Yarwood
3. *Plasma Diagnostics*, Vol. I, O. Anciello and D. L. Flamn
4. *The Earth's Ionosphere: Plasma Physics and Electrodynamics,* Michael C. Kelley, Academic Press
5. *Ionospheric Techniques and Phenomena*, A. Giraud and M. Petit, D. Reidel Publishers

Module 4, 5, 6, 7

Text Books

1. *Solar System Astrophysics*, J. C. Brandt and P. N. Hongo, McGraw Hill
2. *Introduction to Plasma Physics,* F. F. Chen
3. *Physics and Chemistry of the Solar System*, John S. Lewis, Academic Press
4. *Solar Magnetohydrodynamics,* E. R. Priest, D. Reidel Publishers

Reference Books

1. *Origin of the Solar System*, Ed. Dermolf, John Wiley
2. *The Solar Spectrum,* Ed. C. De. Jagar, D. Reidel Publishers
3. *Introduction to Solar-Terrestrial Relation,* Ed. J. Ortnor and H. Maseland, D. Reidel Publishers
4. *Solar Terrestrial Physics*, Ed. E. R. Dyer, D. Reidel Publishers
5. *A Guide to Solar Corona*, D. E. Billings, Academic Press
6. *Principles of Plasma Physics,* Krall and Trievelpiece
7. *The Solar System,* T. Encrenaz, J. P. Bibring and M. Blisnov, Springer Verlag
8. *The Sun: An Introduction,* Michael Stix, Springer Verlag
9. *A Guide to the Sun,* K. J. H. Phillips, Cambridge University Press
10. *Astrophysics of the Sun,* G. Zirin, Cambridge University Press

Paper XVII: ELECTIVE PAPER
Paper Code SST 402 (90 Hrs)

ELECTIVE I – SOLAR PHYSICS

Module 1(Fundamentals of space dynamics) **(20 Hrs)**

Coordinate systems, time systems, celestial triangle, Keplerian orbits, orbit estimation from experimental data, perturbation of orbits including Lagrange's bracket, restricted solution of 3-body problem, stability around Lagarangian points, N-body relative motions and their characteristics, computation of orbits.

Module 2 (Sun and its interior) **(20 Hrs)`**

Sun: physical dimensions, sun as typical star in a galaxy, instruments for solar studies, solar telescopes and spectroscopes and their management, solar constant.
Source of solar energy, thermonuclear reaction and building up of higher elements, solar composition, photosphere, hydrogen convective zone, structure and astrophysics of outer layers of sun, photospheric emissions, measurements of magnetic and velocity fields.

Module 3 (Chromosphere, corona, and solar activity) **(15 Hrs)**

Quiet and active chromosphere spicules and prominences, solar flare, chromospheric emissions and chromospheric phenomena, physical properties of solar atmospheres, origin of the chromosphere, basic structure, density and temperature, composition, magnetic field, radio studies of solar bursts, u-v and x- ray emission, corona and coronal holes, coronal mass ejection.
Sunspot cycle and magnetic field, elements of hydrodynamics and magneto-hydrodynamics, plasmas and their classification, instabilities and drifts, waves in plasma.
Helio-seismology and global star oscillations, p and g modes, -w diagram, effect of solar cycle on solar oscillations.

Module 4 (instrumentation for solar studies) **(10 Hrs)**

Optical telescopes; light gathering power, angular magnification, resolving power, telescopic aberrations, photographic and photometric instruments, spectroscopic, interferometric and polarimetric instruments, Fourier transform spectroscopy.

Module 5 (Planetary Physics and dynamics) **(10 hrs)**

Orbital dynamics, tidal forces on solar system bodies.
Physical dimensions, planetary physics, structure and composition of the planets and their atmospheres,
Terrestrial planets: Mercury, Venus, Earth, Mars,
Major planets: Jupiter, Saturn, Neptune, Uranus, planets and their satellites, asteroids

Module 6 **(15 Hrs)**

Laboratory for solar studies

1. Estimation of abundance of sodium in solar atmosphere using Fraunhofer absorption lines in solar spectrum.
2. Estimation of value of Fraunhofer Filling-In (FFI) from given data and study of the phenomenon.
3. Study of sunspot cycle and its period using internet data.
4. Study of varying solar activity and its relationship with climate change.
5. Calculation of properties of solar wind near the surface of the earth using solar wind data.
6. Verification of Duvall's law about solar oscillations graphically.

Books

Module 1

Text Books

1. *Fundamentals of Astrodynamics*, R. R. Bates et al, Dover
2. *Orbital Motion,* A. E. Roy, Adam Hinglar Ltd

Reference Books

1. *Orbital Mechanics*, Ed. Vladimir A, Chobotov, AIAA Edn Series
2. *Introduction to Celestial Mechanics,* S. W. McCusky, Addison-Wesley
3. *Rocket Motion,* DASS issue

Module 2, 3, 4, 5

Text Books

1. *Electrodynamics*, Griffith
2. *Introduction to Experimental Physics*, W. B. Fretter.
3. *Physics of Geomagnetic Phenomena,* Vol. I and II, S. Matsushita. and W. H. Campbell, Academic Press
4. *Solar Terrestrial Physics*, Ed. E. R. Dyer, D. Reidel Publishers

Reference Books

1. *Solar System Astrophysics,* J. C. Brandt and P. W. Hodge
2. *The Magnetic Field of the Earth,* Roland T. Merrill, Michael W. McElhinny, Phillip L. Mcfadden, Academic Press
3. *Earth's Magnetospheric Process,* Ed. B. M. McCormac, D. Reidel Publishers
4. *Physics of the Magnetosphere*, Eds. R. L. Corovillano, J. T. McCaulley and H. Radosky, D. Reidel Publishers
5. *Solar System Plasma Physics*, Vol. I, II and III, Eds. C. F. Kennel, L. J. Lanzenrutti and E. N. Parker
6. *Dynamics of the Geomagnetically Trapped Radiation (Physics and Chemistry in Space,* Vol II)

ELECTIVE II – SPACE DYNAMICS
Paper Code SST 402 (90 Hrs)

Module 1 (Physics of interplanetary phenomena) (15 Hrs)

Gas and dust particles, dynamics of inter-planetary particles, radiation pressure, zodiacal light, brightness and polarization, temperature variations.
Cometary structures, comets and asteroids, physical processes in the head of the comet, dust tails and grains, origin of comets, origin of solar system.

Module 2 (Instrumentation for solar system) (10 Hrs)

Photographic, photoelectric, spectroscopic, interferometric and polarimetric techniques for the study of phenomena like corona, zodiacal light and bodies in the solar system such as planets, asteroids, comets and meteors.

Module 3 (Rocket Motion) (20 hrs)

Characteristics of propellants, standard atmosphere, principal aerodynamic forces, coordinate systems, general equations of motion, vertical lift-off dynamics under wind and mal-alignment of thrust, multi-staging, 2-d motion of a launch vehicle up to a specified height, computation of launch vehicle motion, polar and geostationary orbit dynamics.

Module 5 (Orbital maneuvers and interplanetary motion) (20 hrs)
Orbital energy, Hohmann and bielectric transfers and their properties, coplanar electric transfers, plane change transfers, impulsive maneuvers in fixed impulse and launch window transfers, very low thrust transfers.
Sphere of gravitation, sphere of influence, velocity at infinity, earth-moon trajectories, analytical approximations as a 2-body problem, patch conic approach, interplanetary trajectories.

Module 6 (galactic motions) (5 hrs)

Introduction to galaxies, invariance of phase space volume, bending of a star motion in the vicinity of another, dynamics of binary stars, statistical modeling of velocity of stars, general characteristics.

Module 7 (simulation of motion of space bodies) (5 Hrs)

Optimization of time for a launch vehicle, motion of a planet, lunar trajectory from earth

Module 8 (15 hrs)

Laboratory work for interplanetary system

1. Calculation of positions of Lagrangian points and representing them graphically for earth-moon system.
2. Calculation of a theoretical earth generated change in gravitational acceleration on rigid moon at Apollo-12 station in the year 1970 and studying its correlation with the number of earthquakes occurred.
3. Plotting electron density profile as a function of height above earth's atmosphere using given ionogram.
4. Determination of extinction coefficient of earth's atmosphere using Beer's law with the help of given data.
5. Study of scattering of electromagnetic waves by spherical grains.
6. Drawing trajectories (synchrones and syndynes of dust particles emitted from the comet

Books

Modules 1, 2

Text Books

1. *Electrodynamics,* Griffith
2. *Solar System Astrophysics,* J. C. Brandt and P. W. Hodge
3. *Introduction to Experimental Physics,* W. B. Fretter.

Reference Books

1. *The Magnetic Field of the Earth,* Roland T. Merrill, Michael W. McElhinny, Phillip L. Mcfadden, Academic Press
2. *Physics of Geomagnetic Phenomena*, Vol. I and II, S. Matsushita. and W. H. Campbell, Academic Press
3. *Earth's Magnetospheric Process,* Ed. B. M. McCormac, D. Reidel Publishers
4. *Physics of the Magnetosphere*, Eds. R. L. Corovillano, J. T. McCaulley and H. Radosky, D. Reidel Publishers
5. *Solar System Plasma Physics*, Vol. I, II and III, Eds. C. F. Kennel, L. J. Lanzenrutti and E. N. Parker
6. *Dynamics of the Geomagnetically Trapped Radiation (Physics and Chemistry in Space,* Vol II)
7. *Solar Terrestrial Physics*, Ed. E. R. Dyer, D. Reidel Publishers

Module 3

Text Books

1. *Introduction to Celestial Mechanics*, S. W. McCusky, Addison-Wesley
2. *Fundamentals of Astrodynamics*, R. R. Bates et al, Dover

Reference Books

1. *Orbital Mechanics*, Ed. Vladimir A, Chobotov, AIAA Edn Series
2. *Orbital Motion,* A. E. Roy, Adam Hinglar Ltd
3. *Rocket Motion*, DASS issue

Modules 5, 6, 7

Text Books

1. *Fundmentals of Astrodynamics*, R. R. Bates et al, Dover
2. *Orbital Motion,* A. E. Roy, Adam Hinglar Ltd

Reference Books

1. *Orbital Methods in Astrodynamics,* P. R. Escobal, John Wiley
2. *Design of Orbital Flights,* J. Johnson et al., McGraw Hill

Paper IV (Lab) EXPERIMENTS FOR ASTRONOMY AND ASTROPHYSICS
Paper Code SST 403 (108 hrs)

Ten among the following experiments will be selected,

1. To estimate the temperature of an artificial star by photometry.
2. To study the characteristics of a CCD camera.
3. To study the solar limb darkening effect.
4. To polar align an astronomical telescope.
5. To estimate the relative magnitudes of a group of stars by a CCD camera.
6. To study the atmospheric extinction for different colors.
7. Differential photometry of a program star w.r.t a standard star.
8. To study the effective temperature of stars by B-V photometry.
9. To estimate the night sky brightness with a photometer.
10. To estimate the distance to the moon by parallax method.
11. Calibration of a 1420 MHz radio receiver and spectrometer.
12. Detection of 21-cm line of neutral hydrogen from our galaxy.
13. To estimate the distance to a Cepheid variable.
14. To study the variability of delta Scuti type stars.
15. To study the variability of RS CVn binaries.
16. To measure the polarization of day/moon light.

Lectures associated with the experiments will be given on a number of topics including:
Time and Coordinates; Telescopes; Atmospheric Effects; Noise and Statistics; Astronomical Detectors; Imaging and Photometry, etc.

Books:
Reference Books

1. *Telescopes and Techniques*, C. R. Kitchin, Springer-Verlag
2. *Observational Astrophysics,* R. C. Smith, Cambridge University Press

3. *Detection of Light: from the Ultraviolet to the Submillimeter*, G. H. Rieke, Cambridge University Press
4. *Astronomical Observations*, G. Walker, Cambridge University Press
5. *Astronomical Photometry*, A. A. Henden and R. H. Kaitchuk, Willmann-Bell
6. *Electronic Imaging in Astronomy*, I. S. McLean, Wiley-Praxis
7. *An Introduction to Radio astronomy*, B. F. Burke and F. Graham-Smith, Cambridge University Press
8. *Radio Astronomy*, John D. Kraus, Cygnus-Quasar Books

Paper V (Lab) LABORATORY FOR PLASMA Paper code: SST 404 (36 Hrs)

Module 1 **(18 Hrs)**

1. Magnetic pulsation experiments.
2. Fluxgate and proton precession magnetometers and their use in measuring the daily variations, absolute value measurements, etc.
3. Measurements of electric field and Maxwell current at ground.
4. Identifying magnetic storms and their different phases, correlating them with geomagnetic indices of electric field phases.

Module 2 **(18 Hrs)**

1. Analysis of magnetic data, separation of internal and external parts.
2. Vacuum generation and measurement of pumping speed.
3. Degassing characteristics of given specimen as a function of temperature.
4. Plasma temperature and density measurement of a glow discharge plasma using single and double probes.
5. Electron energy distribution function near the cathode and in the glow region.

Books

Reference Books:

1. *Plasma Diagnostics*, Vol. I, O. Anciello and D. L. Flamn