UNIVERSITY OF PUNE

Department of Atmospheric and Space Sciences

REVISED

Course Structure and Syllabi for

M. Sc. (Atmospheric Sciences)
and
M. Sc. (Space Sciences)

September 2007

Course Structure for M. Sc. (Atmospheric Science & Space Sciences)

Background

The M. Sc. (Space Sciences) course run by the University of Pune since 1998 has a major component of atmospheric sciences in it and therefore in 2005 a separate degree of M.Sc. (Atmospheric Science) was instituted. **The compulsory courses for both the M.Sc. programs are common.**

The M. Sc. (Atmospheric Sciences) Course was introduced by the University of Pune, as a separate Course vide Circular No 266 of 2005
..
Atmospheric Science is recognized as a subject for M. Sc. degree for the UGC/CSIR NET.

Eligibility

- Any B.Sc./ B.E./ B.Tech. with Physics or Mathematics as one the subject at the graduation level with 50% marks in aggregate.
- For reserved candidates minimum marks at qualifying exam as per university rules.

Admission

- Ten students will be admitted to each of these courses through a National level entrance examination in each of the M.Sc. disciplines.

- Reservation of seats will be as per the rules of University of Pune.

Examination

- A student will have to complete a total of 100 credits details of which are given in the enclosed course structure

- Each credit will be for 20 marks. 10 marks for continuous assessment and 10 marks for final assessment. For back log students who joined courses before July 2006, each credit will be for 20 marks (8 marks for continuous assessment and 12 marks for final assessment). The continuous and final assessment together will form one passing head. The minimum percentage for passing is 40%.

- Continuous assessment can be done through Seminars/ Assignments/ Oral test/ Written test.

- The final assessment for theory courses will be in the form of written examination for the whole course. As the courses are for smaller credits and if a particular course is completed well before the term ends then teacher concerned need not wait for the end of term examination to conduct the final assessment. The final

assessment can be done in consultation with the Head of Department or Course Coordinator or the Chairman Examination Committee.

However the result will be declared only after the end of term exams are completed.

Backlogs

- The student has to clear at least 50% of the credits of the first year before he can be allowed to take admission for the second year courses.

- If the student has a backlog course then he/she can improve the continuous assessment marks of that course only when the course is being run and he/she will be required to register for that course and attend the classes.

- If a particular course is discontinued or not offered then the student will have to register for an alternative course of equal number of credits.

M. Sc. (PPPR)

- Admission: Maximum of five students will be admitted every year on the basis of a written admission test.

- Students registering for M. Sc. (PPPR) in Atmospheric Science will have to take up AS- X01, X02, X31, and X33 as compulsory subjects. The remaining ten credits will have to be taken from the subjects offered under the Atmospheric Science or Space Sciences Stream. Students registering for M. Sc. (PPPR) in Space Sciences Science will have to take up AS- X01, X02, X74, and X75 as compulsory subjects. The remaining ten credits will have to be taken from the subjects offered under the Atmospheric Science or Space Sciences Stream. They cannot offer any of the subjects which are offered to the M.Sc. Physics students.

COURSE STRUCTURE AND CREDIT SYSTEM

Number of Credits

Compulsory Courses

AS X01	Fundamentals of Atmospheric Sciences	3
AS X02	Fundamentals of Space Sciences and Remote Sensing - I	2
AS X03	Classical Mechanics	5
AS X04	Quantum Mechanics	5
AS X05	Mathematical and Statistical Methods - I	5
AS X06	Numerical Methods - I	2
AS X07	Computer Programming - I	3

AS X08	Fundamental of Physics – I	5
AS X09	Fundamental of Physics – II	5
AS X10	Fundamentals of Earth Sciences	3
AS X11	Fundamentals of Space Sciences and Remote Sensing - II	3
AS X12	Statistical Mechanics	5
AS X13	Electrodynamics	5
AS X14	Mathematical and Statistical Methods - II	5
AS X15	Numerical Methods - II	2
AS X16	Computer Programming - II	3
AS 900	Project Work - I	10
AS 000	Project Work - II	10

Students who are planning to take AS- X 61, X62, X63 and X64 will have to take AS- X03, X04, X12 and X13. Those who are taking AS- X03, X04, X12 and X13 cannot take AS- X08 and X09.

Atmospheric Science: (Students of M.Sc. (Atmospheric Science) will have to take at least 20 credits under this stream)

AS X31	Atmospheric Dynamics - I	3
AS X32	Atmospheric Dynamics - II	3
AS X33	Climatology	2
AS X34	Tropical Climatology	3
AS X35	Global Climate	2
AS X36	Synoptic Meteorology	3
AS X37	Satellite Meteorology - I	3
AS X38	Satellite Meteorology - II	2
AS X39	Cloud Physics	2
AS X40	Atmospheric Electricity	2
AS X41	Atmospheric Chemistry – I	2
AS X42	Atmospheric Chemistry – II	2
AS X43	Laboratory Course for Atmospheric Science - I	2
AS X44	Laboratory Course for Atmospheric Science - II	2
AS X45	Remote Sensing	2
ASX46	Space Weather I	2
ASX47	Space Weather II	2

Space Sciences: (Students of M.Sc. (Space Sciences) will have to take at least 20 credits under this stream)

AS X61	Astronomy and Astrophysics - I	5
AS X62	Astronomy and Astrophysics - II	5
AS X63	Experiments for Astronomy and Astrophysics - I	2
AS X64	Experiments for Astronomy and Astrophysics - II	3

AS X65	Theory of Plasma	2
AS X66	Ionosphere and Earth's Main Field	2
AS X67	Instrumentation for Earth's Environment	1
AS X68	Laboratory Work for Plasma - I	1
AS X69	Waves in Space Plasma	1
AS X70	Applications of Space Plasma	2
AS X71	Plasma Outside Solar System	1
AS X72	Instrumentation for Interplanetary Space	1
AS X73	Laboratory Work for Plasma - II	1
AS X74	Fundamentals of Space Dynamics	3
AS X75	Sun and its Interior	2
AS X76	Chromosphere, Corona and Solar Activity	2
AS X77	Instrumentation for Solar Studies	1
AS X78	Laboratory Work for Solar Studies	1
AS X79	Planetary Physics and Dynamics	2
AS X80	Physics of Interplanetary Phenomena	2
AS X81	Instrumentation for Solar System	1
AS X82	Laboratory Work for Interplanetary System	1
AS X83	Rocket Motion	2
AS X84	Orbital Maneuvers and Interplanetary Motion	3
AS X85	Galactic Motions	1
AS X86	Simulation of Motion of Space Bodies	1

These subjects are only for M.Sc. Physics students of Department of Physics who are opting for specialization in Atmospheric or Space Sciences.

AS X90	Space Science-I	5
AS X91	Space Science-II	5
AS X92	Atmospheric Science-I	5
AS X93	Atmospheric Science-II	5
AS X94	Laboratory for Space Science-I	2.5
AS X95	Laboratory for Space Science-II	2.5
AS X96	Laboratory for Atmospheric Science-I	2.5
AS X97	Laboratory for Atmospheric Science-II	2.5

Notes:

1) Every student is required to offer Courses equivalent to 25 credits in each semester. However, a small variation in the number credits in each Semester may be permitted at discretion of the Head of the Department. To be eligible for the award of M Sc degree, a student must complete minimum of 100 credits at the end of fourth semester or thereafter till he/she is eligible to take the examination for that degree.
2) In each Semester, courses offered will be notified by the Head of the Department in consultation with the Faculty of the Department.

3) In the numbering system of the courses the Symbol X will be replaced by 7, 8, 9 or 0 for Semester –I, Semester– II , Semester – III and Semester – IV respectively.
4) Students may opt for few courses from other departments with the permission of the HOD.
5) Field trips for hands on training in the subjects of ASX 43, 44, 68, 73, 78 and 82 may be undertaken at appropriate Laboratories/ Institutions with the consent of the HOD.
6) Students who have backlogs in Compulsory subjects (prior to July 2007) may offer alternate courses having equivalent number of credits from the above courses with the permission of the HOD provided they have not taken any of the courses in Astronomy and Astrophysics offered by IUCAA..
7) Students who are taking courses AS- X08, X09 cannot offer courses AS- X03, X04, X13 and X14

AS X01 FUNDAMENTALS OF ATMOSPHERIC SCIENCES

Module 1: 1 Credit [10 L, 5 T/S/D]:

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).

Module 2: 1 Credit [10 L, 5 T/S/D]:

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: 1 Credit [10 L, 5 T/S/D]:

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.

Books:

1. *An Introduction to Meteorology*, S. Petterssen
2. *Elementary Meteorology*, S. Petterssen
3. *Introduction to Theoretical Meteorology*, S. Hess
4. *Atmospheric Science - An Introductory Survey*, J. M. Wallace and P. V. Hobbs
5. *Atmospheric Physics*, J. V. Iribrine and H. R. Cho
6. *Thermodynamics*, P. C. Rakshit
7. *Thermodynamics*, E. Fermi
8. *The Upper Atmosphere - the Meteorology and Physics*, R. A. Craig
9. *An Introduction to Atmospheric Dynamics*, A. A. Tsonis

AS X02 FUNDAMENTALS OF SPACE SCIENCES AND REMOTE SENSING - I

2 Credits [20 L, 10 T/S/D]:

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.

Satellite orbits and attitude: principles of satellite motion, Kepler's laws, orbital elements, satellite attitude an its control, types of orbits, polar and geostationary, earth- and sun-synchronous, orbit optimization, viewing geometry, launch vehicles and spacecrafts.

Books:

1. *Digital Image Processing*, R. C. Gonzales and R. E. Woods, 2nd Ed, Pearson India, 2002
2. *Satellite Meteorology*, S. Q. Kidder and T. H. Von der Haar, Academic Press, 1995
3. *Lecture Notes on Satellite Meteorology*, Vol 1 and 2, SAC, Ahmedabad
4. *Remote Sensing and Image Interpretation*, T. M. Lillesand and R. W. Kieffer, John Wiley, 2002
5. *Fundamentals of Space Systems*, V. L. Pisacane and R. C. Moore, Oxford University Press, 1994
6. *Fundamentals of Remote Sensing*, George Joseph, 2003
7. *Processing Remote Sensing Data*, M. C. Girgard and C. Girgard, Oxford-IBH, 1999
8. *Quantitative Remote Sensing of Land Surfaces*, Shunlin Liang, Wiley Interscience, 2004
9. *Scale in Remote Sensing and GIS*, D. A. Quattrachi and M. F. Goodchild
10. *Theory of Satellite Orbits in an Atmosphere*, King-Hele Desmond, Butterworths, 1964
    Uncertainty in Remote Sensing and GIS, Ed: G. M. Foddy and P. M. Atkinson
11. *Remote Sensing by George Joseph*
12. Concepts in Space Sciences Edited by R.R. Daniel
13. Mathematical Principles of Remote Sensing by A.. Milman

AS X03 CLASSICAL MECHANICS

Module 1: 1 Credit [10 L, 5 T/S/D]:

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: 1 Credit [10 L, 5 T/S/D]:

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: 1 Credit [10 L, 5 T/S/D]:

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: 1 Credit [10 L, 5 T/S/D]:

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: 1 Credit [10 L, 5 T/S/D]:

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).

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

Books for Reference:

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

AS X04 QUANTUM MECHANICS

Module 1: 1 Credit [10 L, 5 T/S/D]:

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: 1 Credit [10 L, 5 T/S/D]:

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: 1 Credit [10 L, 5 T/S/D]:

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: 1 Credit [10 L, 5 T/S/D]:

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: 1 Credit [10 L, 5 T/S/D]:

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

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
5. *The Principles of Quantum Mechanics*, P. A. M. Dirac, Clarendon Press

AS X05 MATHEMATICAL AND STATISTICAL METHODS - I

Module 1: 2 Credits [20 L, 10 T/S/D]:

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: 3 Credits [30 L, 15 T/S/D]:

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: 1 Credit [10 L, 5 T/S/D]:

Probabilty 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.

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. *Fluid Dynamics*, William F. Hughes and John A. Brighton, Schaum Publishing
20. *Theory and Problems of Matrices*, Frank Ayres, Jr, Schaum Publishing
21. *Theory and Problems of Probability*, S. Lipschutz, Schaum Outline Series, McGraw Hill
22. *Theory and Problems of Fourier Analysis with Application to Boundary Value Problems*, Murray R. Spiegel, Schaum Outline Series, McGraw Hill
23. *The Fourier Transform and its Applications*, Ronald N. Bracewell, McGraw Hill
24. *Fluid Mechanics*, Pijush Kundu, Academic Press
25. *Fluid Mechanics*, David Pneuli and Chaim Goodfinger, Cambridge University Press
26. *An Introduction to Fluid Dynamics*, G K Batchelor, Oxford University Press

AS X06 NUMERICAL METHODS – I

Module 1: 1 Credit [10 L, 5 T/S/D]:

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.

Module 2: 1 Credit [10 L, 5 T/S/D]:

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

Books:

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

AS X07 COMPUTER PROGRAMMING – I

Module 1: 1 Credit [10 L, 5 T/S/D]:

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.

Module 2: 2 Credits [30 L/T/S/D]:

FORTRAN Lab:

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

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

AS X08 FUNDAMENTALS OF PHYSICS – I

Module 1: Classical Mechanics (1 Credits)
Basic Principle of Classical Mechanics,Lagrangian and Hamiltonian Formalism, Conservation Theorems and Symmetry Properties. Central Force, Two Body Problems, Rotating Frame of Reference, Effect of Coriolis Force, Small Oscillations, Rigid Body Motion, Eulerian Angles, Wave Motions: Wave Equation, Phase Velocity, Group Velocity, Dispersion, Special Theory of Relativity,Lorentz Transformation.

Books:

1.Classical Mechanics By Rana Joag
2. Classical Mechanics By Herbert Goldstein
3. Classical Mechanics: systems of particles and Hamiltonian dynamics By Walter Greiner

Module 2: Quantum Mechanics (2 Credits)

Wave Particle Duality, Heisenberg's Uncertainty Principle, Schrödinger Equation, Particle in Box, Harmonic Oscillator, Potential Barrier, Motion in Central Potential, Hydrogen Atom, Orbital Angular Momentum, Angular Momentum Algebra, Spin, Addition of Angular Momentum, Time independent Perturbation, Non degenerate And Degenerate Cases, Application Like Stark Effect, Variational Method, Helium Atom,Vander Waal's Interaction.

Books:

1.A Text Book Of Quantum Mechanics By Mathews Venkatesan
2. Introduction to Quantum Mechanics By Henrik Smith
3. The Principles of Quantum Mechanics: quantum Mechanics 4/e Ismp 27 P
   By Paul Adrien Maurice Dirac
4. A Textbook of Quantum Mechanics By Arora M.G

Module 3: Atomic and Molecular Physics (2 Credits)

Quantum States of an Electron in an Atom, Hydrogen Atom Spectrum, Spin Orbit Coupling, Fine Structure, Spectroscopic Terms and Selection Rules, LS and JJ Coupling, Zeeman, Paschen Beck And Stark Effects ,X-rays, Compton Effect, Principles of ESR, NMR, Emission and Absorption Spectroscopy, Rotational and Vibrational Spectra, Raman Spectra, Selection Rules, Nuclear Spin and Intensity Alteration, Isotopes Effect,Electronic States of Diatomic Molecule, Frank Condon Principle, Introduction to LASER And MASER.

Books:

1.Atomic and Molecular Spectra by Rajkumar
2. Atomic Physics By Wolfgang. Finkelnburg, George E. Brown

AS X09 FUNDAMENTALS OF PHYSICS- II

Module 1: Statistical Mechanics (2 Credits)

Elementary Probability Theory: Random Walk Problem, Binomial Distribution, Poisson Distribution, Gaussian Distribution, Probability Density, Classical And Quantum Statistics, Density Matrix, Ensemble In Quantum Statistical Model, Maxwell Boltzman, Bose Einstein ,Fermi Dirac Gases, Ideal Bose System, Thermodynamic Behavior of an Ideal Bose Gas, Bose-Einstein Condensation.

Books:

1.Statiscal Mechanics by Pathria
2. Introduction to statistical physics By Kerson Huang
3. Statistical Mechanics By R.K. Srivastava, J Ashok

Module 2: Electrodynamics (1 Credits)

Basic Principles of Electrostatics and Mangetostatics, Faraday's Law, Maxwell's Displacement Current, Maxwell's Equations, Scalar And Vector Potentials, Gauge Invariance, Wave Equations, Poyntings Theorem ,Conservation Laws,

Books:

1.Inroduction to Electrodynamics by Griffiths
2. Classical electrodynamics By T. Tsang

Module 3: Electronics (1 Credits)

Physics of Semiconductor, Physics of P-N Junction ,Zener Diode, Transistor, OR,AND,NOT Gates, Feed back Amplifiers, Operational Amplifiers and its Applications, Digital Ic's,NAND ,NOR and XOR Gates, Flip flops, Counters ,Decoders, Encoders.

Books:

1.Integrated Electronics:Analog and Digital Circuit and System by Jacob Millman,Christos C Halkias
2. An Introduction to Electronics By J. (John) Yarwood

Module 4: Nuclear And Particle Physics (1 Credits)

Basics Properties of Nucleus-Size, Shape, Charge Distribution, Spin and Parity, Binding Energy ,Emperical Mass Formula, Liquid Drop Model, Nature of Nuclear Force, Charge Independence and Charge Symmetry of Nuclear Force Evidence of Nuclear Shell Structure ,Single Particle Shell Model-its Validity and Limitations, Collective Models, Interactions of Charge Particles and E.M Rays with Matter, Radioactive Decay-Basic Understanding, Particle Physics: Symmetry and Conservation Laws, Classification Of Fundamental Forces and Elementary Particles Gell-Mann Nishijima Formula, Quark Model

Books :

1.Nuclear Physics By D.C.Tayal
2. Nuclear Physics By Alex Edward Samuel Green
3. Fundamentals In Nuclear Physics: From Nuclear Structure to Cosmology By Michel. Spiro, James Rich

AS X10 FUNDAMENTALS OF EARTH SCIENCES

3 Credits [30 L, 15 T/S/D]:

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.

Books:

1. *Planet Earth- Cosmology, geology and the evolution of life and environment*, A. Emilianic, Cambridge University Press.
2. *Encyclopedic Dictionary of Applied Geophysics*, Sheriff R.E., Society of exploration geophysics, USA.
3. *Isostasy and Flexure of lithosphere*, Watts A.B., Cambridge University Press.
4. *Earthquakes*, Bolt B.A., W. H. Freeman and Company, New York.
5. *Manual of Geology (Vol. I and II)*, Dana J.D., Akashdeep Publishing House.
6. *A text book of general & engineering Geology*, Arora D.S., Mohindra Capital Publishers.
7. Earths Deep Interior by D.J. Crossley

AS X11 FUNDAMENTALS OF SPACE SCIENCES AND REMOTE SENSING - II

3 Credits [30 L, 15 T/S/D]:

Sensors and systems: visible, infrared, water vapour and microwave sensors, sensor characteristics, sensor materials, passive and active sensors, scanning radiometers, spectral signatures.

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

Books: See AS X02

AS X12 STATISTICAL MECHANICS

Module 1: 1 Credit [10 L, 5 T/S/D]:

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.

Module 2: 1 Credit [10 L, 5 T/S/D]:

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: 1 Credit [10 L, 5 T/S/D]:

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, 1st and 2nd order phase transition, phase equilibria.

Module 4: 1 Credit [10 L, 5 T/S/D]:

Fromulation 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: 1 Credit [10 L, 5 T/S/D]:

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:

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

AS X13 ELECTRODYNAMICS

Module 1: 1 Credit [10 L, 5 T/S/D]:

Electrostatics, Coulomb's law, Gauss's law, Poisson's and Laplace's equations, surface distribution of charges, electrostatic potential energy.

Module 2: 1 Credit [10 L, 5 T/S/D]:

Simple boundary value problems illustrating various techniques, using Green's functions, method of images, separation of variables.

Module 3: 1 Credit [10 L, 5 T/S/D]:

Magnetostatics, laws of Biot-Savart and Ampere, vector potentials, magnetic field of a localised charge distribution, magnetic moment, magnetic shielding.

Module 4: 1 Credit [10 L, 5 T/S/D]:

Multipole expansions and material media, multipole expansions for a localised charge distribution, static electric and magnetic fields in material media, boundary conditions.

Module 5: 1 Credit [10 L, 5 T/S/D]:

Time varying fields, Faraday's law, Maxwell's displacement current, Maxwell's equations, scalar and vector potentials, gauge invariance, wave equations, Poynting's theorem, conservation laws.

Books:

1. *Classical Electrodynamics*, J. D. Jackson, John Wiley
2. *Introduction to Electrodynamics*, D. J. Griffiths
3. *Classical Theory of Fields*, L. D. Landau and E. M. Lifshitz, Addison Wesley
4. *Electrodynamics of Continuous Media*, L. D. Landau and E. M. Lifshitz, Addison Wesley
5. *Electrodynamics*, A. Sommerfeld, Academic Press
6. *Classical Electricity and Magnetism*, W. K. H. Panofsky and M. Phillips, Addison Wesley
7. *Feynman Lectures in Physics*, Vol II
8. *Berkeley Series*, Vol II
9. *Electricity and Magnetism*, Reitz and Milford
10. *Introduction to Electrodynamics*, A. Z. Kapri and P. V. Panat, Narosa

ASX14 MATHEMATICAL AND STATISTICAL METHODS – II

Module 1: 2 Credits [20 L, 10 T/S/D]:

Transforms: Fourier series, Fourier transforms, convolution, inverse Fourier transforms and their applications in solving boundary and initial value problems.

Module 2: 1 Credit [10 L, 5 T/S/D]:

Vector calculus: gradient, divergence, curl, line integral, surface integration, Green's theorem, Gauss divergence theorem and Stokes' theorem.

Module 3: 1 Credit [10 L, 5 T/S/D]:

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**.**

Module 4: 1 Credit [10 L, 5 T/S/D]:

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.
Books: See AS X05

AS X15 NUMERICAL METHODS – II

Module 1: 1 Credit [10 L, 5 T/S/D]:

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 2: 1 Credit [10 L, 5 T/S/D]:

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

Books: See ASX06

AS X16 COMPUTER PROGRAMMING – II

Module 1: 1 Credit [10 L, 5 T/S/D]:

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, arrays and pointers.

Module 2: 2 Credits [30 L/T/S/D]:

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

Books: See AS X07

AS X31 ATMOSPHERIC DYNAMICS – I

Module 1: 1 Credit [10 L, 5 T/S/D]:

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: 1 Credit [10 L, 5 T/S/D]:

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: 1 Credit [10 L, 5 T/S/D]:

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.

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)
3. *Atmospheric Science – An Introductory Survey*, J. M. Wallace and P. V. Hobbs
4. *Numerical Analysis and Prediction*, P. D. Thomson
5. *W. M. O. Compendium of Meteorology: Dynamic Meteorology*, Aksel Wiin-Nielsen
6. *The Physics of Atmosphere*, John Houghton
7. *Atmospheric Boundary Layer*, W.M.O. Technical Notes
8. A course in Dynamic Meteorology by N. Pandarinath.

AS X32 ATMOSPHERIC DYNAMICS- II

Module 1: 1 Credit [10 L, 5 T/S/D]:

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 2: 1 Credit [10 L, 5 T/S/D]:

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

Module 3: 1 Credit [10 L, 5 T/S/D]:

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: See AS X31

AS X33 CLIMATOLOGY

2 Credits [20 L, 10 T/S/D]:

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**.**

Books:

1. *Atmospheric Circulation System*s: E. Palmen and Newton
2. *Monsoons*: P. K. Das, NBT
3. *Monsoons (WMO lectures)*, P. K. Das
4. *Southwest Monsoon (IMD Met Monograph)*: Y. P. Rao
5. *World Survey of Climate*, Vol I to XV, Ed: Landsberg
6. *Physical Climatology*, W. D. Sellers
7. *World Climatology*, John G. Lockwood
8. *Climate of the Continents*, W. C. Kendrew
9. *Foundation of Climatology*, E. T. Stringer
10. *An Introduction to Climate*, G. T. Trewartha
11. *Tropical Meteorology*, Herbert Riehl
12. *Tropical Meteorology*, Vol I and II, G. C. Asnani
13. *Weather Forecasting*, A. A. Ramsastry
14. *Tropical Climatology*, Nieuwolt
15. *Climate of South Asia*, G.B. Pant and Rupa Kumar

AS X34 TROPICAL CLIMATOLOGY

3 Credits [30 L, 15 T/S/D]:

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

Books: See AS X33

AS X35 GLOBAL CLIMATE

2 Credits [20 L, 10 T/S/D]:

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.

Books: See AS X33

AS X36 SYNOPTIC METEOROLOGY

3 Credits [30 L, 15 T/S/D]:

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).

Books: **See AS X33**

AS X37 SATELLITE METEOROLOGY - I

3 Credits [30 L, 15 T/S/D]:

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

Books:

1. *Lecture Notes on Satellite Meteorology*, Vol 1 and 2, SAC, Ahmedabad
2. *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
3. *Satellite Meteorology*, S. Q. Kidder and T. H. Von der Haar, Academic Press, 1995
4. *Quantitative Meteorological Data from Satellites*, WMO Technical Note No. 166
5. *Satellite meteorology by R.R. Kelkar*

AS X38 SATELLITE METEOROLOGY - II

2 Credits [20 L, 10 T/S/D]:

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: See AS X37

AS X39 CLOUD PHYSICS

2 Credits [20 L, 10 T/S/D]:

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:

1. *Cloud Physics*, R. R. Rogers
2. *Cloud Dynamics*, Robert A. Houze
3. *Atmospheric Sciences: Introductory Survey*, J. M. Wallace and P. V. Hobbs
4. *Microphysics of Clouds and Precipitation*, H. R. Pruppacher and J. D. Klett
5. *The Physics of Clouds*, B. J. Mason
6. *A Short Course in Cloud Physics*,M. K. Yau.

AS X40 ATMOSPHERIC ELECTRICITY

2 Credits [20 L, 10 T/S/D]:

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

AS X41 ATMOSPHERIC CHEMISTRY -I

2 Credits [20 L, 10 T/S/D]:

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.

Books:

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

AS X42 ATMOSPHERIC CHEMISTRY -II

2 Credits [20 L, 10 T/S/D]:

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**.**

Books:

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

AS X43 LABORATORY COURSE FOR ATMOSPHERIC SCIENCE - I

2 Credits:

1. Plotting and analysis of T-Φ grams, estimation of LCL, CCL, LFC, EL, height of the base and top of the cloud and precipitable water.
2. Study of the instability of the atmosphere and forecasting of thunderstorms using T-Φ 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

Books:

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

AS X44 LABORATORY COURSE FOR ATMOSPHERIC SCIENCES - II

2 Credits:

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

Books: See AS X43

AS X45 REMOTE SENSING

2 Credits [20 L, 10 T/S/D]:

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.

Books: See AS X02

AS X46 SPACE WEATHER I

2 Credits [20 L, 10 T/S/D]:

Space Energy Output and Variability, Space Weather Effects on Corona, Space Storms over Solar Cycle, Coupling of Solar Wind to Earth, Magnetosphere.
Radiation Belts and Ring Current
Ionospheric Response
Solar effects on Sratosphere.

AS X47 SPACE WEATHER II

2 Credits [20 L, 10 T/S/D]:

Space Weather Effects on Communication
Space Weather Effects on Power Grids
Space Radiation Protection
Effects on Spacecrafts hardware and Operations, Effects on Sattellite Navigation, Forecast of Space Weather.

Reference Books
1. Space Weather, Physics and Effects by Volker Bothmer and Loannis.A.Depli Springer
2. Aerospace Environment by T Beer

AS X61 ASTRONOMY AND ASTROPHYSICS - I

Module 1: 3 Credits [30 L, 15 T/S/D]:

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: 1 Credit [10 L, 5 T/S/D]:

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: 1 Credit [10 L, 5 T/S/D]:

Galactic physics: Milky Way galaxy, spiral and elliptical galaxies, galaxies as self gravitating systems, spiral structure, super-massive black holes, active galactic nuclei.

Books:

1. *Modern Astrophyiscs*, B. W. Carroll and D. A. Ostlie, Addison -Wesley
2. *The Physical Universe*, F. Shu, University Science Books
3. *The Physics of Astrophysics*, Vol. I and II, 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

AS X62 ASTRONOMY AND ASTROPHYSICS - II

Module 1: 3 Credits [30 L, 15 T/S/D]:

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 2: 2 Credits [20 L, 10 T/S/D]:

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

AS X63 & X64 EXPERIMENTS FOR ASTRONOMY AND ASTROPHYSICS - I & II

Total 5 Credits [120 Lab. Hours]:

Semester III 2 Credits, Semester IV 3 Credits

10 of the following experiments will be selected, 5 each in Semesters III and IV, depending upon sky conditions, etc:

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:

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

AS X65 FUNDAMENTALS OF SPACE DYNAMICS

3 Credits [30 L, 15 T/S/D]:

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.

Books:

1. *Orbital Mechanics*, Ed. Vladimir A, Chobotov, AIAA Edn Series
2. *Introduction to Celestial Mechanics*, S. W. McCusky, Addison-Wesley
3. *Fundamentals of Astrodynamics*, R. R. Bates et al, Dover
4. *Orbital Motion*, A. E. Roy, Adam Hinglar Ltd
5. *Rocket Motion*, DASS issue

AS X66 THEORY OF PLASMA

2 Credits [20 L, 10 T/S/D]:

Elements of electromagnetism, plasma state, particle picture, kinetic theory, magnetic fields, Fokker-Planck theory, Boltzmann's equation.

Classification of plasma (mathematical): metal gas discharges, classification according to temperature, density, composition, magnetic field, plasma's state in laboratory and space, configurations for plasma's containment, stellar, galactic and cosmic plasmas.

Transport and thermal processes (mathematical): electron and ion temperatures, electric currents, ionospheric conductivity, electrojet ionospheric anomalies, equatorial ionosphere spread-f, sporadic-E.

Plasma instabilities, etc, dusty plasmas, characteristic modes in various plasmas.

Books:

1. *An Introduction to Ionosphere and Magnetosphere*, J. A. Raticliffe
2. *Solar System Astrophysics*, J. C. Brandft and P. W. Hodge
3. *Plasma Diagnostic Techniques*, R. H. Huddlestone and S. L. Leonard
4. *Introduction to Experimental Physics*, W. B. Fretter
5. *High Vacuum Techniques*, J. Yarwood
6. *Plasma Diagnostics*, Vol. I, O. Anciello and D. L. Flamn
7. *The Earth's Ionosphere: Plasma Physics and Electrodynamics*, Michael C. Kelley, Academic Press
8. *Ionospheric Techniques and Phenomena*, A. Giraud and M. Petit, D. Reidel Publishers
9. *Physics of Geomagnetic Phenomena*, Vol. I and II, S. Matsushita and W. H. Campbell, Academic Press
10. *Introduction to Ionospheric Physics*, H. Risbeth and H. Garriot, Academic Press
11. *Physics of Fluids and Plasma by A.R. Choudhuri*

AS X67 IONOSPHERE AND EARTH'S MAIN FIELD

2 Credits [20 L, 10 T/S/D]:

The ionospheric layers D,E,F, and their formation, effect of radiation on earth's atmosphere, photochemical processes, techniques of ionosphere measurements, ionosonde, coherent, incoherent and partial reflection radars, ionospheric scintillations.

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.

Books: See AS X66

AS X68 INSTRUMENTATION FOR EARTH'S ENVIRONMENT

1 Credit [10 L, 5 T/S/D]:

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.

Books: See AS X66

AS X69 LABORATORY FOR PLASMA - I

1 Credit:

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.
5. Analysis of whistler data

Books: See AS X66

AS X70 WAVES IN SPACE PLASMA

1 Credit [10 L, 5 T/S/D]:

Oscillations in acoustic wave radiation from plasma, plasma state, fluid picture, hydromantic waves and pulsations**.**

Wave-particle interaction and plasma instabilities, linear versus nonlinear processes in plasma.

Hydromagnetic waves, geomagnetic pulsations, VLF and whistler phenomena.

Books:

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

AS X71 APPLICATIONS OF SPACE PLASMA

2 Credits [20 L, 10 T/S/D]:

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.

Books: See AS X70

AS X72 PLASMA OUTSIDE SOLAR SYSTEM

1 Credit [10 L, 5 T/S/D]:

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.

Books: See AS X70

AS X73 INSTRUMENTATION FOR INTERPLANETARY SPACE

1 Credit [10 L, 5 T/S/D]:

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: See AS X70

AS X74 LABORATORY WORK FOR PLASMA - II

1 Credit:

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: See AS X70

AS X75 SUN AND ITS INTERIOR

2 Credits [20 L, 10 T/S/D]:

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.

Books:

1. *Electrodynamics*, J. D. Jackson
2. *Solar System Astrophysics*, J. C. Brandt and P. W. Hodge
3. *Introduction to Experimental Physics*, W. B. Fretter.
4. *The Magnetic Field of the Earth*, Roland T. Merrill, Michael W. McElhinny, Phillip L. Mcfadden, A.P.
5. *Physics of Geomagnetic Phenomena*, Vol. I and II, S. Matsushita. and W. H. Campbell, Academic Press
6. *Earth's Magnetospheric Process*, Ed. B. M. McCormac, D. Reidel Publishers
7. *Physics of the Magnetosphere*, Eds. R. L. Corovillano, J. T. McCaulley and H. Radosky, D. Reidel
8. *Solar System Plasma Physics*, Vol. I, II and III, Eds. C. F. Kennel, L. J. Lanzenrutti and E. N. Parker
9. *Dynamics of the Geomagnetically Trapped Radiation (Physics and Chemistry in Space*, Vol II)
10. *Solar Terrestrial Physics*, Ed. E. R. Dyer, D. Reidel Publishers
11. Physics and Chemistry of Solar System, John S. Lewis
12. The Sun by Michael Stix.

AS X76 CHROMOSPHERE, CORONA AND SOLAR ACTIVITY

2 Credits [20 L, 10 T/S/D]:

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, ϕ-w diagram, effect of solar cycle on solar oscillations.

Books: See AS X75

AS X77 INSTRUMENTATION FOR SOLAR STUDIES

1 Credit [10 L, 5 T/S/D]:

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

Books: See AS X75

AS X78 LABORATORY FOR SOLAR STUDIES

1 Credit:

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: See AS X75

AS X79 PLANETARY PHYSICS AND DYNAMICS

2 Credits [20 L, 10 T/S/D]:

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

Books: See AS X75

AS X80 PHYSICS OF INTERPLANETARY PHENOMENA

2 Credits [20 L, 10 T/S/D]:

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.

Books: See AS X75

AS X81 INSTRUMENTATION FOR SOLAR SYSTEM

1 Credit [10 L, 5 T/S/D]:

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.

Books: See AS X75

AS X82 LABORATORY WORK FOR INTERPLANETARY SYSTEM

1 Credit:

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: See AS X75

AS X83 ROCKET MOTION

2 Credits [20 L, 10 T/S/D]:

Characteristics of propellants, standard atmosphere, principal aerodynamic forces, coordinate systems, general equations of motion, vertical lift-off dynamics under wind and malalignment of thrust, multistaging, 2-d motion of a launch vehicle up to a specified height, computation of launch vehicle motion.

Books: AS X84.

AS X84 ORBITAL MANEUVERS AND INTERPLANETARY MOTION

3 Credits [30 L, 15 T/S/D]:

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.

Books:

1. *Orbital Methods in Astrodynamics,* P. R. Escobal, John Wiley
2. *Fundmentals of Astrodynamics,* R. R. Bates et al, Dover
3. *Orbital Motion,* A. E. Roy, Adam Hinglar Ltd
4. *Design of Orbital Flights,* J. Johnson et al., McGraw Hill

AS X85 GALACTIC MOTIONS

1 Credit [10 L, 5 T/S/D]:

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 a velocity of a star, general characteristics.

Books: See AS X84

AS X86 SIMULATION OF MOTION OF SPACE BODIES

1 Credit [10 L, 5 T/S/D]:

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

Books: See AS X84

AS X90 SPACE SCIENCE I

2 Credit [20 L, 10 T/S/D]: SPACE DYNAMICS

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.

Books:

1. *Orbital Mechanics*, Ed. Vladimir A, Chobotov, AIAA Edn Series
2. *Introduction to Celestial Mechanics*, S. W. McCusky, Addison-Wesley
3. *Fundamentals of Astrodynamics*, R. R. Bates et al, Dover
4. *Orbital Motion*, A. E. Roy, Adam Hinglar Ltd

1 Credit [10 L, 5 T/S/D]: SOLAR PHYSICS I

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.

Books:

5. *Electrodynamics*, J. D. Jackson
6. *Solar System Astrophysics*, J. C. Brandt and P. W. Hodge
7. *Introduction to Experimental Physics*, W. B. Fretter.
8. *The Magnetic Field of the Earth*, Roland T. Merrill, Michael W. McElhinny, Phillip L. Mcfadden, Academic Press
9. *Physics of Geomagnetic Phenomena*, Vol. I and II, S. Matsushita. and W. H. Campbell, Academic Press
10. *Earth's Magnetospheric Process*, Ed. B. M. McCormac, D. Reidel Publishers
11. *Physics of the Magnetosphere*, Eds. R. L. Corovillano, J. T. McCaulley and H. Radosky, D. Reidel Publishers
12. *Solar System Plasma Physics*, Vol. I, II and III, Eds. C. F. Kennel, L. J. Lanzenrutti and E. N. Parker
13. *Dynamics of the Geomagnetically Trapped Radiation (Physics and Chemistry in Space*, Vol II)
10. *Solar Terrestrial Physics*, Ed. E. R. Dyer, D. Reidel Publishers

2 Credit [20 L, 10 T/S/D]: SPACE PLASMA I

The ionospheric layers D,E,F, and their formation, effect of radiation on earth's atmosphere, photochemical processes, techniques of ionosphere measurements, ionosonde, coherent, incoherent and partial reflection radars, ionospheric scintillations.

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.

Books:

1. *An Introduction to Ionosphere and Magnetosphere*, J. A. Raticliffe
2. *Solar System Astrophysics*, J. C. Brandft and P. W. Hodge
3. *Plasma Diagnostic Techniques*, R. H. Huddlestone and S. L. Leonard
4. *Introduction to Experimental Physics*, W. B. Fretter
5. *High Vacuum Techniques*, J. Yarwood

6. *Plasma Diagnostics*, Vol. I, O. Anciello and D. L. Flamn
7. *The Earth's Ionosphere: Plasma Physics and Electrodynamics*, Michael C. Kelley, Academic Press
8. *Ionospheric Techniques and Phenomena*, A. Giraud and M. Petit, D. Reidel Publishers
9. *Physics of Geomagnetic Phenomena*, Vol. I and II, S. Matsushita and W. H. Campbell, Academic Press
10. *Introduction to Ionospheric Physics*, H. Risbeth and H. Garriot, Academic Press

AS X91 SPACE SCIENCE II

1 Credit [10 L, 5 T/S/D]: ROCKET MOTION
Characteristics of propellants, standard atmosphere, principal aerodynamic forces, coordinate systems, general equations of motion, multistaging, 2-d motion of a launch vehicle up to a specified height, computation of launch vehicle motion.
Books
Free flight of a rocket By Gantmaker

2 Credit [20 L, 10T/S/D]: SOLAR PHYSICS II
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.
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.

Books:
Same as in solar physics I

2 Credit [20 L,10 T/S/D]: SPACE PLASMA II
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.

Books:
Same as in space Plasma I

AS X92 ATMOSPHERIC SCIENCE-I

5 Credits

Atmosphere and its composition, layering, Troposphere, Stratosphere, Vertical variation of temperature, Ozone and its spatial and temporal variation, Measurement of Ozone Density, Ozone hole Temperature, pressure and wind distribution in the atmosphere, General Circulation

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.

Global Climatology: The mean Temperature distribution over the Globe, Annual Mean Sea Level Pressure Pattern, Seasonal variation of global Pressure, Global distribution of the Surface Wind Flows, Upper Air Climatology, Global distribution of the Precipitation(

Tropical Climatology: Monsoon and Tropical Cyclones

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.

Meteorological instruments (Conventional and Modern) Barometers- Fortin and Kew Pattern, Barograph, Thermometers: Dry Bulb, wet Bulb, Maximum, Minimum, Thermister, Hygrister, Radiosonde, Ozone sonde, Pyroheliometer, Pyregeometer, Weather Radar,

Atmospheric Thermodynamics: The Gas Laws, Boyles Law ,Charles' Law, The Equation of State of an Ideal Gas. Mixture of Gases. The First Law of Thermodynamics, Specific heat, Adiabatic processes, Entropy and the second law of thermodynamics, Thermodynamics of water vapor. Moisture Parameters, Vapor Pressure, Equation of State of Moist Air, Clausius Clapyeron Equation. Hydrostatic equation and geopotential, Dry adiabatic Lapse Rate, Saturated adiabatic and Pseudoadiabatic Processes The Saturated Adiabatic Lapse Rate, Equivalent potential temperature, equivalent temperature and wet bulb potential temperature, Lifting Condensation Level (LCL),Convective Condensation Level (CCL): Level of free convection (LFC): Equilibrium level (EL): Thermodynamic diagrams, Stability categories, conditional instability, Computation of Different types of Instabilities, CAPE, CINE

Radiative transfer Radiative Transfer in the Atmosphere- Temperature of the Sun and spectral distribution of solar radiation, long wave radiation, black body radiation budget of radiation energy.

Books:

1. *An Introduction to Meteorology*, S. Petterssen
2 *Elementary Meteorology*, S. Petterssen
3. *Introduction to Theoretical Meteorology*, S. Hess
4. *Atmospheric Science - An Introductory Survey*, J. M. Wallace and P. V. Hobbs
14. *Atmospheric Physics*, J. V. Iribrine and H. R. Cho
15. *An Introduction to Atmospheric Thermodynamics*, A. A. Tsonis
7. The Physics of Atmosphere, John Houghton
8. *Atmospheric Circulation Systems*: E. Palmen and Newton
9. *Monsoons*: P. K. Das, NBT
10. *Monsoons (WMO lectures)*, P. K. Das
11. *Southwest Monsoon (IMD Met Monograph)*: Y. P. Rao
12. *Physical Climatology*, W. D. Sellers
13. *World Climatology*, John G. Lockwood
14. *Climate of the Continents*, W. C. Kendrew

15. *Foundation of Climatology*, E. T. Stringer
16. *An Introduction to Climate*, G. T. Trewartha
17. *Tropical Meteorology*, Herbert Riehl
18. *Tropical Meteorology*, Vol I, II and III G. C. Asnani
19. *Lecture Notes on Satellite Meteorology*, Vol 1 and 2, SAC, Ahmedabad
20. Satellite Meteorology by R.R. Kelkar

AS X93 ATMOSPHERIC SCIENCE-II

5 Credits

Cloud Micro Physics : Cloud morphology, atmospheric aerosols, cloud condensation nuclei. Warm cloud microphysics, cold cloud microphysics. Weather Modification experiments:

Atmospheric Electricity 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.

Atmospheric Dynamics: Total Differentiation, Rotating Coordinate Frame
Fundamental Forces: Pressure Gradient force, The gravitational force
Viscous Force. Momentum equation in Rotating Coordinates
The Equation of motion in Spherical Coordinates, Coriolis force
Pressure Gradient Force, Gravity, Friction. Scale Analysis. The Equation of Continuity, Isobaric Coordinate: Transformation relation, The equation of motion in the p – System, Equation of continuity in isobaric coordinates, Natural coordinate system and horizontal momentum equations, Geostrophic Flow, Inertial Flow, Cyclostrophic Flow, Gradient Flow, trajectory and streamline, Geopotential, Thermal wind Vertical shear of geostrophic wind, barotropic atmosphere and baroclinic Atmosphere, vertical motion, Circulation, Vorticity and Divergence, Vorticity Equation.

General Circulation and Atmospheric Energetics: General Circulation, Conservation of Kinetic Energy and Angular Momentum, Total Potential Energy and Concept of available potential energy

Atmospheric Chemistry 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. Tropospheric chemical cycles: carbon cycle, nitrogen cycle, sulphur cycle.

Methods of determining past climates: Tree ring analysis, ice core analysis etc.
Climate Change (Long Term (orbital variations), Short Term (feedback mechanisms)

Books:

1. *Atmospheric Science - An Introductory Survey*, J. M. Wallace and P. V. Hobbs
2. *Atmospheric Physics*, J. V. Iribrine and H. R. Cho
3. *Introduction to Dynamic Meteorology*, J. R. Holton, (1st, 2nd and 3rd Editions)
4. The Physics of Atmosphere, John Houghton
5. *Atmospheric Circulation Systems*: E. Palmen and Newton
6. *Lecture Notes on Satellite Meteorology*, Vol 1 and 2, SAC, Ahmedabad
7. *Satellite Meteorology*, S. Q. Kidder and T. H. Von der Haar, Academic Press, 1995
8. *.Satellite Meteorology, R.R. Kelkar, BS Publications, 2006*
9. *Cloud Physics*, R. R. Rogers
10. *Cloud Dynamics*, Robert A. Houze

11. *Lightning*, M. A. Uman
12. *The Electrical Nature of Storms*, McGorman and Rust
13. *The Earth's Electrical Environment*, National Academy Press, USA
14. *Atmospheric Electrodynamics*, H. Volland
15. *Introduction to Atmospheric Chemistry*, P. V. Hobbs
16 *Chemistry of Atmospheres*, Richard P. Wayne.
17. ` A short Course in Dynamic Meteorology by N. Pandarinath

AS X94 LABORATORY FOR SPACE SCIENCE I

Credits (Only Five experiments)

1. Computation of orbits from experimental data
2. 2-D simulation of a satellite motion
3. Estimation of abundance of sodium in solar atmosphere using Fraunhofer absorption lines in solar spectrum.
4. Study of sunspot cycle and its period using internet data.
5. Magnetic pulsation experiments.
6. Fluxgate and proton precession magnetometers and their use in measuring the daily variations, absolute value measurements, etc.

AS X95 LABORATORY FOR SPACE SCIENCE II

2.5 credits (only five experiments)

1. Simulation of a two stage motion
2. Determination of extinction coefficient of earth's atmosphere using Beer's law with the help of given data.
3. Drawing trajectories (synchrones and syndynes of dust particles emitted from the comet.
4. Identifying magnetic storms and their different phases, correlating them with geomagnetic indices of electric field phases.
5. Analysis of whistler data
6. Analysis of magnetic data, separation of internal and external parts.

AS X96 LABORATORY FOR ATMOSPHERIC SCIENCE I

2.5 Credits (only five experiments)

1. Plotting and analysis of T-Φ grams, estimation of LCL, CCL, LFC, EL, height of the base and top of the cloud and precipitable water.
2. Analysis of vertical section and vertical time section.
3. Analysis of surface and upper air/ pilot charts of typical synoptic situation: western disturbances
4. Analysis of surface and upper air/ pilot charts of typical synoptic situation: monsoon situation
5. Analysis of surface and upper air/ pilot charts of typical synoptic situation: tropical cyclone
6. Construction of Wind Rose

AS X96 LABORATORY FOR ATMOSPHERIC SCIENCE II

2.5 Credits (only five experiments)

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