University College of Science, Osmania University

THE SYLLABUS FOR M. Sc. ASTRONOMY SEMESTER-WISE COURSE

Scheme of Instruction and Examination (w. e. f. the academic year 2023-2024)

Proposed Choice Based Credit System – (CBCS)

1. This course will be of four semester duration open to first and second class B.Sc.'s with Physics and Mathematics as two optional.
2. Admission will be based on merit in the Entrance Test in Physics conducted by the University.
3. Semester wise theory and practical courses to be taken during the four semesters of M.Sc. is listed below:

Scheme of Instruction and Examination

SEMESTER -I

S. No.	Sub. Code	Subject	Instructions Hrs/Week	Duration of Exam	Max. Marks	Credits
1	AS 101	Basic Physics	3	3	50 + 50	3
2	AS 102	Mathematical Methods of Physics	3	3	50 + 50	3
3	AS 103	Basic Astronomy	3	3	50 + 50	3
4	AS 104	Classical (Celestial) Mechanics	3	3	50 + 50	3
PRACTICALS						
5	AS Pr 151	Numerical Methods and Computer Applications using Python	8+8	3	100	4
6	AS Pr 152	Data Handling using GNU plot and Astronomical Distance Estimation Techniques	8+8	3	100	4
		Total:	**44**		**600**	**20**

Theory Paper AS-10l: Basic Physics

Unit – I : Electromagnetic Theory

Maxwell's Equations and their derivations and integral forms. Scalar and Vector potentials, Coulomb and Lorentz gauge. Electromagnetic waves. Poynting Theorem.

Unit – II : Transformations

Canonical transformations, Conditions for canonical transformation and problem, Poisson brackets, invariance of PB under canonical transformation, Rotating frames of reference, inertial forces in rotating frames.

Unit – III : Statistical Mechanics

Entropy and Probability, Ensembles, Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac statistics. Fermi energy, Mean energy of fermions at absolute zero, Fermi energy as a function of temperature, Electronic specific heat, Bose-Einstein Condensation

Unit – IV : Special Theory of Relativity

Concept of Special Theory of Relativity, Lorentz Transformation, Length Contraction and time dilation, Relativistic addition of velocities, relation between energy and momentum

Unit – V: Applications of Relativity

Concept of General Theory of Relativity, Equivalence of mass and energy, Relativistic Doppler shift and aberration of light. Lagrangian and Hamiltonian of relativistic particles, Relativistic degenerate electron gas.

REFERENCES

1. Introduction to Electrodynamics by David Griffiths.
2. Foundations of Electromagnetic Theory by J R Reitz and F J Milford.
3. Classical Mechanics by H. Goldstein, Narosa Publishing Home, New Delhi.
4. Classical Mechanics by N. C. Rana and P. S. Joag, Tata Mc-Graw Hill Publishing Company Limited, New Delhi.
5. Introduction to Classical Mechanics by R. G. Takawale and P. S. Puranik, Tata Mc-GrawHill Publishing, Company Limited, New Delhi.
6. Classical Mechanics by J. C. Upadhyaya, Himalaya Publishing House.
7. Statistical Mechanics by K. Huang, John Willey & Sons (2nd Edition).
8. Statistical Mechanics by Satya Prakash, KedarNath Ram Nath Publication (2008).
9. Statistical Mechanics by Loknathan and Gambhir.
10. Statistical Mechanics by Landau and Liftsiftz.
11. Special Theory of relativity by Resnik.
12. The Lighter side of Gravity by J. V. Narlikar.

Theory Paper AS-102: Mathematical Methods of Physics

Unit – I : Ordinary differential equations

Second order homogeneous and non-homogeneous differential equations with constant and variable coefficients, The Superposition Principle. Solution by power series method due to Frobenius method. Solutions of Legender's and Bessel's differential equations.

Unit – II : Partial differential equations

Solutions by the method of separation of variables. Wave equation in one and two dimensions, Poisson's and Laplace's equations, Heat Conduction (or Diffusion) equation and their solutions. Solution of Euler's differential equation, Riccati equation.

Unit – III : Special functions

The Hermite Polynomials, One-dimensional Linear Harmonic Oscillator, Solution of Hermite's Differential Equation, Gamma, Beta, Legendre and Associated Legendre, Bessel functions of the first kind and their properties.

Unit – IV : Fourier Series

Definition of Fourier Series and expansion of a functions of x. Extension of interval. Advantages of Fourier series. Complex form of Fourier series.

Unit – V : Fourier Transforms

Fourier's integrals. Fourier transform and their inverse. Transforms of Derivatives, Parseval's relation. Use of Fourier transform in solving some definite integrals.

REFERENCES

1. Shepley and Ross: Differential Equations.
2. Piper and Harvill: Applied Mathematics for Engineers and Physicists.
3. J. Irving and Mullineus: Mathematics in Physics and Engineering.
4. V. I. Awmianoc translated by D. E. Brown: A course of Higher Mathematics Vol. IV.
5. I. N. Sneddon: Fourier series.
6. Charlie Harper: Introduction to Mathematical Physics.

Theory Paper AS-103: Basic Astronomy

Unit - I: Positional Astronomy

Identification of the objects visible in the night sky to the unaided eye: constellations and nomenclature of stars. The cardinal points and circles on the celestial sphere. Spherical triangle and related problems.

Sky coordinates and motions: Horizontal, Equatorial, ecliptic and galactic system of co-ordinates.

Unit – II: Astronomical Systems of Measurements

Seasons, Twilight, Sidereal, Apparent and Mean solar time and their relations, Equation of time, Calendar, Julian date and heliocentric correction. Effects of atmospheric refraction, aberration, parallax, precession, nutation and proper motion on the coordinates of stars.

Unit – III: Distances and Magnitudes

Distances of stars, stellar motions, parallax methods to measure distances to stars. Magnitude systems. Apparent and Absolute magnitudes and distance modulus. colour index. Atmospheric extinction.

Unit – IV: The Sun and its features

Origin of Universe-the Big Bang-Expansion of Universe, Formation and evolution of solar system. The Sun, Surface features of the sun in white and monochromatic light. Internal structure. Sun spots and magnetic fields on the sun. Solar activity.

Unit – V: Planetary physics

Planets: Their types - planet atmospheres - extra solar planets - Surface features of planets, Internal structure, Atmospheres and Magnetic fields of Planets and their moons. Results of space probes.
Minor Planets: Discovery and designation, Origin, Nature and orbits of Asteroids, Comets, Meteors,and meteor showers.

REFERENCES

1. W. M. Smart: Text book of Spherical Astronomy.
2. A. E. Roy: Orbital Motion.
3. Mc Cusky: Introduction to Celestial Mechanics.
4. K. D. Abhyankar: Astrophysics: Stars and Galaxies. Tata McGraw Hill Publication (Chap.2)
5. G. Abell: Exploration of the Universe.
6. A. Unsold: New Cosmos.
7. BaidyanathBasu: An Introduction to Astrophysics
8. An Introduction to Astrophysics by Ajit Kumar Sharma.
9. The Sun by M.Stix
10. Fundamental Astronomy by H.Karttunen, H.Oja and K.J.Donner.

Theory Paper AS-104: Classical (Celestial) Mechanics

Unit – I : The Two-Body Problem

Motion in a Central Force Field. Motion in an inverse square law force field. Kepler's Laws. Formulation of the two-body problem. Integrals of area, angular momentum, and energy. Equation of the relative orbit and its solution. Kepler's equation and its solution.

Unit – II: The Three-Body Problem

The Three-Body Problem – its equations of motion. Restricted three-body problem. Tisserand's criterion. Lagrange's solution for the motion of three bodies. Surfaces of zero relative velocity, Lagrangian points. Double points.

Unit – III: The Many-Body Problem

The Equations of Motion in the Many-body Problem. Stability of straight line and equilateral triangle solutions. The ten integrals of motion of the n-body problem. Transfer of origin to one of the particles. The perturbing function. Virial theorem.

Unit – IV: The Lagrangianand Hamiltonian Formulation

Lagrangian& Hamiltonian formulation of Mechanics. Equations of motion in Lagrangian formulation. Mechanics of a particle in Lagrangian formulation. Equations of motion of two-body problems and three body problem in Lagrangian formulation. Cyclic or ignorable coordinates. Contact transformation, Hamilton-Jacobi partial differential equation.

Unit – V: Rocket Dynamics and Transfer Orbits

Fundamental equations of motion of a rocket. Motion of a rocket in a gravitational field and in an atmosphere. Step rockets. Minimum energy orbits. Transfer orbits. Parking orbits. Perturbations of artificial satellites due to atmospheric drag and flattening of the earth.

REFERENCES

1. H. Goldstein: Classical Mechanics, Narosa Publishing Home, New Delhi.
2. N. C. Rana: Classical Mechanics.
3. J.C.Upadhyaya: Classical Mechanics, Himalaya Publishing House.
4. R. G. Takwale and P. S. Puranik: Introduction to Classical Mechanics.
5. W. M. Smart: Text book of Spherical Astronomy.
6. A. E. Roy: Orbital Motion.
7. Mc Cusky: Introduction to Celestial Mechanics.
8. K. D. Abhyankar: Astrophysics of the solar system.
9. F. R. Moulton: An Introduction to Celestial Mechanics.
10. Danby: Fundamentals of Celestial Mechanics.

Practical Paper AS-151: Numerical Methods and Computer Applications using Python

Part - A

1. Methods of least squares
3. Numerical interpolation: Forward, backward, central
4. Numerical differentiation and integration Trapeziodal rule, Simpson 1/3, 3/8 rules
5. Solution of ordinary differential equations using RK methods for first to fourth order DE

Part -B

1. Operating Systems : UNIX / LINUX.
2. Editors : Word and vi
3. Programming concepts : Python
4. Numerical Analysis using Python.

Practical Paper AS-153: Data Handling using GNU plot and Astronomical Distance Estimation Techniques

Part - A

1. Plotting 2D and 3D Data
2. Polynomial and function fitting
3. Histograms, error determinations
4. Lest - Square methods and fittings
5. Correlation and Regression analysis

Part - B

1. Parallax Method
2. Main sequence method
3. Cepheids Method
4. Galaxies Red shift Method
5. Tully- Fisher relation Method

REFERENCES

1. J. B. Scarborough: Numerical Analysis.
2. R. Subramanian. P. Achutan. and K. Venkatesan (Translators): Numerical Analysis for Engineers and Physicists.
3. M. K. Jain. S. R. K. Iyengar and R. K. Jain: Numerical Methods for Scientific and Engineering Computation.
4. Python for Data Science, Alen Campbell
5. Programming Python, Mark Lutz, O'Reilly
6. Python Programming : Using problem solving approach, Reema, Thareja, Oxfor Higher Education
7. Norton’s Atlas

THE SYLLABUS FOR M. Sc. ASTRONOMY SEMESTER-WISE COURSE

Scheme of Instruction and Examination (w. e. f. the academic year 2023 - 2024)

Proposed Choice Based Credit System – (CBCS)

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Scheme of Instruction and Examination

SEMESTER -II

S. No.	Sub. Code	Subject	Instructions Hrs/Week	Duration of Exam	Max. Marks	Credits
1	AS 201	Quantum Mechanics	3	3	50 + 50	3
2	AS 202	Fluid Mechanics and Magneto Hydro Dynamics	3	3	50 + 50	3
3	AS 203	Stellar Spectroscopy & Atmosphere	3	3	50 + 50	3
4	AS 204	Stellar Structure & Evolution	3	3	50 + 50	3
PRACTICALS						
5	AS Pr 251	Photometry and Spectroscopy using IRAF	8+8	3	100	4
6	AS Pr 252	Practical Astronomy and Astronomical Data Analysis using software applications	8+8	3	100	4
		Total:	**44**		**600**	**20**

Theory Paper AS-201: Quantum Mechanics

Unit -I: Foundation of Quantum Mechanics

Schrodinger wave equation and probability interpretation, Simple one dimensional problems – wells, barriers and harmonic oscillator (One and three dimensional), Time dependent Schrodinger equation and problems.

Unit-II: General Formalism of Quantum Mechanics

Physical interpretation of eigen values, eigen functions, eigen values, and eigen functions of momentum operator. Eigen values and eigen functions of L^2 and $L_z$operators, ladder operators L_+ and L_- and their operations.

Unit-III: Spin and Momentum operators

Pauli theory of spins (Pauli's matrices), Addition of angular momenta, Computation of Clebsch-Gordon co-efficients in simple cases (J_1=1/2, J_2=1/2) Central forces with an example of hydrogen atom.

Unit-IV: Approximation Theory

Time-independent Perturbation theory: Non degenerate and degenerate cases. Applications: Zeeman effect, Stark effect, Time-dependent Perturbation theory: Transition amplitude 1st and 2nd order, selection, rules, constant perturbation (1st order). Fermi's golden rule, Interaction of atom with EM radiation, dipole approx, Einstein coefficient for emissions and transition probabilities.

Unit-V: Scattering

Absorption cross-section, Differential and total cross sections, Thomson and Rayleigh scattering, Mie Scattering, Born approximation, Validity of Born Approx., Application to square well potential.

REFERENCES

1. An overview of Basic Theoretical Astrophysics by K D Abhyankar and AW Joshi, Universities Press.
2. A Text book of Quantum Mechanics by P. M. Mathews and K.Venkatesan, Tata McGraw Hill.
3. Quantum Mechanics by A. Ghatak and S. Lokanathan, Macmillan India Ltd.
4. Quantum Mechanics by L. I. Schiff, McGraw Hill.
5. Modern Quantum Mechanics by J. J. Sakurai.
6. Quantum Physics by R. Eisberg and R. Resnick(Wiley and Sons).
7. Introduction to quantum mechanics by D. I. Griffiths (Pearson Education)(IInd Edition).
8. Introductory Quantum mechanics by W. Granier, Springer Publication.
9. Introductory Quantum Mechanics by R. Liboff, 4th Edition, Pearson Education Ltd.

Theory Paper AS-202: Fluid Mechanics and Magnetohydrodynamics

Unit -I: Fluid Mechanics

Steady and Unsteady flows, Velocity potential, Vorticity vector, equation of continuity, acceleration of fluid, Euler's equation of motion, Bernoulli's equation, circulation and Vortex motion, Kelvin's theorem, viscosity of fluid motion, Navier Stokes equation of motion of a viscous fluid.

Unit -II: Gas Dynamics

Wave motion and its solution, speed of sound in a gas, formation of shocks, mach number, isentropic gas flows, Mach number and its dependency across the shock with pressure, density and temperature, Ram pressure, Normal shocks, Rankine -Hugoniot relations.

Unit-III: Motion of charged particles and Instabilities

Motion of charged particles in electric and magnetic field, Motion of charged particle in electromagnetic field, particle drifts in non-uniform magnetic field, Mirror effect, Adiabatic invariants.

Unit -IV: Comptonization and Instabilites

Detail study of Compton and inverse Compton effect, y-parameter, Compton spectrum Kelvin-Helmholtz instability, Rayleigh-Taylor instability.

Unit-V: Magnetohydrodynamics

Maxwell's equations (medium in motion) and its simplification, Magnetic diffusion, equation of motion of conducting fluid, fluid in motion, magnetic Reynolds number and its dimensional analysis, Alfven theorem, Magnetic body force, Magnetohydrodynamics, Pinch confinement of plasma, MHD waves and its applications.

REFERENCES

1. F. Chorlton: Textbook of Fluid Mechanics
2. Jackson: Classical theory of Radiation.
3. Oleg Glebov: Motion of Charged particles.
4. The Physics of Fluids and Plasmas: An Introduction for Astrophysicists Arnab Rai Choudhuri.
5. The physics of astrophysics gas dynamics 2 (sessions of both in Astronomy) university science books (1994) Frank Shu.

Theory Paper AS-203: Stellar Spectroscopy & Atmospheres

Unit -I: Spectra of Stars

Spectral lines and Spectral types, basic ideas on spectral line formation, HR diagram, HD and MK spectral classification of stellar spectra. Explanation of stellar spectra in terms of Boltzmann and Saha equations.

Unit -II: Qualitative description of causes of spectral line Broadening

Equivalent widths, Natural damping, Collisional damping, Superposition of Doppler and damping profiles, Statistical broadening of hydrogen lines, Stark effect in helium lines,

Electron pressure in early type stars.

Unit-III: Curve of Growth

Theory of the curve of growth, Application of the curve of growth to the study of solar and stellar atmospheres, Limitations of the curve of growth method.

Unit-IV: Equation of Transfer

Definitions concerning the radiation field, Equation of transfer and its formal solution, Hypothesis of plane parallel and spherically symmetric stratification, Local thermodynamic equilibrium, Radiative equilibrium, Grey approximation.

Unit-V: Abundances of Elements

Abundance of elements in sun and stars, Fine analysis-Stromgren's method,
Stellar atmospheric models, Composition differences in population I and II stars, Peculiar A stars and metallic line stars, Magnetic field in stars.

REFERENCES

1. L. H. Aller: Astrophysics.
2. J. Greenstein(Ed): Stellar Atmospheres.
3. Hynek: Astrophysics.
4. Mihalas: Stellar Atmospheres.
5. E. Ambartzumian: Theoretical Astrophysics.
6. K. D. Abhyankar: Astrophysics Stars and Galaxies.
7. C. R. Kitchin: Astrophysical Techniques (4^{th} edition).

Theory Paper AS-204: Stellar Structure & Evolution

Unit-I: Fundamental Equations

Stellar time scales. Equation of mass distribution. Equation of hydrostatic equilibrium. Virial Theorem. Equation of energy transport by radiative and convective processes. Equation of thermal equilibrium. Equation of state. Stellar Opacity. Eddington limit. Stellar energy sources.

Unit-II: Stellar Models

Boundary conditions (central and surface). Russell-Vogt theorem. Polytropic model. Lane-Emden equation and its solution. Properties of polytropes. Homology transformations. Dimensional analysis: Mass-Luminosity and Mass – Radius relations.

Unit-III: Stellar Evolution

Jean's criterion for gravitational contraction and its difficulties. Star forming regions. Protostars. T-Tauri stars. Brown Dwarfs. Pre-Main Sequence Evolution: Hayashi tracks and Henyey tracks.

Schoenberg-Chandrasekhar limit. Main-Sequence and Post Main Sequence Evolution of stars of different masses. Eddington Luminosity. Planetary Nebulae. Ages of galactic & globular clusters.

Unit-IV: Superdense Objects - White Dwarfs

White Dwarfs. Use of Polytropic model for completely degenerate stars. Chandrasekhar Mass. Mass-radius relation for White Dwarfs. Non-degenerate upper layers and abundance of Hydrogen. Stability of White Dwarfs. Cooling mechanism in White Dwarfs. Accretion by White Dwarfs and its consequences.

Unit -V: Superdense Objects-Neutron stars and Black Holes

Supernovae, Neutron stars, Black Holes. Pressure ionization and mass-radius relation for cold bodies. Masses of Neutron stars and Black Holes.

REFERENCES

1. M. Schwarzschild: Stellar Evolution
2. R. Kippenhahn A. Weigert: Stellar Structure and Evolution
3. Dina Prialnik: An Introduction to the Theory of Stellar Structure and Evolution
4. BaidyanathBasu: An Introduction to Astrophysics.
5. S. Chandrasekhar: Stellar Structure
6. Cox and Guili: Principles of Stellar Interiors – Vol. I & II
7. Shapiro and Tevkolsky: White Dwarfs, Neutron Stars and Black Holes
8. R. Bowers and T. Deeming: Astrophysics
9. Frank H. Shu: The Physical Universe

Practical Paper AS-251: Photometry and Spectroscopy using IRAF

Part - A

1. DS9
2. Ximtool
3. Imexamine
4. Apphot
5. Photometric data archives

Part - B

1. Twodspec
2. Apextract
3. Apall
4. Wavelength calibration
5. Splot
6. Spectroscopic data archives

Practical Paper AS-253: Practical Astronomy and Astronomical Data Analysis using Software applications

1. Basic Definations and Fundamental Concepts

2. Identification of features of Celestial sphere and Constellations

3. Determining period of rotation of the sun using virtual observatory

4. HR Diagram of star clustrs

5. Astro ImageJ / SalsaJ

6. NAAP

REFERENCES

1. Peter MB Shames, Doug Tody: A user's Introduction to the IRAF command language version 2.3
2. Frederic P. Miller Agnes F. Vandome, Mc Brewster John: IRAF, VDM Publishing, 2010.
3. Chrisphin Karthick, M: Astronomical data Reduction guide.
4. Smart: Spherical Astronomy.
5. Bowuwer and Clemence: Methods of Celestial Mechanics.
6. J. Nassau: Practical Astronomy.
7. CLEA,VIREO websites (web resources).

M.Sc., Astronomy III & IV - semester - Scheme of Instruction and Examination

SEMESTER – III

S. No.	Sub. Code	Subject	Instructions Hrs/Week	Duration of Exam	Max. Marks	Credits
1	AS 301	Astronomical Techniques	3	3	50 + 50	3
2	AS 302	Advance Astrophysics	3	3	50 + 50	3
3	AS 303	**Elective-1.** A. Astrostatistics**(OR)** B. Machine Learning and Deep Learning	3+3	3	50 + 50	3
4	AS 304	**Elective-2.** A. Electronics **(OR)** B. Radio Astronomy	3+3	3	50 + 50	3
PRACTICALS						
5	AS Pr 351	Electronics	8	3	100	4
6	AS Pr 352	Spectroscopy	4	1.5	50	2
6	AS Pr 353	Seminar	4	1.5	50	2
		Total:	**34**		**600**	**20**

SEMESTER - IV

S. No.	Sub. Code	Subject	Instructions Hrs/Week	Duration of Exam	Max. Marks	Credits
1	AS 401	Space Physics	3	3	50 + 50	3
2	AS 402	Binary stars	3	3	50 + 50	3
3	AS 403	**Elective** A. The Milky Way Galaxy & ISM **(OR)** B. Galaxies & Universe	8+8	3	50 +50	3
PRACTICALS						
5	AS Pr 451	Photometry	12 (4x3)	3	100	2
6	AS Pr 452	Sky Observations		1.5	50	2
7	AS Pr 453	Project Work	-	3	150	5
		Total:	**34**		**600**	**22**

Theory Paper AS-301: Astronomical Techniques

Unit-I: <u>Optical and IR Telescopes</u>

Basic Optics, Types of telescopes- refractive, reflective and catadioptric telescopes. Telescope mounting systems. Solar telescopes. Importance of Infrared astronomy, IR telescopes, properties of IR telescopes, Major IR missions. Active and adaptive optics.

Unit-II: <u>Space Telescopes</u>

Importance of space based astronomy. Space Telescopes. Space based instrumentation and science, Ultraviolet Fundamentals, Ultraviolet Telescopes, Major UV space Mission, X-Ray Fundamentals, X-Ray Telescopes, Major X-Ray space Mission, Astrosat (ISRO), XMM-Newton, Chandra and Swift and their scientific results. Gamma-Ray Fundamentals, Gamma-Ray Telescopes

Unit-III: Detectors

Classification of detectors, characteristics of detectors. Detectors for optical and infrared wavelength regions. Working of Charge Coupled Device (CCD). sensitivity, noise, quantum efficiency, spectral response, Johnson noise, signal to noise ratio. Application of CCD for stellar imaging. Observational techniques of astronomical sources from space in infrared, EUV, X-ray and Gamma-ray regions of the electromagnetic spectrum.

Unit-IV: Photometry and Spectroscopy

Astronomical photometry. Observing technique with a photometer. Application of CCD for photometry. Correction for atmospheric extinction. Transformation to a standard photometric system. Astronomical spectroscopy. Application of CCD for spectroscopy.

Unit-V: Radio Astronomical Techniques

Radio window. Antenna parameters. Various types of antennas -based on steerability. construction of simple radio telescopes. Receiver systems and their calibration. Design and construction of a simple radio interferometer. VLBI Systems. Aperture Synthesis.

REFERENCES

1. C. R. Kitchin: Astrophysical Techniques (4 th edition).
2. Ian S. McLean: Electronic Imaging in Astronomy: Detectors and instrumentation (2^{nd} ed.).
3. Steve B. Howell: Handbook of CCD Astronomy (2 nd edition).
4. A. E. Roy and D. Clarke: Astronomy Principles and Practice (Part-3, 4 th edition).
5. W. A. Hiltner (Ed): Astronomical Techniques.
6. Gordon Walker: Astronomical Observations - an Optical Perspective (CUP).
7. Henden and Kaitchuck: Astronomical Photometry.
8. C. R. Miczaika and W. M. Sinton: Tools of the Astronomers
9. Carleton: Methods of Experimental Physics. Vol. XIIA.
10. G. F. Knoll: Radiation Detection and Measurement (2nd edition).

Theory Paper AP-302: Advance Astrophysics

Unit-I: Fundamentals for Radiations

Jefimenkas equation, Lienard-Wiechart potentials, Field of moving point charges, electrical dipole radiation in terms of potentials, power radiated by a point charge

Unit-II: Radiative processes

Ionization losses in non-relativistic and relativistic cases, radiation of an accelerated charge, its spectral distribution, Bremmstrauhlung spectrum and its application in astrophysics, electron energy loss rate in uniform magnetic field, inverse Compton spectrum and its application in astrophysical sources, Sunyaev-Zeldovich effect, Synchroton-self Compton radiation

Unit-III: Solar Dynamo

Magnetic flux freezing, Alfven theorem of flux freezing, magnetic buoyancy, Induction equation, reconnection of magnetic lines of force, toroidal and poloidal magnetic fields, Omega effect, alpha

effect and connection to solar cycle, mean field dynamo theory, meridional flow, filaments/prominences, coronal loops, coronal mass ejections (CMEs), heating of corona, Parker solution of solar wind, effect of magnetic field on solar wind

Unit-IV: Fundamental of Stellar Oscillations

Equation of continuity, Equation of motion, Energy equation, Adiabatic approximation, Equilibrium structure, perturbation analysis, Acoustic waves, internal gravity waves, pulsation constant, P modes, g modes, f modes.

Unit-V: Helioseismology and Astroseismology

Basics of Helioseismology, Solar oscillation and different modes, stellar oscillations in different types of stars, Fundamental stellar parameters and their derivation using astroseismology

REFERENCES

1. Introduction to Electrodynamics: J. D. Griffiths, Cambridge University Press
2. *Radiative Processes* in Astrophysics: Rybicki and Lightman, Wiley interscience
3. High energy Astrophysics: M. S. Longair, , Cambridge University Press
4. Astrophysics for physicists: A. R. Choudhuri, Cambridge University Press
5. The Sun, An Introduction: Mechael, Springer-Verlag
6. Plasma Astrophysics: J.G. Kirk, D. B. Melrose, E. R. Priest, Springer-Verlag
7. Astroseismology: Aerts, Christensen-Dalsgaard, Kurtz, Springer
8. The Non-Radial *Oscillations* of Stars in General Relativity: S. *Chandrasekhar,* University of Chicago Press

Theory Paper AS-303: Elective -1A. AstroStatistics

Unit-I: Basic Statistics

Mean, Median, Mode. Standard deviation. Concepts of probability theory, discrete and continuous random variables, bivariate probability distributions. Binomial, Poisson and Gaussian distributions.

Unit-II: Regression & Hypothesis

Correlation, regression and covariance, Testing of hypothesis –null hypothesis, alternate hypothesis, types of errors, critical and acceptance regions, level of significance.

Unit-III: Sample Testing

Large sample tests for mean(s), variances. Small sample t- tests for single mean and different mean, F distribution and F-test, Chi-square distribution. Chi-square test, Chi-square test for goodness of fitting, ANOVA - one way classification.

Unit-IV: Multivariate Data Analysis

Categorical data analysis, and model building. covariance matrix, Eigen function, Eigen values, principal components classification, discriminate analysis, Fisher method, within-class scatter matrix, between-class scatter matrix.

Unit-V: Clustering Methods

clustering, cluster linkage methods, single, complete, average and centroid linkages, distance estimation, k-means method, hierarchical clustering, dendrogram.

REFERENCES

1. Statistical Methods by S P Gupta.
2. Applied Multivariate Statistical Analysis by Richard A Johnson and Dean W Wichern.
3. An Introduction to Statistical Learning, with Applications in R by James, Witten, Hastie and Tibshirani
(Springer, 2013).
4. Practical Statistics for Astronomers, Cambridge Observing Handbook for Astronomers, J V Wall.
5. Modern Statistical Methods for Astronomy: with R Applications, Eric Feigelson, G Jogesh Babu
6. Statistical Challenges in Modern Astronomy, Eds: Eric Feigelson, G Jogesh Babu.
7. Data Mining Concepts & Techniques by Jiawei Han and Micheline Kamber. (Elsevier)

Theory Paper AS-303: Elective - 1B. Machine Learning and Deep Learning

Unit-I:Basic Statistics

Normal distributions, Expectation, Moments of Distribution, and Central limit theorem, Bayes theorem, Prior, Posterior, Bayes optimal classifiers, Maximum Likelihood method

Unit-II: Supervised Learning-Regression

Linear Regression, multiple linear Regressions, K-nearest neighbors, under fitting, over fitting, Support Vector regression (SVM), Random forest method.

Unit-III: Supervised Learning-Classification

Logistic regression, Principal Component Analysis, LDA, Singular Value Decomposition, Independent Component Analysis, K nearest neighbor, support vector classifier, Gradient boosting method.

Unit-IV: Unsupervised Learning

Supervised vs Unsupervised learning, learning steps, Decision tree, linkages, Hierarchical clustering, Non- Hierarchical clustering, K-means clustering, Density Based Scan Clustering (DBSCAN), Gaussian clustering model.

Unit-V: Deep learning

Regularization, convolutional neural networks (CNN): Architectures, convolution / pooling layers, recurrent neural networks: its Architectures, Back Propagation through time, variational autoencoders, generative models, applications.

REFERENCES

1. Statistical Methods by S P Gupta.
2. Applied Multivariate Statistical Analysis by Richard A Johnson and Dean W Wichern.

3. An Introduction to Statistical Learning, with Applications in R by James, Witten, Hastie and Tibshirani
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4. Practical Statistics for Astronomers, Cambridge Observing Handbook for Astronomers, J V Wall.
5. Modern Statistical Methods for Astronomy: with R Applications, Eric Feigelson, G Jogesh Babu
6. Statistical Challenges in Modern Astronomy, Eds: Eric Feigelson, G Jogesh Babu.
7. Data Mining Concepts & Techniques by Jiawei Han and Micheline Kamber. (Elsevier)
8. Ian Goodfellow, YoshuaBengio and Aaron Courville. Deep Learning. MIT Press 2016
9. Navin Kumar Manaswi, Deep Learning with Applications using Python, Apress, NewYork, 2018.

Theory Paper AS-304: Elective - 2A. Electronics

Unit-I: Semiconductor Devices

CMOS, Transistor, Biasing of multi stage RC-coupled amplifier

Power Supply

DC voltage regulators. Concept of DC to DC converter, UPS and Inverters.

Unit-II: Feedback Amplifiers

Classification of Amplifiers. The concept of feedback, Positive and negative feedback. Advantages of negative feedback. Emitter follower.

Sinusoidal Oscillators

Criterion for oscillations, Phase shift, Wein bridge, Hartley and Colpitts oscillators, IC 555 Astable, Monostable and Bistablemultivibrator.

Unit-III: Operational Amplifiers

Inverting and Non-inverting Op-Amps. Concept of input/output impedance, Input bias current, Offset input voltage, Slew rate, CMMR, Gain, Frequency response, Band Width. IC 555, Applications of Operational Amplifiers: Active filters, rectifiers.

Unit-IV: Digital Electronics

BCD, Octal, Hexadecimal, ASCII, Signed binary number representation with 1's and 2's complement methods, Binary arithmetic, Boolean algebra, logic gates and circuits, adder / subtractor, encoder / decoder, comparator, multiplexer / de-multiplexer, parity generator, combinatorial/Sequential Circuits, Flip-Flops, Counters/Registers, A/D and D/A conversion.

Unit-V: Modulation and Detection

Amplitude modulation, Frequency components in an AM signal, Balanced amplitude modulator, Envelope and Square law detectors. Frequency modulation, Frequency components in FM signal, Basic Reactance modulator, FM discriminator. Phase modulation. Introduction to Digital modulation and demodulation techniques.

REFERENCES

1. Power Supplies by B. S. Sonde.
2. Operational Amplifiers by G. B. Clayton (5th edition) Newnes.
3. Operational Amplifiers Applications by G. B. Clayton.
4. Integrated Electronics by Millman and Hallkias.
5. Pulse Digital & Switching Waveforms by Millman and Taub.
6. Microelectronics by Millman&Grabel.
7. Fundamentals of electronics by J. D. Ryder.
8. Electronic Communication System by Kennedy.

Theory Paper AS-304: Elective - 2B. Radio Astronomy

Unit-I: Radio Astronomy Fundamentals

Radio window of electromagnetic spectrum, nature of radio signal, Brightness, brightness temperature and antenna temperatures, sensitivity, brightness distribution, discrete radio sources of thermal and non thermal radiation, radiative transfer, flux density, Nyquist theorem and the noise temperature.

Unit-II: Theories of Generation of Radio Waves

Bremstrahlung, gyro-synchrotron radiation, Plasma radiation, propagation of radio waves in ionized gases, Wave Polarization, polarization ellipse and Poincare sphere, Stoke's parameters, Faraday rotation.

Unit-III: Solar Radio astronomy

Quiet Sun radiation, slowly varying component, Solar radio bursts on centimetre and decimetre meter wavelength, Solar radio bursts on meter wavelength (type I, II, III, IV & V) bursts and their association with flares.

Unit-IV: Galactic Radio Astronomy

Galactic disk radio component, HII regions and supernovae remnants, 21-cm hydrogen line, CO and OH line radiations. Spiral structure of the galaxy, pulsars and energy losses.

Unit-V: Extragalactic Radio Astronomy

Cosmic microwave background radiation (CMBR), radio galaxies, radio quite and radio loud galaxies, spectral classifications, active galactic nuclei, Type I and II classifications, broad line and narrow line regions, QSO's, The unified model of Quasars

REFERENCES

1. J. D. Kraus: Radio Astronomy.
2. Mukul R. Kundu: Solar Radio Astronomy
3. Bernard F. Burke and F. Graham-Smith: An introduction to Radio Astronomy (3rd edition)
4. Alan Sandage and others: Galaxies and the Universe
5. Thomas L. Wilson, Kristen Rohlfs, Susanne Huttemeister: Tools of Radio Astronomy (5th Edition)
6. Jeff Lashley: The Radio Sky and How to Observe It.

Practical Paper AS-351: Electronics

1. Regulated Power Supply

2. RC Coupled Amplifier

3. Experiments on OPAMP

4. Experiments on Multi-vibrators

5. Experiments on Oscillators

Practical Paper AS-352: Spectroscopy

1. Knowing and Understanding a spectra

2. Classification, measurement of equivalent width and distance of stellar spectra using virtual observatory

3. Plotting and measuring spectra.

4. Determining orbital elements of spectroscopic binary from radial velocity curve.

Practical Paper AS-353: Seminar

REFERENCES

1. An Altas of Stellar spectra by Morgan, Keenan and Kellman.
2. Clea Software Manual, Department of Physics, Gettysburg College, Gettysburg.
3. C. R. Kitchin: Astrophysical Techniques (4 th edition).

Theory Paper AS-401: Space Physics

Unit-I: Introduction to Earth's Atmosphere

Origin and Composition of the atmosphere, Different Atmospheric Layers: Temperature, Pressure, and Density Distribution with height, Hydrostatic Equation, Greenhouse Gases and Effective temperature of the Earth, Atmospheric Aerosols: Concentration and Size distribution, Production and Removal mechanism. Comparative study of atmospheric properties of Venus and Mars

Unit-II: The Earth's Middle and Upper Atmosphere

Composition and structure of Stratosphere and Mesosphere, Stratospheric ozone chemistry, Formation and structure of the ionosphere, studies of ionosphere by ground and space based techniques, D, E and F region irregularities, Ionization and energy exchange processes. Exosphere.

Unit-III: Solar Radiation

Spectral distribution of solar radiation, Spectrum of Radiation, Radiation law's, Absorption and scattering of solar radiation, Estimation of Solar Irradiance at the upper Atmosphere, Rayleigh and Mie scattering

Unit-IV: Solar Wind

Solar wind: Fast and slow solar wind, Observations of solar wind, Interplanetary magnetic field, Solar wind and its interaction with planetary atmosphere, Variation of solar wind with solar activity, solar wind at heliopause.

Unit-V: Solar Terrestrial Relationship

Short and long term variability of solar constant, planetary magnetosphere, Structure of the bow shocks, Geomagnetic storm, sub-storms, Magnetic reconnection processes, radiation belts, Aurorae.

REFERENCES

1. J. A. Rateliffe: An Introduction to the Ionosphere and Magnetosphere.
2. Kaula. W.M: An Introduction to Planetary Physics.
3. Harold Zirin: Astrophysics of the Sun.
4. A. Chandrasekar: Basics of Atmospheric Science
5. The Earth's Ionosphere Plasma Physics and Electrodynamics by Michael C. Kelley
6. V. Bedmtay and Kleczek: Basic Mechanism of Solar Activity
7. Michael D. Papagiannis: Space Physics and Space Astronomy

Theory Paper AS-402: Binary Stars

Unit -I: Visual and spectroscopic binaries

Introduction to binary stars. Binary types and their classification. Method of observing visual binaries and their orbital elements. Single and double-lined spectroscopic binaries. Method of observing Spectroscopic binaries, Geometry of a spectroscopic binary. Radial velocity curve and its important features. Importance of binary stars in determining the stellar masses.

Unit -II: Eclipsing Binaries

Definition of eclipsing binaries. Method of observing eclipsing binaries. Types of light curves of eclipsing binaries. Classification of eclipsing binaries. Outline of various methods of solving eclipsing binary light curves. W UMa - Definition, properties, period changes, models and evolution. Information obtained from the studies of eclipsing binary light curves.

Unit-III: Other Close Binaries

Astrometric binaries, Algols- Definition, paradox, properties, period changes, models and evolution. RS CVn's- Definition, properties, period changes, models and evolution. White Dwarf binaries - Definition, classifications viz. polars, Intermediate polars and cataclysmic variables.

Unit-IV: X-ray binaries

Accretion disk, Shakura-Sunyev disk, its spectrum. X-ray binaries - Definition, LMXB and HMXB. Neutron star X-ray binaries. Classification viz. atoll and Z sources. Black hole X-ray binaries, classification based on X-ray spectrum.

Unit-V: Exoplanets Detection techniques

Introduction to exoplanets, Exoplanet History and Planetary Orbits. Detecting planets via astrometry, direct imaging, microlensing, radial velocities, transits, Exoplanet Atmospheres and Interiors.

REFERENCES

1. L. Binnendijk: Properties of Double Stars.
2. F. B.Wood and J.Sahade: Interacting Binary Stars.
3. Z. Kopal: Close Binary Systems.
4. Pringle and Wade: Interacting Binary Stars.

5. K. D. Abhyankar: Astrophysics-Stars and Galaxies (Chap.6) Tata McGraw Hill.
6. The Exoplanet Handbook, 2nd Ed., by Michael Perryman , 2018 (CUP).
7. Transiting Exoplanets, by Carole Haswell (2010; Cambridge University Press)
8. Z. Kopal: Dynamics of Close Binary Systems.
9. Bowers and Deeming: Astrophysics. Vol.1 & 2.
10. Accretion power in Astrophysics: Frank, King and Raine, (CUP).

Theory Paper AS-403: Elective – 1A. The Milky Way Galaxy & Interstellar Matter

Unit-I: The Milky Way Galaxy

The structure, size using optical and radio observations. mass of the milky way Galaxy and their determinations. Stellar populations in the Milky Way. Distribution of Gas in the Milky Way. Interstellar reddening law. 21-cm line observations. Interstellar magnetic fields in the Milky Way.

Unit-II: Stellar Motions

Standards of Rest – the Fundamental Standard of Rest and the Local Standard of Rest. Solar motion and its determination. Motion of stars in spiral galaxies. Oort's theory of galactic rotation. Determination of Oort's constants. Peculiar velocities.

Unit-III: Spiral Wave Kinematics

Motion of stars near the centre of the Milky Way. Inference of the presence of super massive black hole at the centre. Rotational curve and its interpretation. Dark Matter. Gravitational lensing

Unit-IV: Structure & contents of the Milky Way Galaxy

Star forming regions in the Milky Way. Distribution of X-ray and Gamma ray sources in the Milky Way. Emission mechanisms associated with high energy emissions. Importance of multi-wavelength studies of the Milky Way.

Unit-V: Models for Milky ways

Mathematical models of the Milky way: Uniform sphere model, Isothermal sphere, Plummer's and Hernquist model, Jaffe's model, velocities of bodies, Disk models viz. Exponential and Kepler's disk model

REFERENCES

1. James Binney: Galactic Astronomy: Structure and Kinematics of Galaxies
2. Elmegreen: Galaxies & Galactic Structure. Prentice Hall 1998.
3. Sparke and Gallagher: Galaxies in the Universe.
4. Frank Shu: The Physical Universe. A. Unsold: The New Cosmos (3rd Edition). Springer-Verlag 1983.
5. Mihalas and J. Binney: Galactic Astronomy. W. H. Freeman 1981.
6. K. D. Abhyankar: Astrophysics - Stars and Galaxies. Tata McGraw Hill Publication.
7. L. Spitzer: Physical Processes in the Interstellar Medium. John Wiley 1978.
8. M. Sandage and J. Kristian: (Ed.) Galaxies and the Universe, Cambridge Univ. Press.
9. Bowers and Deeming: Astrophysics Vols.1 and 2.
10. BaidyanathBasu: Introduction to Astrophysics.

Theory Paper AS-403: Elective – 1B. Galaxies and Universe

Unit-I: Fundamental concept

Introduction - What are galaxies? The Universe of galaxies and their discovery, properties of Milky way, Various catalogues and data sources. Classification of galaxies – Hubble's Morphological Classification, de Vaucouleur Classification, The Yerkes (or Morgan) scheme, DDO system. Masses

and sizes of galaxies and the techniques of determining them. Methods of determining extra-galactic distances. Integrated galaxy light, Reddening, K correction.

Unit-II: Profiles of Galaxies

Differential galaxy light, Azimuthal profiles of Ellipticals and Spirals, Isophotal twists in Ellipticals and Spirals. Radial profiles for Spirals and Barred Spirals. Distribution of gas in galaxies. Radiation from neutral atomic, molecular and ionised gas. Total gas mass in a galaxy. Radial gas density profiles.

Unit-III: Dynamical aspects of galaxies

Stellar motion in elliptical and spiral galaxies. Doppler-shift motions in spiral disks, rotational curves, Tully-Fisher relation. Mass distribution in disk galaxies. Early-type galaxy rotations and velocity dispersions. The fundamental plane of Elliptical galaxies. Masses of early-type galaxies.

Unit-IV: Star formation in galaxies

Star formation rates. Complexes and propagating star formation. Starburst galaxies, Star formation in Interacting galaxies. Active Galaxies. Seyferts, Radio galaxies and Quasars. The unified model of Quasars, Importance of multi-wavelength studies of galaxies.

Unit-V: Cosmology

Expansion of the universe. Interpretation of the red-shift. CMBR. Fundamentals of cosmology, Friedmann equations and solutions - the Big Bang & the Steady State models.

REFERENCES

1. Elmegreen: Galaxies & Galactic Structure. Prentice Hall 1998.
2. Sparke and Gallagher: Galaxies in the Universe.
3. Frank Shu: The Physical Universe.
4. A. Unsold: The New Cosmos (3rd Edition). Springer-Verlag 1983.
5. Mihalas and J.Binney: Galactic Astronomy. W. H. Freeman 1981.
6. K. D.Abhyankar: Astrophysics - Stars and Galaxies. Tata McGraw Hill Publication.
7. L. Spitzer: Physical Processes in the Interstellar Medium. John Wiley 1978.
8. M. Sandage and J. Kristian: (Ed.) Galaxies and the Universe. University of Chicago Press.
9. Bowers and Deeming: Astrophysics Vols.1 and 2.
10. BaidyanathBasu: Introduction to Astrophysics. Prentice Hall of India, 2004.
11. Jayant Narlikar: Introduction to Cosmology. Jones & Bartlett Publishers, Inc, 1998.

Practical Paper AS-451: Photometry

1. Determination of atmospheric extinction -method-I.
2. Determination of atmospheric extinction -method-II.
3. Photometric standardization
4. Light curve of variables

Practical Paper AS-452: Sky Observation

1. Identification and evolution of celestial sphere with naked eye observations.

2. Identification, imaging and study of celestial objects using 12 inch Meade telescope

Practical Paper AS-452: Project Work

REFERENCES

1. C.R.Kitchin: Astrophysical Techniques (4th edition).
2. W. A. Hiltner (Ed): Astronomical Techniques.
3. Steve B. Howell: Handbook of CCD Astronomy (2nd edition).

University College of Science, Osmania University

THE SYLLABUS FOR M. Sc., ASTROPHYSICS SEMESTER WISE COURSE

Scheme of Instruction and Examination (w. e. f. the academic year 2019-2020)

Proposed Choice Based Credit System – (CBCS)

1. This course will be of 4 Semester duration opened to First and Second class B.Sc.'s with Physics and Mathematics as two optional.
2. Admission will be based on merit in the entrance test in Physics conducted by the University.
3. The syllabus for both Theory and Practical courses in I and II Semesters is common for M.Sc. Astrophysics and M.Sc. Physics courses. Hence the theory and practical classes of I and II Semester will be held in the Physics Department, O.U. along with M.Sc. Physics students. The Theory and Practical courses of III and IV Semesters will be taught in the Department of Astronomy.

Scheme of Instruction and Examination

SEMESTER – III

Sl. No.	Sub. Code	Subject	Instructions Hrs/Week	Duration of Exam	Max. Marks	Credits
1	AP 301	Basic Astronomy	3	3	50 + 50	3
2	AP 302	Advance Astrophysics	3	3	50 + 50	3
3	AP 303 **Elective-1.**	A. AstroStatistics**(OR)** B. Machine and Deep Learning	3+3	3	50 + 50	3
4	AP 304 **Elective-2.**	A. Classical (Celestial) Mechanics **(OR)** B.Stellar Structure and Evolution	3+3	3	50 + 50	3
PRACTICALS						
5	AP Pr 351	Photometry and Spectroscopy using IRAF and Archival Data	4	3	100	4
6	AP Pr 352	Computer Applications using Python	4	1.5	50	2
6	AP Pr 353	Seminar	4	1.5	50	2
		Total:	**34**		**600**	**20**

SEMESTER – IV

S. No.	Sub. Code	Subject	Instructions Hrs/Week	Duration of Exam	Max. Marks	Credits
1	AP 401	Space Physics	3	3	50 + 50	3
2	AP 402	Astronomical Techniques	3	3	50 + 50	3
3	AP 403 **Elective-1**	A. The Milky Way Galaxy & ISM **(OR)** B. Galaxies and Universe	3+3	3	50 + 50	3
PRACTICALS						
5	AP Pr 451	Astronomical Distance Estimation using GNU plot	8	3	100	4
	AP Pr 452	Sky Observations	4	1.5	50	2
6	AP Pr 453	Project Work	-	3	150	5
		Total:	**22**		**600**	**20**

Theory Paper AP-301: Basic Astronomy

Unit - I – Positional Astronomy

Identification of the objects visible in the night sky to the unaided eye: constellations and nomenclature of stars. The cardinal points and circles on the celestial sphere. Spherical triangle and related problems. Sky coordinates and motions: Horizontal, Equatorial, ecliptic and galactic system of co-ordinates.

Unit – II – Astronomical Systems of Measurements

Seasons, Twilight, Sidereal, Apparent and Mean solar time and their relations, Equation of time, Calendar, Julian date and heliocentric correction. Effects of atmospheric refraction, aberration, parallax, precession, nutation and proper motion on the coordinates of stars.

Unit- III- Stars, Distances and Magnitudes

HR diagram, distances of stars, stellar motions, parallax methods to measure distances to stars, Magnitude systems, Apparent and Absolute magnitudes and distance modulus. colour index. Atmospheric extinction.

Unit -IV - Variable Stars

Variable stars, Variable Stars as distance indicators, Classification and properties of various types of intrinsic and eruptive variable stars. Astrophysical importance of the study of variable stars. Novae and Supernovae.

Unit – V - Binary stars

Binary stars and their types; properties and importance of visual, spectroscopic, eclipsing binaries; Accretion disk, X-ray binaries, Importance of binary stars as source of basic astrophysical data.

REFERENCES

1. W. M. Smart: Text book of Spherical Astronomy.
2. A. E. Roy: Orbital Motion.
3. Mc Cusky: Introduction to Celestial Mechanics.
4. K. D. Abhyankar: Astrophysics: Stars and Galaxies, Tata McGraw Hill Publication, (Chap.2).
5. G. Abell: Exploration of the Universe.
6. A. Unsold: New Cosmos.
7. BaidyanathBasu: Introduction to Astrophysics.

Theory Paper AP-302: Advance Astrophysics

Unit -I: Fundamentals for Radiations

Jefimenkas equation, Lienard-Wiechart potentials, Field of moving point charges, electrical dipole radiation in terms of potentials, power radiated by a point charge

Unit -II: Radiative processes

Ionization losses in non-relativistic and relativistic cases, radiation of an accelerated charge, its spectral distribution, Bremmstrauhlung spectrum and its application in astrophysics, electron energy loss rate in uniform magnetic field, inverse Compton spectrum and its application in astrophysical sources, Sunyaev-Zeldovich effect, Synchroton-self Compton radiation

Unit-III: Solar Dynamo

Magnetic flux freezing, Alfven theorem of flux freezing, magnetic buoyancy, Induction equation, reconnection of magnetic lines of force,, toroidal and poloidal magnetic fields, Omega effect, alpha effect and connection to solar cycle, mean field dynamo theory, meridional flow, filaments/prominences, coronal loops, coronal mass ejections (CMEs), heating of corona, Parker solution of solar wind, effect of magnetic field on solar wind

Unit-IV: Fundamental of Stellar Oscillations

Equation of continuity, Equation of motion, Energy equation, Adiabatic approximation, Equilibrium structure, perturbation analysis, Acoustic waves, internal gravity waves, pulsation constant, P modes, g modes, f mode.

Unit -V: Helioseismology and Astroseismology

Basics of Helioseismology, Solar oscillation and different modes, stellar oscillations in different types of stars, Fundamental stellar parameters and their derivation using astroseismology

REFERENCES

1. Introduction to Electrodynamics: J. D. Griffiths, Cambridge University Press
2. *Radiative Processes* in Astrophysics: Rybicki and Lightman, Wiley interscience
3. High energy Astrophysics: M. S. Longair, , Cambridge University Press
3. Astrophysics for physicists: A. R. Choudhuri, Cambridge University Press
4. The Sun An Introduction: Mechael, Springer-Verlag
5. Plasma Astrophysics: J.G. Kirk, D. B. Melrose, E. R. Priest, Springer-Verlag
6. Astroseismology: Aerts, Christensen-Dalsgaard, Kurtz, Springer
7. The Non-Radial *Oscillations* of Stars in General Relativity, S. *Chandrasekhar* , University of Chicago Press

Theory Paper AS-303: Elective - 1A. AstroStatistics

Unit-I: Basic Statistics

Mean, Median, Mode. Standard deviation. Concepts of probability theory, discrete and continuous random variables, bivariate probability distributions. Binomial, Poisson and Gaussian distributions.

Unit-II: Regression & Hypothesis

Correlation, regression and covariance, Testing of hypothesis –null hypothesis, alternate hypothesis, types of errors, critical and acceptance regions, level of significance.

Unit-III: Sample Testing

Large sample tests for mean(s), variances. Small sample t- tests for single mean and different mean, F distribution and F-test, Chi-square distribution. Chi-square test, Chi-square test for goodness of fitting, ANOVA - one way classification.

Unit-IV: Multivariate Data Analysis

Categorical data analysis, and model building. covariance matrix, Eigen function, Eigen values, principal components classification, discriminate analysis, Fisher method, within-class scatter matrix, between-class scatter matrix.

Unit-V: Clustering Methods

clustering, cluster linkage methods, single, complete, average and centroid linkages, distance estimation, k-means method, hierarchical clustering, dendrogram.

REFERENCES

1. Statistical Methods by S P Gupta.
2. Applied Multivariate Statistical Analysis by Richard A Johnson and Dean W Wichern.
3. An Introduction to Statistical Learning, with Applications in R by James, Witten, Hastie and Tibshirani (Springer, 2013).
4. Practical Statistics for Astronomers, Cambridge Observing Handbook for Astronomers, J V Wall.
5. Modern Statistical Methods for Astronomy: with R Applications, Eric Feigelson, G Jogesh Babu
6. Statistical Challenges in Modern Astronomy, Eds: Eric Feigelson, G Jogesh Babu.
7. Data Mining Concepts & Techniques by Jiawei Han and Micheline Kamber. (Elsevier)

Theory Paper AS-303: Elective - 1B. Machine Learning and Deep Learning

Unit-I: Basic Statistics

Normal distributions, Expectation, Moments of Distribution, and Central limit theorem, Bayes theorem, Prior, Posterior, Bayes optimal classifiers, Maximum Likelihood method

Unit-II: Supervised Learning-Regression

Linear Regression, multiple linear Regression, K-nearest neighbors, under fitting, over fitting, Support Vector regression (SVM), Random forest method.

Unit-III: Supervised Learning-Classification

Logistic regression, Principal Component Analysis , LDA, Singular Value Decomposition, Independent Component Analysis, K nearest neighbor, support vector classifier, Gradient boosting method.

Unit-IV: Unsupervised Learning

Supervised vs Unsupervised learning, learning steps, Decision tree, linkages, Hierarchical clustering, Non- Hierarchical clustering, K-means clustering, Density Based Scan Clustering (DBSCAN), Gaussian clustering model.

Unit-V: Deep learning

Regularization, convolutional neural networks (CNN): Architectures, convolution / pooling layers, recurrent neural networks: its Architectures, Back Propagation through time, variational autoencoders, generative models, applications.

REFERENCES

1. Statistical Methods by S P Gupta.
2. Applied Multivariate Statistical Analysis by Richard A Johnson and Dean W Wichern.
3. An Introduction to Statistical Learning, with Applications in R by James, Witten, Hastie and Tibshirani (Springer, 2013).
4. Practical Statistics for Astronomers, Cambridge Observing Handbook for Astronomers, J V. Wall.
5. Modern Statistical Methods for Astronomy: with R Applications, Eric Feigelson, G Jogesh Babu
6. Statistical Challenges in Modern Astronomy, Eds: Eric Feigelson, G Jogesh Babu.
7. Data Mining Concepts & Techniques by Jiawei Han and Micheline Kamber. (Elsevier)
8. Ian Goodfellow, YoshuaBengio and Aaron Courville. Deep Learning. MIT Press 2016
9. Navin Kumar Manaswi, Deep Learning with Applications using Python, Apress, New York, 2018.

Theory Paper AP-303: Elective - 2A. Stellar Structure & Evolution

Unit – I: Fundamental Equations

Stellar time scales. Equation of mass distribution. Equation of hydrostatic equilibrium. Virial Theorem. Equation of energy transport by radiative and convective processes. Equation of thermal equilibrium. Equation of state. Stellar Opacity. Eddington limit. Stellar energy sources.

Unit – II: Stellar Models

Boundary conditions (central and surface). Russell-Vogt theorem. Polytropic model. Lane-Emden equation and its solution. Properties of polytropes. Homology transformations. Dimensional analysis: Mass-Luminosity and Mass – Radius relations.

Unit – III: Stellar Evolution

Jean's criterion for gravitational contraction and its difficulties. Star forming regions. Protostars. T-Tauri stars. Brown Dwarfs. Pre-Main Sequence Evolution: Hayashi tracks and Henyey tracks. Schoenberg-Chandrasekhar limit. Main-Sequence and Post Main Sequence Evolution of stars of different masses. Eddington Luminosity. Planetary Nebulae. Ages of galactic & globular clusters.

Unit –IV: Superdense Objects - White Dwarfs

White Dwarfs. Use of Polytropic model for completely degenerate stars. Chandrasekhar Mass. Mass-radius relation for White Dwarfs. Non-degenerate upper layers and abundance of Hydrogen. Stability of White Dwarfs. Cooling mechanism in White Dwarfs. Accretion by White Dwarfs and its consequences.

Unit – V: Superdense Objects-Neutron stars and Black Holes

Supernovae, Neutron stars, Black Holes. Pressure ionization and mass-radius relation for cold bodies. Masses of Neutron stars and Black Holes.

REFERENCES

1. M. Schwarzschild: Stellar Evolution
2. R. Kippenhahn A. Weigert: Stellar Structure and Evolution
3. Dina Prialnik: An Introduction to the Theory of Stellar Structure and Evolution
4. BaidyanathBasu: An Introduction to Astrophysics.
5. S. Chandrasekhar: Stellar Structure
6. Cox and Guili: Principles of Stellar Interiors – Vol. I & II
7. Shapiro and Tevkolsky: White Dwarfs, Neutron Stars and Black Holes
8. R. Bowers and T. Deeming: Astrophysics
9. Frank H. Shu: The Physical Universe

Theory Paper AP-303: Elective - 2B. Classical (Celestial) Mechanics

Unit – I: The Two-Body Problem

Motion in a Central Force Field. Motion in an inverse square law force field. Kepler's Laws. Formulation of the two-body problem. Integrals of area, angular momentum, and energy. Equation of the relative orbit and its solution. Kepler's equation and its solution.

Unit – II: The Three-Body Problem

The Three-Body Problem – its equations of motion. Restricted three-body problem. Tisserand's criterion. Lagrange's solution for the motion of three bodies. Surfaces of zero relative velocity, Lagrangian points. Double points.

Unit – III: The Many-Body Problem

The Equations of Motion in the Many-body Problem. Stability of straight line and equilateral triangle solutions. The ten integrals of motion of the n-body problem. Transfer of origin to one of the particles. The perturbing function. Virial theorem.

Unit – IV: The Lagrangianand Hamiltonian Formulation

Lagrangian& Hamiltonian formulation of Mechanics. Equations of motion in Lagrangian formulation. Mechanics of a particle in Lagrangian formulation. Equations of motion of two-body problems and three body problem in Lagrangian formulation. Cyclic or ignorable coordinates. Contact transformation, Hamilton-Jacobi partial differential equation.

Unit – V: Rocket Dynamics and Transfer Orbits

Fundamental equation of motion of a rocket, motion of a rocket in gravitational field and in an atmosphere. Step rockets. Minimum energy orbits. Transfer orbits. Parking orbits. Perturbations of artificial satellites due to atmospheric drag and flattening of the earth.

REFERENCES

1. H. Goldstein: Classical Mechanics, Narosa Publishing Home, New Delhi.
2. N. C. Rana: Classical Mechanics.
3. J.C.Upadhyaya: Classical Mechanics, Himalaya Publishing House.
4. R. G. Takwale and P. S. Puranik: Introduction to Classical Mechanics.
5. W. M. Smart: Text book of Spherical Astronomy.
6. A. E. Roy: Orbital Motion.
7. Mc Cusky: Introduction to Celestial Mechanics.
8. K. D. Abhyankar: Astrophysics of the solar system.
9. F. R. Moulton: An Introduction to Celestial Mechanics.
10. Danby: Fundamentals of Celestial Mechanics.

Practical Paper AP-151: Photometry and Spectroscopy using IRAF and Archival Data

Part - A

1. DS9
2. Ximtool
3. Imexamine
4. Apphot
5. Photometric data archives

Part - B

1. Twodspec
2. Apextract
3. Apall
4. Wavelength calibration
5. Splot
6. Spectroscopic data archives

Practical Paper AP-352: Computer Applications using Python

1. Operating Systems : LINUX.
2. Editors : Word and vi
3. Programming concepts : Python
4. Numerical Analysis using Python.

Practical Paper AP-153: Seminar

REFERENCES

1. J. B. Scarborough: Numerical Analysis.
2. R. Subramanian. P. Achutan. and K. Venkatesan (Translators): Numerical Analysis for Engineers and Physicists.
3. M. K. Jain. S. R. K. Iyengar and R. K. Jain: Numerical Methods for Scientific and Engineering Computation.
4. Python for Data Science, Alen Campbell
5. Programming Python, Mark Lutz, O'Reilly
6. Python Programming : Using problem solving approach, Reema, Thareja, Oxfor Higher Education
7. Norton’s Atlas

Theory Paper AS-401: Space Physics

Unit-I: Introduction to Earth's Atmosphere

Origin and Composition of the atmosphere, Different Atmospheric Layers: Temperature, Pressure, and Density Distribution with height, Hydrostatic Equation, Greenhouse Gases and Effective temperature of the Earth, Atmospheric Aerosols: Concentration and Size distribution, Production and Removal mechanism, Comparative study of atmospheric properties of Venus and Mars,

Unit-II: The Earth's Middle and Upper Atmosphere

Composition and structure of Stratosphere and Mesosphere, Stratospheric ozone chemistry, Formation and structure of the ionosphere, studies of ionosphere by ground and space based techniques, D, E and F region irregularities, Ionization and energy exchange processes. Exosphere.

Unit-III: Solar Radiation

Spectral distribution of solar radiation, Spectrum of Radiation, Radiation law's, Absorption and scattering of solar radiation, Estimation of Solar Irradiance at upper Atmosphere, Rayleigh and Mie scattering

Unit-IV: Solar Wind

Solar wind: Fast and slow solar wind, Observations of solar wind, Interplanetary magnetic field, Solar wind and its interaction with planetary atmosphere, Variation of solar wind with solar activity, solar wind at heliopause.

Unit-V: Solar Terrestrial Relationship

Short and long term variability of solar constant, planetary magnetosphere, Structure of the bow shocks, Geomagnetic storm, sub-storms, Magnetic reconnection processes, radiation belts, Aurorae.

REFERENCES

1. J. A. Rateliffe: An Introduction to the Ionosphere and Magnetosphere.
2. Kaula. W.M: An Introduction to Planetary Physics.
3. Harold Zirin: Astrophysics of the Sun.
4. A. Chandrasekar: Basics of Atmospheric Science
5. The Earth's Ionosphere Plasma Physics and Electrodynamics by Michael C. Kelley
6. V. Bedmtay and Kleczek: Basic Mechanism of Solar Activity
7. Michael D. Papagiannis: Space Physics and Space Astronomy

Theory Paper AP-402: Astronomical Techniques

Unit-I: Optical and IR Telescopes

Basic Optics, Types of telescopes- refractive, reflective and catadioptric telescopes. Telescope mounting systems. Solar telescopes. Importance of Infrared astronomy, IR telescopes, properties of IR telescopes, Major IR missions. Active and adaptive optics.

Unit-II: Space Telescopes

Importance of space based astronomy. Space Telescopes. Space based instrumentation and science. Ultraviolet Fundamentals, Ultraviolet Telescopes, Major UV space Mission, X-Ray Fundamentals, X-Ray Telescopes, Major X-Ray space Mission, Astrosat (ISRO), XMM-Newton, Chandra and Swift and their scientific results. Gamma-Ray Fundamentals, Gamma-Ray Telescope.

Unit-III: Detectors

Classification of detectors, characteristics of detectors. Detectors for optical and infrared wavelength regions. Working of Charge Coupled Device (CCD). sensitivity, noise, quantum efficiency, spectral response, Johnson noise, signal to noise ratio. Application of CCD for stellar imaging. Observational techniques of astronomical sources from space in infrared, EUV, X-ray and Gamma-ray regions of the electromagnetic spectrum.

Unit-IV: Photometry and Spectroscopy

Astronomical photometry. Observing technique with a photometer. Application of CCD for photometry. Correction for atmospheric extinction. Transformation to a standard photometric system. Astronomical spectroscopy. Application of CCD for spectroscopy.

Unit-V: Radio Astronomical Techniques

Radio window. Antenna parameters. Various types of antennas -based on steerability. construction of simple radio telescopes. Receiver systems and their calibration. Design and construction of a simple radio interferometer. VLBI Systems. Aperture Synthesis.

REFERENCES

1. C. R. Kitchin: Astrophysical Techniques (4 th edition).
2. Ian S. McLean: Electronic Imaging in Astronomy: Detectors and instrumentation (2^{nd} ed.).
3. Steve B. Howell: Handbook of CCD Astronomy (2 nd edition).
4. A. E. Roy and D. Clarke: Astronomy Principles and Practice (Part-3, 4 th edition).
5. W. A. Hiltner (Ed): Astronomical Techniques.
6. Gordon Walker: Astronomical Observations - an Optical Perspective (CUP).
7. Henden and Kaitchuck: Astronomical Photometry.
8. C. R. Miczaika and W. M. Sinton: Tools of the Astronomers
9. Carleton: Methods of Experimental Physics. Vol. XIIA.
10. G. F. Knoll: Radiation Detection and Measurement (2nd edition)

Theory Paper AS-403: Elective – 1A. The Milky Way Galaxy & Interstellar Matter

Unit-I: The Milky Way Galaxy

The structure, size using optical and radio observations. mass of the milky way Galaxy and their determinations. Stellar populations in the Milky Way. Distribution of Gas in the Milky Way. Interstellar reddening law. 21-cm line observations. Interstellar magnetic fields in the Milky Way.

Unit-II: Stellar Motions

Standards of Rest – the Fundamental Standard of Rest and the Local Standard of Rest. Solar motion and its determination. Motion of stars in spiral galaxies. Oort's theory of galactic rotation. Determination of Oort's constants. Peculiar velocities.

Unit-III: Spiral Wave Kinematics

Motion of stars near the centre of the Milky Way. Inference of the presence of super massive black hole at the centre. Rotational curve and its interpretation. Dark Matter. Gravitational lensing

Unit-IV: Structure & contents of the Milky Way Galaxy

Star forming regions in the Milky Way. Distribution of X-ray and Gamma ray sources in the Milky Way. Emission mechanisms associated with high energy emissions. Importance of multi-wavelength studies of the Milky Way.

Unit-V: Models for Milkyway

Mathematical models of the Milky way: Uniform sphere model, Isothermal sphere, P lummer's and Hernquist model, Jaffe's model, velocities of bodies, Disk models viz. Exponential and Kepler's disk model

REFERENCES

1. James Binney: Galactic Astronomy: Structure and Kinematics of Galaxies
2. Elmegreen: Galaxies & Galactic Structure. Prentice Hall 1998.
3. Sparke and Gallagher: Galaxies in the Universe.
4. Frank Shu: The Physical Universe. A. Unsold: The New Cosmos (3rd Edition). Springer-Verlag 1983.
5. Mihalas and J. Binney: Galactic Astronomy. W. H. Freeman 1981.
6. K. D. Abhyankar: Astrophysics - Stars and Galaxies. Tata McGraw Hill Publication.
7. L. Spitzer: Physical Processes in the Interstellar Medium. John Wiley 1978.
8. M. Sandage and J. Kristian: (Ed.) Galaxies and the Universe. CUP.
9. Bowers and Deeming: Astrophysics Vols.1 and 2.
10. BaidyanathBasu: Introduction to Astrophysics.

Theory Paper AS-403: Elective – 1B. Galaxies and Universe

Unit-I: Fundamental concept

Introduction - What are galaxies? The Universe of galaxies and their discovery. Various catalogues and data sources. Classification of galaxies – Hubble's Morphological Classification, de Vaucouleur Classification, The Yerkes (or Morgan) scheme, DDO system. Masses and sizes of galaxies and the techniques of determining them. Methods of determining extra-galactic distances. Integrated galaxy light, Reddening, K correction.

Unit-II: Profiles of Galaxies

Differential galaxy light, Azimuthal profiles of Ellipticals and Spirals, Isophotal twists in Ellipticals and Spirals. Radial profiles for Spirals and Barred Spirals. Distribution of gas in galaxies. Radiation from neutral atomic, molecular and ionised gas. Total gas mass in a galaxy. Radial gas density profiles.

Unit-III: Dynamical aspects of galaxies

Stellar motion in elliptical and spiral galaxies. Doppler-shift motions in spiral disks, rotational curves, Tully-Fisher relation. Mass distribution in disk galaxies. Early-type galaxy rotations and velocity dispersions. The fundamental plane of Elliptical galaxies. Masses of early-type galaxies.

Unit-IV: Star formation in galaxies

Star formation rates. Complexes and propagating star formation. Starburst galaxies, Star formation in Interacting galaxies. Active Galaxies. Seyferts, Radio galaxies and Quasars. The unified model of Quasars, Importance of multi-wavelength studies of galaxies.

Unit-V: Cosmology

Expansion of the universe. Interpretation of the red-shift. CMBR. Fundamentals of cosmology, Friedmann equations and solutions - the Big Bang & the Steady State models.

REFERENCES

1. Elmegreen: Galaxies & Galactic Structure. Prentice Hall 1998.
2. Sparke and Gallagher: Galaxies in the Universe.
3. Frank Shu: The Physical Universe.
4. A. Unsold: The New Cosmos (3rd Edition). Springer-Verlag 1983.
5. Mihalas and J.Binney: Galactic Astronomy. W. H. Freeman 1981.
6. K. D.Abhyankar: Astrophysics - Stars and Galaxies. Tata McGraw Hill Publication.
7. L. Spitzer: Physical Processes in the Interstellar Medium. John Wiley 1978.
8. M. Sandage and J. Kristian: (Ed.) Galaxies and the Universe. University of Chicago Press.
9. Bowers and Deeming: Astrophysics Vols.1 and 2.
10. BaidyanathBasu: Introduction to Astrophysics. Prentice Hall of India, 2004.
11. Jayant Narlikar: Introduction to Cosmology. Jones & Bartlett Publishers, Inc, 1998.

Practical Paper AP-451: Astronomical distance estimation Using GNU plot

1. Parallax Method
2. Main sequence method
3. Cepheids Method
4. Supernovae Method
5. Galaxies Red shift Method
6. Tully- fisher relation Method

Practical Paper AP-452: Sky Observations

1. Identification and evolution of celestial sphere with naked eye observations.

2. Identification, imaging and study of celestial objects using 12 inch Meade telescope

Practical Paper AP-453: Project Work

REFERENCES

1. C.R. Kitchin: Astrophysical Techniques (4^{th} edition).
2. W. A. Hiltner (Ed): Astronomical Techniques.
3. Steve B. Howell: Handbook of CCD Astronomy (2^{nd} edition).

Syllabus for Ph.D (Astronomy) course work
(with effect from the Academic Year 2014-15)

The Ph.D course work test consists of the Two Theory Papers each of three hours duration and 100 marks.

Theory Paper – I : Research Methodology (the paper shall consist of general topics and is common for all candidates and titled " Advanced Astrophysics").

Theory Paper – II : One of the following Broad Field of Research

(a) Binaries, Variable Stars and Star Clusters.
(b) Radio Astronomy and Space Science
(c) Galaxies & Galactic Dynamics

Theory Paper- I
ADVANCED ASTROPHYSICS

Unit1:
Astronomical Instrumentation and Analysis techniques

Telescopes: Types of telescopes, Mounts, f-ratio
Detectors: Detectors for optical and infrared regions and characteristics, Astronomical CCD's, bias, flats, dark current, noises, signal to noise ratio, Nyquist theorem, Quantum efficiency, front and back illuminated CCDs
Concepts of Photometry: Apparent and absolute magnitudes differential photometry, aperture photometry, spectroscopy: radial velocity measurements
General Data Analysis: light curves, mean, median, RMS, Gaussian and Poisson distributions, kinds of errors, propagation of errors, least square fitting, various function fitting in Gnuplot, goodness of fit, chi square distribution, auto-correlation and cross-correlation function, regression, Fast and Discrete Fourier transforms, periodogram

Unit 2:
Stellar Spectroscopy

Spectra of stars: HR diagram, HD and MK spectral classification of stellar spectra,Radiation laws,radiative transfer terms definition and usage, the fundamental equation of radiative transfer, definition of source function and optical depth
Radiative Processes:free-free emission (Bremstrahlung), bound-free (photo-electric effect) and free-bound processes and spectra, cyclotron and synchrotron radiation, Compton scattering, inverse Compton scattering, y-parameter
Spectral Lines: Basic ideas on spectral line formation, Boltzmann equation, Gaussian and Lorentz profiles, Voigt function, line broadening mechanisms and what they diagnose about a stellar atmosphere, equivalent width
Curve of Growth: Theory of the curve of growth, Application of the curve of growth tothe study of solar and stellar atmospheres.

Unit 3:
Stellar Structure and Evolution

Equations of Stellar Structure: Basic hydrodynamics, hydrostatic equilibrium, mass continuity, energy generation, radiative transport, convective transport, required constitutive relations
Homologous Models & Polytropes: Homologous relations, definition and examples of polytropes
Nuclear Energy Generation*:* P-P chain and its properties, triple-alpha reaction, CNO cycle and its properties, minimum mass for hydrogen fusion and brown dwarfs, Hefusion and beyond, iron catastrophe
Pre-Main Sequence Stellar Evolution: Hertzsprung-Russell diagram, Jeans mass and Radius, Pre-main sequence evolutionary tracks, accretion disk diagnostics
Post-Main Sequence Stellar Evolution*:* Evolution of low mass stars including formation of planetary nebulae and white dwarfs, evolution of high mass stars to supernova and neutron star or black hole formation

Unit 4:
Galaxies and Interstellar Matter

Stellar Motions: Distribution of stars in space, Statistical parallaxes, Galactic Structure: General galactic rotational law, Spiral structure of our Galaxy from optical and radioobservations, Size and mass of our galaxy.

Extragalactic Systems: Classification of galaxies and clusters of galaxies, Galaxyinteractions, Determination of the masses, Determination of extragalactic distances

High Energy Astrophysics: Galactic and Extragalactic X-ray and Gamma ray sources and their distributions of sources in our galaxy

Accreting Systems: Eddington luminosity and mass accretion limit, Bondi accretion, Shakura-Sunyaev alpha disks

Active Galaxies: Active galaxies and galactic nuclei, Properties of Radio galaxies andQuasars.

Interstellar Matter: Composition and properties of interstellar matter, Interstellarextinction, Estimate of colour excess, Visual absorption, Interstellar reddening law.

Distribution of HI in the Galaxy: 21-cm line observations, Stromgren's theory of H IIregions.

REFERENCES

1. Astrophysical Techniques, C. R. Kitchen
2. Astrophysical Techniques, W. A. Hiltner
3. Data Reduction and error analysis: Bevington
4. Radiative process in astrophysics: Rybicki and Lightman
5. Astrophysics-Stars and Galaxies, K. D. Abhyankar
6. Stellar structure and evolution, Kippenhahn
7. High Energy astrophysics, M. S. Longair Vol I, II and III
8. Galactic Astronomy, Mihalas and Binney
9. *Quasars* and Active Galactic Nuclei: An Introduction Ajit K. *Kembhavi*, Jayant V. Narlikar
10. *Interstellar medium and intergalactic medium, Bruce Draine*

Theory Paper- II (a)
BINARIES, VARIABLE STARS AND STAR CLUSTERS

Unit 1:
Visual, spectroscopic and eclipsing binaries, Elements of visual, spectroscopic andeclipsing binaries, Instruments and method of observing visual, spectroscopic andEclipsing binaries, Astrophysical information like, masses, temperature, distances etc. from the study of visual, spectroscopic binariesand eclipsing binaries, Zwier's method of analysing visual binary orbits, Geometry of aspectroscopic binary, radial velocity curve and its important features, single and double –lined spectroscopic binaries, Lehman-Filhe's method of determining the elements of thespectroscopic binaries, Distortion and reflection effects on radial velocity curves, types oflight curves, classification of eclipsing binaries, rectification of the light curves, Russell–Merrill and Kopal's method of determining the elements of eclipsing binaries, effects ofrotation and gas streams in close binary systems.

Unit2:
Epoch, phase, period of a light curve, period changes, O-C calculation, models and evolutionary status of W UMa, β Lyrae,Alogls and RS CVn binaries, Cataclysmic variables, X-ray binaries, various mechanisms of X-ray emission production,low & high mass X-ray binaries.Generalproperties of population I and population II Cepheids, RR Lyrae, δ Scuti, βCMa, semi-irregular and long period variables, Ap and Am stars, blue stragglers and theirposition on the HR diagram. Period luminosity relation, pulsation constant, causes ofpulsation. Variables in star cluster, isochrones, determination of age of cluster.

Unit 3:
Astronomical photometry, broad band and narrow band photometric standard systems,their importance and limitations, Method of reduction to obtain light curves of variable and eclipsing binaries using CCD's. Atmospheric extinction and itsdependence on colour. Transformation to standard photometric systems. Wilson Devinney method, Grid search method. Spectroscopy, wavelength calibration, flux calibration.

Unit 4:
Accretion disk, thin disk approximation, its spectrum, Comptonization, X-ray binaries - Definition, LMXB and HMXB. White Dwarf binaries - Definition, classifications viz. polars, Intermediate polars and cataclysmic variables, optical and X-ray properties. Neutron star X-ray binaries, classification viz. atoll and Z sources, their optical, X-ray and Radio properties, pulsars. Black hole X-ray binaries, classification based on X-ray spectrum, LH, SPL and TD states, X-ray –Radio correlation, Quasi-periodic Oscillations.

REFERENCES:

1. L.Binnendijk: Properties of Double Stars.
2. Z.Kopal: Close Binary Systems.
3. Pringle and Wade: Interacting Binary Stars.
4. K.D.Abhyankar: Astrophysics-Stars and Galaxies (Chap.6) Tata McGraw Hill Pub.
5. Aitken: Binary Stars.
6. Z.Kopal: Dynamics of Close Binary Systems.
7.Bowers and Deeming: Astrophysics. Vols.1 and 2.
8. Accretion power in Astrophysics: Frank, King and Raine, Cambridge University press.
9. Radiative process in astrophysics: Rybicki and Lightman
10. Astrophysical Process: Longair series

Theory Paper-II (b)

RADIO ASTRONOMY AND SPACE SCIENCE

Unit 1:

Amplifiers and Oscillators

Introduction to operational amplifiers, classification of amplifiers – Analysis of simple operational amplifier circuits; Frequency response of amplifiers. Concept of feedback - Positive and Negative feedback. Advantages of Negative feedback, stability of feedback circuits using Barkhausen criteria - Emitter follower - RC coupled amplifier.Phase shift, Wein Bridge, Hartley and Colpitts Oscillators, Crystal Oscillator. IC 555 Astable, Monostable and Bistable multivibrator.

Unit 2:

Radio Astronomy Techniques

Electro-magnetic spectrum. Propagation of electromagnetic waves. Radio window. Various types of radio telescope antennas. Design and construction of a simple radio telescope. Receiver systems and their calibration. Design and construction of a simple radio interferometer. LB and VLBI Systems. Aperture Synthesis, Giant Meter Radio Telescope (GMRT) and its applications inastronomical studies.

Unit 3:

Space Studies

Near earth environment. Earth's atmosphere. Formation of ionosphere, morphology ofionospherethe D, E and F-regions, variations of atmospheric densities and temperature, irregularities in the ionosphere. Lyman glow of the night sky, airglow studies, Radio studies of ionosphere. Observation of differential Doppler Effect and Faraday Effect. Measurement of total electron content of earth's ionosphere.

Unit 4:

Radar Techniques

Radar equation, pulse and continuous wave radar astronomy systems. Radar studies of planets and meteors. Solar radiations. Solar radio telescope at Japal Rangapur Observatory. Indian MST radar. MST Radar for Ionospheric studies. Meteor Astronomy. Shower and non-shower meteors. MST radar studies of Meteors.

References:

1. Integrated Electronics by Millman and Hallkias
2. Fundamentals of electronics by J.D. Ryder
3. Astrophysical concepts – Martin Harwit.
4. New Cosmos A. Unsold
5. Radio Astronomy: J.D.Kraus.
6. Radio Astronomy: J.V.Evans and T.Hagfers.
7. Meteor Astronomy – A.C.B.Lovell
8. Meteor Science and Engineering,D.W.R.Mckinley
9. Introduction to Space Science – W.B.Hess and G.M.Mead.
10. Solar Radio Astronomy – M.R.Kundu.

Theory Paper – II (c)
GALAXIES & GALACTIC DYNAMICS

Unit 1:

Milky Way Galaxy & other Galaxies

Mass and size of the Milky Way Galaxy. Interstellar Medium its composition. Structure of our Galaxy from optical and radio observations. Distribution of stars in the MW Galaxy. Motion of Stars within the Galaxy. Galactic rotational law. External galaxies and their classifications.

Unit 2:
Dynamics of Stellar Systems

The N-body problem. Stellar systems as N-body systems. Dynamical evolution of star clusters. Virial theorem. Jacobi's criterion of stability and virial theorem. Masses of stellar systems and clusters of galaxies from the virial theorem. Effects of stellar encounters. The Relaxation time. Tidal effects of the galaxy and interstellar clouds. The collisionless Boltzmann equation. The hydrodynamical equations. Jean's theorem. Mathematical models of Galaxies – Sersic, Plummer and King's models.

Unit 3:
Dynamics of Interacting Galaxies

Techniques of N-body simulations. Energy changes in the distant and non-penetrating pairs. Hyperbolic close collisions. Slow collisions and mergers. Formation of galactic bridges & tails and ring galaxies. Results of N-body simulations. Induced star formation in interacting galaxies. Active galaxies and galactic nuclei. Properties of Radio galaxies and Quasars.

Unit 4:
Large scale structure of the Universe

Clusters and Super clusters of Galaxies. The expanding universe. Interpretation of Red-shift. Microwave background radiation. Models of creation and evolution of the universe. Dark matter in galaxies and galactic clusters and its implications on the models of cosmology. Composition of the dark matter.

REFERENCES

1. James Binney and Scott Tremaine: Galactic Dynamics. Princeton Univ. Press.
2. Mihalas and J.Binney: Galactic Astronomy. W.H.Freeman 1981.
3. D.Mihalas: Galactic Astronomy
4. L.Spitzer: Physical Processes in the Interstellar Medium. John Wiley 1978.
5. M.Sandage and J.Kristian: (Ed.) Galaxies and the Universe. University of Chicago Press.
6. S. Chandrasekhar: Principles of Stellar Dynamics
7. K.C.Freeman: Galaxies and Universe.
8. S.D.M.White: The Origin and Evolution of Galaxies. (Eds: Jones and Jones).
9. S.M.Alladin: Lecture notes on "Dynamics of Stellar Systems".
10. J.E. Barnes: Dynamics of Galaxy interactions, Lecture notes 1996, Swiss Society for
11. Astrophysics and Astronomy "Galaxies: Interactions and Induced Star Formation".
12. K.D.Abhyankar: Astrophysics - Stars and Galaxies. Tata McGraw Hill Publication.
13. Bowers and Deeming: Astrophysics Vols.1 and 2.
14. Baidyanath Basu: Introduction to Astrophysics.