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 2016-2017)

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	4	3	100	4
2	AS 102	Mathematical Methods of Physics	4	3	100	4
3	AS 103	Basic Astronomy	4	3	100	4
4	AS 104	Classical (Celestial) Mechanics	4	3	100	4
PRACTICALS						
5	AS Pr 151	Numerical Methods	8	3	100	4
6	AS Pr 152	Computer Applications	8	3	100	4
		Total:	**32**		**600**	**24**

SEMESTER -II

S. No.	Sub. Code	Subject	Instructions Hrs/Week	Duration of Exam	Max. Marks	Credits
1	AS 201	Quantum Mechanics	4	3	100	4
2	AS 202	Fluid Mechanics and Magneto Hydro Dynamics	4	3	100	4
3	AS 203	Stellar Spectroscopy & Atmosphere	4	3	100	4
4	AS 204	Stellar Structure & Evolution	4	3	100	4
PRACTICALS						
5	AS Pr 251	Photometry & Spectroscopy using IRAF and usage of Archival Data	8	3	100	4
6	AS Pr 252	Practical Astronomy	8	3	100	4
		Total:	**32**		**600**	**24**

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

Scheme of Instruction and Examination (w.e.f. the academic year 2014-2015)

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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.
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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	4	3	100	4
2	AS 302	Radio Astronomy	4	3	100	4
3	AS 303	Electronics	4	3	100	4
4	AS 304	CB – 1. Basics of Astronomy & Astrophysics CB – 2. Space physics	4	3	100	4
PRACTICALS						
5	AS Pr 351	Electronics	8	3	100	4
6	AS Pr 352	Spectroscopy	8	3	100	4
		Total:	32		600	24

Note: CB -1 and CB - 2 Papers (Basics of Astronomy & Astrophysics and Space Physics) offered at the Department of Astronomy to the students of other science courses who studied Mathematics and Physics at Graduation level. This course offered, if minimum number of students enrolled for the course.

SEMESTER - IV

S. No.	Sub.Code	Subject	Instructions Hrs/Week	Duration of Exam	Max. Marks	Credits
1	AS 401	Space Physics	4	3	100	4
2	AS 402	Binary stars	4	3	100	4
3	AS 403	Astrostatistics	4	3	100	4
4	AS 404	CB-1. The Milky Way Galaxy & ISM CB-2. Galaxies & Universe	4	3	100	4
PRACTICALS						
5	AS Pr 451	Photometry	8	3	100	4
6	AS Pr 452	Project Work	8	3	100	4
		Total:	**32**		**700**	**24**

SEMESTER -I

Theory Paper AS-10l: Basic Physics

Unit 1 Electromagnetic Theory

Coulomb's law, Electric fields and potential. Principle of Superposition. Electric Dipoles, field of a dipole. Gauss's Law. Electric current. Ampere's law. Biot-Savart's law. Faraday's law. Equation of continuity, displacement current, Maxwell's Equations. Scalar and Vector potentials, Coulomb and Lorentz gauge. Electromagnetic waves. Poynting Theorem.

Unit 2 Transformations

Generalized Coordinates, 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 3 Statistical Mechanics

Entropy and Probability, Liouville's theorem (Classical), 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, Compressibility of Fermi gas, Bose-Einstein Condensation

Unit 4 Relativity and Application

Concept of Special Theory of Relativity, Lorentz Transformation, Length Contraction and time dilation, Relativistic addition of velocities, conservation of mass and momentum, 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, Kedar Nath 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 - 1

Ordinary differential equations

Definition, order and degree of a differential equation. First and second order homogeneous and non-homogeneous differential equations with constant and variable coefficients, Bernoulli Equation. The Superposition Principle. Solution by power series method due to Frobenius method. Solutions of Legender's, Bessel's, Laguerre's and Hermit's differential equations.

Unit - 2

Partial differential equations

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

Unit - 3

Special functions

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

Unit - 4

Fourier Series and Transforms

Definition of Fourier Series and expansion of a functions of x. Extension of interval. Advantages of Fourier series. Complex form of Fourier series. Fourier's integrals. Fourier transform and their inverse. Transforms of Derivatives, Parseval's relation. Use of Fourier transform in solving some simple 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 - 1

Celestial Sphere and Time and Mean Position of stars

Constellations and nomenclature of stars. The cardinal points and circles on the celestial sphere. Equatorial. ecliptic and galactic system of co-ordinates. Spherical triangle and related problems. Twilight, Seasons, 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 - 2

Stellar Distances and Magnitudes

Distances of stars from the trigonometric. secular. and moving cluster parallaxes. Stellar motions. Magnitude scale and magnitude systems. Atmospheric extinction. Absolute magnitudes and distance modulus. colour index. Black-body approximation to the continuous radiation and temperatures of stars.

Unit - 3

The Sun and Planets

Origin of the solar system. Surface features of the sun in white and monochromatic light. Internal structure. Sun spots and magnetic fields on the sun. Solar activity. Surface features of planets, Internal structure, Atmospheres and Magnetic fields of Planets and their moons. Results of space probes.

Unit - 4

Asteroids, Meteors and Comets

Discovery and designation, Origin, Nature and orbits of Asteroids, Meteors and Comets. Meteor showers and sporadic meteors. Periodic comets. Spectra. Brightness variation in Comets. Gas production rates, dust and ion tails.

REFERENCES

1. W.M.Smart: Text book of Spherical Astronomy.
2. A.E.Roy: Orbital Motion.
3. McCusky: 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. Baidyanath Basu: An Introduction to Astrophysics

Theory Paper AS-104: Classical (Celestial) Mechanics

Unit – 1 Newtonian Formulation and The Two Body Problem

Frames of reference. Generalised coordinates. Newton's laws of motion. Mechanics of a particle. Equations of motion of a particle. Mechanics of a system of particles. Law of Gravitation. 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. F and g series. Orbit computation by Laplace and Gauss methods.

Unit – 2 Three-Body Problem and The N-Body Problem

The Three Body Problem – its equations of motion. Lagrange's solution for the motion of three bodies. Restricted three body problem. Surfaces of zero relative velocity. Double points. Stability of straight line and equilateral triangle solutions. Tisserand's Criterion for identification of comets. The ten integrals of motion of the n-body problem. Transfer of origin to one of the particles. The perturbing function. Virial theorem.

Unit – 3 The Lagrangian Formulation

Constraints, Classification of Constraints, Principal of Virtual Work, D' Alembert's Principal, Lagrangian & Hamiltonian formulation of Mechanics. Equations of motion in Lagrangian formulation. Mechanics of a particle in Lagrangian formulation. Equations of motion of two body problem and three body problem in Lagrangian formulation. Cyclic or ignorable coordinates. Contact transformation, Hamilton-Jacobi partial differential equation.

Unit – 4 Rigid body motion and Orbital Mechanics

Euler's theorem. Euler's equations of motion. Euler's angles. Motion of a rocket. 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. R.G.Takwale and P.S.Puranik: Introduction to Classical Mechanics.
4. W.M.Smart: Text book of Spherical Astronomy.
5. A.E.Roy: Orbital Motion.
6. McCusky: Introduction to Celestial Mechanics.
7. K.D.Abhyankar: Astrophysics of the solar system.
8. F.R.Moulton: An Introduction to Celestial Mechanics.
9. Danby: Fundamentals of Celestial Mechanics.

Practical Paper AS-151: Numerical Methods

1. Precision of measurements and accuracy of calculations.
2. Normal Distribution and method of least squares.
3. Numerical interpolation.
4. Numerical differentiation and integration.
5. Solution of ordinary differential equations.

Practical Paper AS-152: Computer Applications

1. Operating Systems : WINDOWS, UNIX/LINUX.
2. Editors : Word and vi
3. Numerical Analysis using available software.
4. Programming concepts: Language : C/ FORTRAN
5. GNU plot

REFERENCES

1. J.B.Scarborough: Numerical Analysis.
2. R.Subramanian. P.Achutan. and K.Venkatesan (Translators): Numerical Analysis for Engineers and Physicists.
3. P.S.Grover: Programming and computing with FORTRAN IV.
4. M.K.Jain. S.R.K.Iyengar and R.K.Jain: Numerical Methods for Scientific and Engineering Computation.
5. R.C.Desai: FORTRAN Programming and Numerical Methods.
6. E.Balaguruswamy: Let us C

SEMESTER- II

Theory Paper AS-201: Quantum Mechanics

Unit – 1 Foundation of Quantum Mechanics

Inadequacy of classical Physics, single slit and double slit experiments, de, Broglie wave , 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 – 2 General Formalism of Quantum Mechanics

Postulates of Quantum Mechanics, Representation of states and dynamical variables, observables, self-adjoint operators, eigen functions and eigen values, degeneracy, 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_-, 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 – 3 Approximation Theory

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

Unit – 4 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, symmetric and anti-symmetric wave functions.

REFERENCES

1. An overview of Basic Theoretical Astrophysics by K D Abhyankar & A W 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 Granier, Springer Publication.
9. Introductory Quantum Mechanics by Li boff, 4th Edition, Pearson Education Ltd.

Theory Paper AS-202: Fluid Mechanics and Magnetohydrodynamics

Unit – 1

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 – 2

Gas Dynamics

Compressibility effects in real fluid, 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, elementary analysis of oblique shocks.

Unit – 3

Motion of charged particles and Instabilities

Motion of charged particle in static uniform electric field, magnetic field, and electromagnetic field, particle drifts in non-uniform magnetic field, Mirror effect, Adiabatic invariants, Synchrotron radiation and its spectrum, Detail study of Compton and inverse Compton effect, y-parameter, Compton spectrum, Kelvin-Helmholtz instability, Parker instabilities, Rayleigh-Taylor instability, kink instability.

Unit – 3

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, MHD shock waves, MHD effects in shock formation, Hartmann number, Alfven velocity

REFERENCES

1. F. Chorlton: Textbook of Fluid Mechanics
2. Jackson: Classical theory of Radiation.
3. Oleg Glebov: Motion of Charged particles.
4. John R.Reitz, Frederick J.Milford, Robert W. Christy: Foundations of Electromagnetic Theory (4th Edition).

Theory Paper AS-203: Stellar Spectroscopy & Atmospheres

Unit - 1

Spectra of Stars

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

Unit - 2

Qualitative description of causes of spectral line Broadening

Equivalent widths, Natural damping. Collisional damping. Statistical broadening of hydrogen lines. Stark effect in helium lines. Electron pressure in early type stars. Superposition of Doppler and damping profiles. 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 - 3

Equation of transfer

Definitions concerning the radiation field. Equation of transfer. Hypothesis of plane parallel and spherically symmetric stratification. Formal solution for this case. Local thermodynamic equilibrium. Radiative equilibrium. Grey approximation. Departures from greyness. Blanketing effect.

Unit - 4

Abundances of elements

Abundance of elements in stars, Abundance of elements in the sun by the method of fine analysis-Stromgren's method, use of weight functions, abundances of elements in normal stars. Composition of differences in population I and II stars. Anomalous abundances in cool 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 – 1 Fundamental Equations

Basic properties of stars and observational methods. 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 – 2 Stellar Models

Fundamental equations. Overall problem. Boundary conditions (central and surface). Russell-Vogt theorem. Polytropic model. Lane-Emden equation and its solution. Properties of polytropes. Applications (Polytrope for perfect gas, convective stars, Eddington model, solar polytrope). Hayashi Line. Hayashi Forbidden Zone. Homology transformations. Dimensional analysis: Mass-Luminosity and Mass – Radius relations.

Unit – 3 Stellar Evolution

Jean's criterion for gravitational contraction and its difficulties. Star forming regions. Protostars. T-Tauri stars. Brown Dwarfs. Pre-Main Sequence Evolution: Pre-Main Sequence contraction under radiative and convective equilibrium. HR diagrams. Hayashi tracks and Henyey tracks. Schoenberg-Chandrasekhar limit. Main-Sequence and Post Main Sequence Evolution of stars of different masses. Growth of isothermal core, Shell burning and subsequent development. Eddington Luminosity. Planetary Nebulae. Ages of galactic & globular clusters.

Unit – 4 Superdense Objects

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. Supernovae, Neutron stars, Black Holes. Pressure ionization and mass-radius relation for cold bodies. Maximum mass of a Neutron star. Masses of Stellar 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. Baidyanath Basu: 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 & Spectroscopy using IRAF and usage of Archival Data

1) Photometry

a) DS9
b) Ximtool
c) Imexamine
d) Apphot

2) Spectroscopy

a) Twodspec
b) Apextract
c) Apall
d) Wavelength calibration
e) Splot

3) Archival Data

a) VIZIER
b) SIMBAD
c) NED
d) HEASARC

Practical Paper AS-252: Practical Astronomy

1. Identification of various great circles on the celestial sphere and important constellations using Norton's Atlas.
2. Determination of magnitude of artificial source of light and a star.
3. Observation of variable stars using a telescope.
4. Imaging the sky.
5. Measurement of Solar Limb darkening using Photometer.
6. Astrometry of Asteroids using virtual Observatory
7. Determining period of rotation of the sun using virtual observatory

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.

SEMESTER – III

Theory Paper AS-301: Astronomical Techniques

Unit 1 Telescopes

Basic Optics, Types of telescopes. Telescope mounting systems. Optical telescopes, Infrared, Ultraviolet, X-ray and Gamma-ray telescopes. Schmidt telescopes. Solar telescopes. Design and construction of a simple optical telescopes. Active and adoptive optics in astronomical study. Sky charts and their importance.

Unit 2 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, photometry and spectroscopy. Importance of space based astronomy. Observational techniques of astronomical sources from space in infrared, EUV, X-ray and Gamma-ray regions of the electromagnetic spectrum.

Unit 3 Photometry and Spectroscopy

Astronomical photometry. Simple design of an astronomical photometer. Observing technique with a photometer. Correction for atmospheric extinction. Transformation to a standard photometric system. Astronomical spectroscopy. Spectral classification. Simple design of astronomical spectrograph. Radial velocity measurements.

Unit 4 Radio Astronomical Techniques

Electromagnetic spectrum. Radio window. Antenna parameters. Various types of antennas. Non-steerable, partially steerable and fully steerable radio telescopes. Design and construction of a simple radio telescope. Receiver systems and their calibration. Design and construction of a simple radio interferometer. MST Radar for Ionospheric studies. LB and 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} edition).
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 (Cambridge Univ Press).
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-302: Radio Astronomy

Unit 1

Radio Astronomy Fundamentals

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

Unit 2

Theories of Generation of Radio Waves

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

Unit 3

Solar Radio astronomy

Quiet Sun radiation, slowly varying component, Solar radio bursts on centimeter and decimeter meter, Solar radio wave bursts of type I, II, III, IV and V and their association with flares.

Unit 4

Galactic and Extragalactic Radio Astronomy

Cosmic microwave background radiation (CMBR) and disk component, HII regions and supernovae remnants, 21-cm hydrogen and OH line radiations. Spiral structure of the galaxy, pulsars, radio galaxies, QSO's and active galactic nuclei-their implications on cosmology.

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 (3^{rd} edition)
4. Alan Sandage and others: Galaxies and the Universe
5. Thomas L. Wilson, Kristen Rohlfs,Susanne Huttemeister: Tools of Radio Astronomy (5^{th} edn)
6. Jeff Lashley: The Radio Sky and How to Observe It

Theory Paper AS-303: Electronics

Unit 1 Semiconductor Devices & Amplifiers

Characteristics of Tunnel Diode, Photo diode, BJT , JFET, MOS, CMOS, UJT, SCR , IC 741, 555 Biasing of Transistor, Self bias, Single Stage RC coupled amplifier and its frequency response

Unit 2
Power Supply

Concept of current limit, fold back current limiting, constant voltage constant current (CVCC) using IC-723. Three terminal adjustable regulator. Switching regulator using TL 494 (Texas Instruments). Concept of DC to DC converter. Introduction to UPS and Inverters.

Operational Amplifiers

Concept of input/output impedance, Input bias current, offset input voltage, slew rate, CMMR, Gain, frequency response, Band Width in different types of OP-AMPs such as BJT, JFET, MOS FET.

Operational Amplifiers Applications

Active filters : LPF, HPF, BPF, and Notch filter 1st and 2nd order with designing. (Concept of Roll off, octave, Decade). Instrumentation Amplifier. Function Generator – Square wave, triangular, sawtooth , sine wave. Half wave and full wave precision rectifiers. Sample and hold circuits.

Feed back Amplifiers

Classification of Amplifiers, The concept of feed back, Positive and Negative feed back. Advantages of Negative feed back. Emitter follower

Unit -3 Sinusoidal Oscillators (Using BJT's)

Criterion for oscillations, Phase shift, Wein bridge, Hartley and Colpitts Oscillators, Crystal Oscillator. IC 555 Astable, Monostable and Bistable multi-vibrator.

Unit -4 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.

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 – CB -1: Basics of Astronomy & Astrophysics

(Course suited for students with Mathematics & Physics background at Graduation level)

Unit 1: The Heavens Above

Celestial Sphere and Time

Constellations. The celestial sphere. Coordinate systems: Equatorial, ecliptic system. Seasons, Sidereal, Apparent and Mean solar time. Calendar. Julian date.

Stellar Distances and Magnitudes

Distance scale in astronomy. Determination of distances to planets and stars. Magnitude scale. Atmospheric extinction. Absolute magnitudes and distance modulus.

Unit 2: Our Solar System

Theories of formation of the Solar System.

The Sun

Photosphere, chromosphere and corona of the Sun. Sun spots and magnetic fields on the sun. Solar activity, solar wind.

Planets and their Satellites

Surface features, atmospheres and magnetic fields of Earth, Moon and Planets. Satellites and rings of planets. Asteroids, Meteors, Meteorites and Comets.

Unit 3: Stars: What are they?

Stars. Spectral classification. Energy generation in stars. Basics of Star formation & Evolution. The HR diagram. Super dense objects - White dwarfs, Neutron stars & Pulsars. Black holes.

Unit 4: The Milky Way Galaxy & Galaxies beyond

Structure of the Milky Way Galaxy

What are galaxies? Different types of galaxies. Hubble's classification. Structure, size & mass of the Milky Way galaxy. Position of our Sun and its motion around the galactic centre.

Cosmology

The expanding universe. Cosmological models: Big Bang and Steady State models. Dark matter

REFERENCES

1. H. Karttunen, P Kroger, H Oja, M Poutanen & K. J. Donner editors. Fundamental Astronomy.
2. W.M.Smart: Foundations of Astronomy.
3. Frank H. Shu: The Physical Universe-An Introduction to Astronomy.
4. K D Abhyankar: Astrophysics of the Solar System.
5. Baidyanath Basu: Introduction to Astrophysics.
7. Jayant Narlikar: Structure of Universe

Theory Paper AS-304 – CB -2: Space Physics

(Course suited for students of M. Sc., Earth Sciences)

Unit 1:

Introduction to space physics

Introduction to the Electromagnetic radiation, fundamentals of EM waves, effects of environment, propagation of waves, the sun and the solar corona, the sunspots and solar cycle, solar flares, solar wind and the heliosphere, planetary magnetospheres.

Unit 2:

Atmospheres

The Neutral atmosphere, atmospheric nomenclature, geopotential height, expansion and contraction, fundamental forces in the atmosphere, apparent forces, atmospheric composition, solar radiation interaction with the neutral atmosphere, climate change, atmospheric aerosols.

Unit 3:

Ionosphere

Formation of the ionosphere, morphology of ionosphere, the D, E and F-regions, Ionospheric variations, chemistry of the ionosphere, ionospheric parameters, E and F region anomalies and irregularities in the ionosphere, the aurora, Lyman glow of the night sky, the geo-corona and airglow studies, ionosondes.

Unit :4

Satellite Communication

Satellite System – Historical development of satellites – communication satellites – orbiting satellites – satellite frequency bands – satellite multiple access formats, satellite orbits and inclination – Look angles, orbital perturbations, space craft and its subsystems – attitude and orbit control system – Telemetry, Tracking and Command – Power system –Transponder – Reliability and space qualification – launch vehicles

REFERENCES

1. An Introduction to Dynamic Meteorology – James R Holton.
2. Climatology, An atmospheric Science – John E. Oliver and John J. Hindore.
3. Electronic Communication systems – George Kennedy and Bernard Davis.
4. Introduction to Ionospheric Physics – Henry Rishbeth and Owen K. Garriot.
5. Satellite Communication – Robert M. Gagliardi
6. Satellite Communication – Manojit Mitra

Practical Paper AS-351: Electronics

1. DC Power Supply

2. RC Coupled Amplifier

3. Experiments on OPAMP

4. Experiments on Antennas

    (a) Dipole Antenna

    (b) Loop Antenna

    (c) Directivity and Polarisation

5. Simple Radio Receiver

    (a) Sensitivity of a Receiver

    (b) Selectivity of a Receiver

    (c) Fidelity of a Receiver

6. Study of Extra -terrestrial Radio waves (Solar Radiation)

Practical Paper AS-352: Spectroscopy

1. Knowing and understanding a spectra

2. Observing different spectral lines for various elements using spectrum builder

3. Classification of stellar spectra using virtual observatory

4. Making a Simple Spectroscope.

5. Determining radial velocities of Stars.

REFERENCES

1. Millman and Hallkias: Electronic Devices and Circuits
2. Millman and Hallkias: Integrated Electronics
3. J. D. Kraus: Radio Astronomy.
4. W. A. Hiltner (Ed): Astronomical Techniques.
5. Steve B. Howell: Handbook of CCD Astronomy (2^{nd} edition).

SEMESTER- IV

Theory Paper AS-401: Space Physics

Unit 1 The Earth's Upper Atmosphere

Variations of atmospheric densities and temperature. Formation and structure of Ionosphere. Studies of ionosphere by ground based and space techniques. The radiation belts, Aurorae. Lyman glow of the night sky. Atmospheric aerosols, the geo-corona and airglow studies.

Unit 2 Sun and Interplanetary Medium

Structure of solar atmosphere. Solar convection and differential rotation. Large scale and small scale magnetic fields. Solar granulation and super granulation. Sunspots. Solar flares. EUV, X-ray and gamma-ray studies of sun. Solar X-ray and radio bursts. Solar wind and its interaction with planetary atmosphere. Structure of bow shocks. Magnetosphere. Ring Current. Radiation belts and interplanetary magnetic field. Interplanetary dust.

Unit 3 Moon

Origin of the moon. Eclipses and Occultation. Weak magnetic fields and atmosphere. Lunar ranging experiments. Studies of lunar interior and surface features, various space missions to the moon and their results, Chandrayaan-I. Satellites of other planets of the solar system.

Unit – 4 Planets

Infrared spectroscopy of planetary atmospheres. Exploration of Mars. Recent space missions to Mars. Indian MOM mission. Voyager space mission studies of outer planets and their satellites and rings. Comparative studies of planetary atmospheres. Planetary ionospheres. Extra-solar system planets (qualitative).

REFERENCES

1. J.A.Ratcliffe: An Introduction to the Ionosphere and Magnetosphere.
2. Kaula. W.M.: An Introduction to Planetary Physics.
3. Harold Zirin: Astrophysics of the Sun.
4. W.N.Hess and G.Mead(Ed): Introduction to Space Science.
5. V.Bedmtay and Kleczek: Basic Mechanism of Solar Activity.
6. Sagan C. Owen T. C. and Smith. H.J.: Planetary Atmospheres.
7. Kaufmann, W.J.: Exploration of the Solar System.
8. Baugher, J.F.: The space age solar system
9. K.D. Abhayankar: Astrophysics of the solar system.

Theory Paper AS-402: Binary Stars

Unit – 1 Visual Binaries

Introduction to binary stars. Binary types and their classification. Method of observing visual binaries. Orbital elements of visual binaries. Zwier's method of analysing visual binary orbits. Information obtained from the studies of visual binaries. Astrometric binaries. Importance of binary stars in determining the stellar masses.

Unit – 2 Spectroscopic Binaries

Single and double-lined spectroscopic binaries. Geometry of a spectroscopic binary. Radial velocity curve and its important features. Correction of radial velocities for rotation and revolution of the earth. Lehman-Filhe's method for determining the orbital elements of Spectroscopic binaries. Information obtained from the studies of spectroscopic binaries. Distortion and reflection effects on radial velocity curve.

Unit – 3 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. Information obtained from the studies of eclipsing binary light curves. Algols- Definition, paradox, properties, period changes, models and evolution. RS CVn's- Definition, properties, period changes, models and evolution. W UMa - Definition, properties, period changes, models and evolution.

Unit – 4 X-ray binaries

Accretion disk, Shakura-Sunyev disk, its spectrum, . X-ray binaries - Definition, LMXB and HMXB. White Dwarf binaries - Definition, classifications viz. polars, Intermediate polars and cataclysmic variables, X-ray properties. Neutron star X-ray binaries, classification viz. atoll and Z sources, pulsars. Black hole X-ray binaries, classification based on X-ray spectrum.

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 Pub.
6. W.S.Fitch(Ed): Multiple Periodic Phenomenon in Variable Stars: IAU Colloquium No.29.
7. Bonner and Dupree(Ed): Solar Phenomena in Stars and Stellar Systems.
9. Z.Kopal: Dynamics of Close Binary Systems.
10. Bowers and Deeming: Astrophysics. Vols.1 and 2.
11. Accretion power in Astrophysics: Frank, King and Raine, Cambridge University press.

Theory Paper AS-403: Astrostatistics

Unit 1

Basic Statistics

Diagrammatic and graphical presentation of data, tabulation of data, frequency distribution.
Mean, Median, Mode. Standard deviation. Binomial, Poisson and Gaussian distributions. Concepts of probability theory, discrete and continuous random variables, bivariate probability distributions.

Unit 2

Regression & Testing of Hypothesis

Covariance, correlation and regression, point estimation, interval estimation. Testing of hypothesis – null hypothesis, alternate hypothesis, types of errors, critical and acceptance regions, level of significance. Large sample tests for mean(s), variances. Small sample tests - t, F and Chi-square, ANOVA - one way and two way classifications.

Unit 3

Multivariate Data Analysis

Categorical data analysis, and model building. Principal components classification & discriminate analysis and clustering (k-means and hierarchical).

Unit 4

Data Mining and Analysis

Association rules, Neural networks, Decision trees – using case based methods for astronomy applications. Analysis of data from astronomical catalogues and public domain using R package.

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 by J.B.Wall, Cambridge Observing Handbook for Astronomers.
5. Modern Statistical Methods for Astronomy with R Applications, Eric Feigelson, G Jogesh Babu.
6. Statistical Challenges in Modern Astronomy, edited by Eric Feigelson, G Jogesh Babu.
7. Data Mining Concepts & Techniques by Jiawei Han and Micheline Kamber (Elsevier).

Theory Paper AS-404: CB – 1: The Milky Way Galaxy & Interstellar Matter

Unit 1 The Milky Way Galaxy

The structure, size and mass of the Milky Way Galaxy. Methods of determining the mass of our galaxy. Stellar populations in the Milky Way. Position of our Sun in the Galaxy. Distribution of Gas in the Milky Way. The interstellar medium – its composition and properties. Amount of interstellar matter. Oort limit. Interstellar extinction. Estimate of colour excess. Visual absorption. Interstellar reddening law and Polarization. 21-cm line observations. Interstellar magnetic fields in the Milky Way. Stromgren's theory of H II regions.

Unit 2 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. Statistical parallaxes. Peculiar velocities. Bottlinger's diagram. Spiral structure in the Milky Way. Determination of its structure from optical and radio observations.

Unit 3 Spiral Wave Kinematics

Epicycles, Spiral density Waves, Resonances. Resonance features. Motion of stars near the center of the Milky Way. Inference of the presence of supermassive black hole at the center. Rotational curve and its interpretation. Dark Matter. Candidates for Dark Matter.

Unit 4 Structure & contents of the Milky Way Galaxy

Location of the Spiral Arms. 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. Mass distribution in the Milky Way. Mathematical models of the Milky Way. Galactic encounters of the Milky Way in its neighbourhood.

REFERENCES

10. James Binney: Galactic Astronomy: Structure and Kinematics of Galaxies
11. Elmegreen: Galaxies & Galactic Structure. Prentice Hall 1998.
12. Sparke and Gallagher: Galaxies in the Universe.
13. 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. University of Chicago Press.
9. Bowers and Deeming: Astrophysics Vols.1 and 2.
10. Baidyanath Basu: Introduction to Astrophysics.

Theory Paper AP-404: CB – 2. Galaxies and Universe

Unit – 1 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's 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. Broad band colors of galaxies.

Unit 2 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. Distribution of clouds. Radial gas density profiles.

Unit 3 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. Dark matter in galaxies. Dark matter in galactic clusters. Gravitational lensing.

Unit 4 Star formation in galaxies

Global star formation rates. Complexes and propagating star formation. Starburst galaxies, Active Galaxies. Star formation in Interacting galaxies. Role of galaxy interactions on evolution of galaxies. Seyferts, Radio galaxies and Quasars. The unified model of Quasars, Radio Galaxies and Seyferts. Importance of multi-wavelength studies of galaxies. Galaxy formation. Expansion of the universe.

Interpretation of the red-shift. CMBR. Fundamentals of cosmology – 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. Baidyanath Basu: 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.
2. Comparative analysis of H- R diagrams of open clusters to determine distances and ages using virtual educational observatory
3. Differential photometry and Light curve of variables
4. Photometric standardization

Practical Paper AS-452: 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).

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 2016-2017)
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	4	3	100	4
2	AP 302	Stellar Structure and Evolution	4	3	100	4
3	AP 303	Classical (Celestial) Mechanics	4	3	100	4
4	AP 304	CB – 1. Basics of Astronomy & Astrophysics CB – 2. Space physics	4	3	100	4
PRACTICALS						
5	AP Pr 351	Numerical Methods	8	3	100	4
6	AP Pr 352	Computer Applications	8	3	100	4
		Total:	**32**		**600**	**24**

SEMESTER – IV

S. No.	Sub. Code	Subject	Instructions Hrs/Week	Duration of Exam	Max. Marks	Credits
1	AP 401	Space Physics	4	3	100	4
2	AP 402	Astronomical Techniques	4	3	100	4
3	AP 403	Astrostatistics	4	3	100	4
4	AP 404	CB-1. The Milky Way Galaxy & ISM CB-2. Galaxies and Universe	4	3	100	4
PRACTICALS						
5	AP Pr 451	Photometry & Spectroscopy using IRAF and usage of Archival Data	8	3	100	4
6	AP Pr 452	Project Work	8	3	100	4
		Total:	**32**		**600**	**24**

SEMESTER -3

Theory Paper AP-301: Basic Astronomy

Unit - 1
Celestial Sphere and Time

Constellations and nomenclature of stars. The cardinal points and circles on the celestial sphere. Equatorial, ecliptic and galactic system of co-ordinates. Spherical triangle and related problems. Aspects of sky from different places on the earth. Twilight, Seasons, Sidereal. Apparent and Mean solar time and their relations. Equation of time. Ephemeris and Atomic Times. Calendar. Julian date and heliocentric correction.

Unit - 2
Apparent and Mean Position of stars

Effects of atmospheric refraction, aberration, parallax, precession, nutation and proper motion on the coordinates of stars. Reduction from apparent to mean places and vice versa.

Unit - 3
Stellar Distances and Magnitudes

Distances of stars from the trigonometric, secular and moving cluster parallaxes. Stellar motions. Magnitude scale and magnitude systems. Atmospheric extinction. Absolute magnitudes and distance modulus. Colour index. Black-body approximation to the continuous radiation and temperatures of stars. Variable stars as distance indicators.

Unit - 4
Binaries and Variable Stars

Visual, spectroscopic and eclipsing binaries. Importance of binary stars as source of basic astrophysical data. Classification and properties of various types of intrinsic and eruptive variable stars. Astrophysical importance of the study of variable stars. Novae and Supernovae.

REFERENCES

1. W.M.Smart: Text book of Spherical Astronomy.
2. A.E.Roy: Orbital Motion.
3. McCusky: 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. Baidyanath Basu: Introduction to Astrophysics.

Theory Paper AP-302: Stellar Structure and Evolution

Unit – 1

Fundamental Equations

Basic properties of stars and observational methods. 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 - 2

Stellar Models

Fundamental equations. Overall problem. Boundary conditions (central and surface). Russell-Vogt theorem. Polytropic model. Lane-Emden equation and its solution. Properties of polytropes. Applications (Polytrope for perfect gas, convective stars, Eddington model, solar polytrope). Hayashi Line. Hayashi Forbidden Zone. Homology transformations. Dimensional analysis: Mass – Luminosity and Mass – Radius relations.

Unit - 3

Stellar Evolution

Jean's criterion for gravitational contraction and its difficulties. Star forming regions. Protostars. T-Tauri stars. Brown Dwarfs. Pre-Main Sequence Evolution: Pre-Main Sequence contraction under radiative and convective equilibrium. HR diagrams. Hayashi tracks and Henyey tracks. Schoenberg-Chandrasekhar limit. Main-Sequence and Post Main Sequence Evolution of stars of different masses. Growth of isothermal core, Shell burning and subsequent development. Eddington Luminosity. Planetary Nebulae. Ages of galactic & globular clusters.

Unit - 4

Superdense Objects

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. Supernovae, Neutron stars, Black Holes. Pressure ionization and mass-radius relation for cold bodies. Maximum mass of a Neutron star. Masses of Stellar 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. K.D.Abhyankar: Astrophysics: Stars and Galaxies.
5. Baidyanath Basu: An Introduction to Astrophysics.
6. S.Chandrasekhar: Stellar Structure.
7. Cox and Guili: Principles of Stellar Interiors – Vol. I & II.
8. Shapiro and Tevkolsky: White Dwarfs, Neutron Stars and Black Holes.
9. R.Bowers and T.Deeming: Astrophysics.
10. Frank H. Shu: The Physical Universe.

Theory Paper AP-303: Classical (Celestial) Mechanics

Unit – 1
Newtonian Formulation and The Two Body Problem

Frames of reference. Generalised coordinates. Newton's laws of motion. Mechanics of a particle. Equations of motion of a particle. Mechanics of a system of particles. Law of Gravitation. 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. F and g series. Orbit computation by Laplace and Gauss methods.

Unit – 2
Three-Body Problem and The N-Body Problem

The Three Body Problem – its equations of motion. Lagrange's solution for the motion of three bodies. Restricted three body problem. Surfaces of zero relative velocity. Double points. Stability of straight line and equilateral triangle solutions. Tisserand's Criterion for identification of comets. The ten integrals of motion of the n-body problem. Transfer of origin to one of the particles. The perturbing function. Virial theorem.

Unit – 3
The Lagrangian Formulation

Constraints, Classification of Constraints, Principal of Virtual Work, D' Alembert's Principal, Lagrangian & Hamiltonian formulation of Mechanics. Equations of motion in Lagrangian formulation. Mechanics of a particle in Lagrangian formulation. Equations of motion of two body problem and three body problem in Lagrangian formulation. Cyclic or ignorable coordinates. Contact transformation, Hamilton-Jacobi partial differential equation.

Unit – 4
Rigid body motion and Orbital Mechanics

Euler's theorem. Euler's equations of motion. Euler's angles. Motion of a rocket. 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. R.G.Takwale and P.S.Puranik: Introduction to Classical Mechanics.
4. W.M.Smart: Text book of Spherical Astronomy.
5. A.E.Roy: Orbital Motion.
6. McCusky: Introduction to Celestial Mechanics.
7. K.D.Abhyankar: Astrophysics of the solar system.
8. F.R.Moulton: An Introduction to Celestial Mechanics.
9. Danby: Fundamentals of Celestial Mechanics.

Theory Paper AP-304 – CB -1. Basics of Astronomy & Astrophysics

(Course suited for students with Mathematics & Physics background at Graduation level)

Unit 1:

The Heavens Above

Celestial Sphere and Time

Constellations. The celestial sphere. Coordinate systems: Equatorial, ecliptic system. Seasons, Sidereal, Apparent and Mean solar time. Calendar. Julian date.

Stellar Distances and Magnitudes

Distance scale in astronomy. Determination of distances to planets and stars. Magnitude scale. Atmospheric extinction. Absolute magnitudes and distance modulus.

Unit 2:

Our Solar System

Theories of formation of the Solar System.

The Sun

Photosphere, chromosphere and corona of the Sun. Sun spots and magnetic fields on the sun. Solar activity, solar wind.

Planets and their Satellites

Surface features, atmospheres and magnetic fields of Earth, Moon and Planets. Satellites and rings of planets. Asteroids, Meteors, Meteorites and Comets.

Unit 3:

Stars: What are they?

Stars. Spectral classification. Energy generation in stars. Basics of Star formation & Evolution. The HR diagram.

Super dense objects - White dwarfs, Neutron stars & Pulsars. Black holes.

Unit 4:

The Milky Way Galaxy & Galaxies beyond

Structure of the Milky Way Galaxy

What are galaxies? Different types of galaxies. Hubble's classification. Structure, size & mass of the Milky Way galaxy. Position of our Sun and its motion around the galactic centre.

Cosmology

The expanding universe. Cosmological models: Big Bang and Steady State models. Dark matter

REFERENCES

1. H. Karttunen, P Kroger, H Oja, M Poutanen & K. J. Donner editors. Fundamental Astronomy.
2. W.M.Smart: Foundations of Astronomy..
3. Frank H. Shu: The Physical Universe-An Introduction to Astronomy.
4. K D Abhyankar: Astrophysics of the Solar System.
5. Baidyanath Basu: Introduction to Astrophysics.
7. Jayant Narlikar: Structure of Universe

Theory Paper AP-304 – CB -2. Space Physics

(Course suited for students of M. Sc., Earth Sciences)

Unit 1:

Introduction to space physics

Introduction to the Electromagnetic radiation, fundamentals of EM waves, effects of environment, propagation of waves, the sun and the solar corona, the sunspots and solar cycle, solar flares, solar wind and the heliosphere, planetary magnetospheres.

Unit 2:

Atmospheres

The Neutral atmosphere, atmospheric nomenclature, geopotential height, expansion and contraction, fundamental forces in the atmosphere, apparent forces, atmospheric composition, solar radiation interaction with the neutral atmosphere, climate change, atmospheric aerosols.

Unit 3:

Ionosphere

Formation of the ionosphere, morphology of ionosphere, the D, E and F-regions, Ionospheric variations, chemistry of the ionosphere, ionospheric parameters, E and F region anomalies and irregularities in the ionosphere, the aurora, Lyman glow of the night sky, the geo-corona and airglow studies, ionosondes.

Unit :4

Satellite Communication

Satellite System – Historical development of satellites – communication satellites – orbiting satellites – satellite frequency bands – satellite multiple access formats, satellite orbits and inclination – Look angles, orbital perturbations, space craft and its subsystems – attitude and orbit control system – Telemetry, Tracking and Command – Power system –Transponder – Reliability and space qualification – launch vehicles

REFERENCES

1. An Introduction to Dynamic Meteorology – James R Holton.
2. Climatology, An atmospheric Science – John E. Oliver and John J. Hindore.
3. Electronic Communication systems – George Kennedy and Bernard Davis.
4. Introduction to Ionospheric Physics – Henry Rishbeth and Owen K. Garriot.
5. Satellite Communication – Robert M. Gagliardi
6. Satellite Communication – Manojit Mitra

Practical Paper AP-351: Numerical Methods

1. Precision of measurements and accuracy of calculations.
2. Normal Distribution and method of least squares.
3. Numerical interpolation.
4. Numerical differentiation and integration.
5. Solution of ordinary differential equations.

Practical Paper AP-352: Computer Applications

1. Operating Systems : WINDOWS, UNIX/LINUX.
2. Editors : Word and vi
3. Numerical Analysis using available software.
4. Programming concepts: Language : C/ FORTRAN
5. Installation of IRAF.

REFERENCES

1. J.B.Scarborough: Numerical Analysis.
2. R.Subramanian. P. Achutan and K. Venkatesan (Translators): Numerical Analysis for Engineers and Physicists.
3. P.S.Grover: Programming and computing with FORTRAN IV.
4. M.K.Jain. S.R.K.Iyengar and R.K.Jain: Numerical Methods for Scientific and Engineering Computation.
5. R.C.Desai: FORTRAN Programming and Numerical Methods.

Theory Paper AP-401: Space Physics

Unit - 1

The Earth's Upper Atmosphere

Variations of atmospheric densities and temperature. Formation and structure of Ionosphere. Studies of ionosphere by ground based and space techniques. The radiation belts. Aurorae. Lyman glow of the night sky. The geo-corona and airglow studies. Atmospheric extinction, Aerosols, gases.

Unit - 2

Sun and Interplanetary Medium

Structure of solar atmosphere. Solar convection and differential rotation. Large scale and small scale magnetic fields. Solar granulation and super granulation. Sunspots. Solar flares. EUV, X-ray and gamma-ray studies of sun. Solar X-ray and radio bursts.

Solar wind. Interaction with planetary atmosphere. Structure of bow shocks. Magnetosphere. Ring Current. Radiation belts and interplanetary magnetic field. Interplanetary dust.

Unit - 3

Moon

Origin of the moon. Solar and Lunar eclipses. Lunar ranging experiments. Studies of lunar surface from various space missions and their results. Chandrayaan-I Mission. Satellites of other planets of the solar system.

Unit - 4

Planets

Infrared spectroscopy of planetary atmospheres. Exploration of Mars. Recent space missions to Mars. Indian MOM mission. Voyager space mission studies of outer planets and their satellites and rings. Comparative studies of planetary atmospheres. Planetary ionospheres. Extra-solar system planets (qualitative).

REFERENCES

1. J.A.Ratcliffe: An Introduction to the Ionosphere and Magnetosphere.
2. Kaula. W.M.: An Introduction to Planetary Physics.
3. Harold Zirin: Astrophysics of the Sun.
4. W.N.Hess and G.Mead(Ed): Introduction to Space Science.
5. V.Bedmtay and Kleczek: Basic Mechanism of Solar Activity.
6. Sagan C. Owen T. C. and Smith. H.J.: Planetary Atmospheres.
7. Kaufmann, W.J.: Exploration of the Solar System.
8. Baugher, J.F.: The space age solar system
9. K.D. Abhayankar: Astrophysics of the solar system.

Theory Paper AP-402: Astronomical Techniques

Unit 1

Telescopes

Basic Optics, Types of telescopes. Telescope mounting systems. Optical telescopes, Infrared, Ultraviolet, X-ray and Gamma-ray telescopes. Schmidt telescopes. Solar telescopes. Design and construction of a simple optical telescopes. Active and adaptive optics in astronomical study. Sky charts and their importance.

Unit 2

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, photometry and spectroscopy. Importance of space based astronomy. Observational techniques of astronomical sources from space in infrared, EUV, X-ray and Gamma-ray regions of the electromagnetic spectrum.

Unit 3

Photometry and Spectroscopy

Astronomical photometry. Simple design of an astronomical photometer. Observing technique with a photometer. Correction for atmospheric extinction. Transformation to a standard photometric system. Astronomical spectroscopy. Spectral classification. Simple design of astronomical spectrograph. Radial velocity measurements.

Unit 4

Radio Astronomical Techniques

Electromagnetic spectrum. Radio window. Antenna parameters. Various types of antennas. Non-steerable, partially steerable and fully steerable radio telescopes. Design and construction of a simple radio telescope. Receiver systems and their calibration. Design and construction of a simple radio interferometer. MST Radar for Ionospheric studies. LB and 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} edition).
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 (Cambridge Univ Press).
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-403: Astrostatistics

Unit 1
Basic Statistics

Diagrammatic and graphical presentation of data, tabulation of data, frequency distribution. Mean, Median, Mode. Standard deviation. Binomial, Poisson and Gaussian distributions. Concepts of probability theory, discrete and continuous random variables, bivariate probability distributions.

Unit 2
Regression & Testing of Hypothesis

Covariance, correlation and regression, point estimation, interval estimation. Testing of hypothesis –null hypothesis, alternate hypothesis, types of errors, critical and acceptance regions, level of significance. Large sample tests for mean(s), variances. Small sample tests - t, F and Chi-square, ANOVA - one way and two way classifications.

Unit 3
Multivariate Data Analysis

Categorical data analysis and model building. Principal components classification & discriminate analysis and clustering (k-means and hierarchical).

Unit 4
Data Mining and Analysis

Association rules, Neural networks, Decision trees, , – using case based methods for astronomy applications. Analysis of data from astronomical catalogues and public domain using R package.

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 by J.V.Hall, Cambridge Observing Handbook for Astronomers.
5. Modern Statistical Methods for Astronomy: with R Applications by Eric Feigelson and G Jogesh Babu.
6. Statistical Challenges in Modern Astronomy, edited by Eric Feigelson, G Jogesh Babu.
7. Data Mining Concepts & Techniques by Jiawei Han and Micheline Kamber. (Elsevier)

Theory Paper AP-404: CB – 1. The Milky Way Galaxy & Interstellar Matter

Unit 1
The Milky Way Galaxy

The structure, size and mass of the Milky Way Galaxy. Methods of determining the mass of our galaxy. Stellar populations in the Milky Way. Position of our Sun in the Galaxy. Distribution of Gas in the Milky Way. The interstellar medium – its composition and properties. Amount of interstellar matter. Oort limit. Interstellar extinction. Estimate of colour excess. Visual absorption. Interstellar reddening law and Polarization. 21-cm line observations. Interstellar magnetic fields in the Milky Way. Stromgren's theory of H II regions.

Unit 2
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. Statistical parallaxes. Peculiar velocities. Bottlinger's diagram. Spiral structure in the Milky Way. Determination of its structure from optical and radio observations.

Unit 3
Spiral Wave Kinematics

Epicycles, Spiral density Waves, Resonances. Resonance features. Motion of stars near the center of the Milky Way. Inference of the presence of supermassive black hole at the center. Rotational curve and its interpretation. Dark Matter. Candidates for Dark Matter.

Unit 4
Structure & contents of the Milky Way Galaxy

Location of the Spiral Arms. 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. Mass distribution in the Milky Way. Mathematical models of the Milky Way. Galactic encounters of the Milky Way in its neighbourhood.

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. University of Chicago Press.
9. Bowers and Deeming: Astrophysics Vols.1 and 2.
10. Baidyanath Basu: Introduction to Astrophysics.

Theory Paper AP-404: CB – 2. Galaxies and Universe

Unit – 1

Fundamental concepts

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's 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. Broad band colors of galaxies.

Unit 2

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. Distribution of clouds. Radial gas density profiles.

Unit 3

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. Dark matter in galaxies. Dark matter in galactic clusters. Gravitational lensing.

Unit 4

Star formation in galaxies

Global star formation rates. Complexes and propagating star formation. Starburst galaxies, Active Galaxies. Star formation in Interacting galaxies. Role of galaxy interactions on evolution of galaxies. Seyferts, Radio galaxies and Quasars. The unified model of Quasars, Radio Galaxies and Seyferts. Importance of multi-wavelength studies of galaxies. Galaxy formation. Expansion of the universe. Interpretation of the red-shift. CMBR. Fundamentals of cosmology – 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. Baidyanath Basu: Introduction to Astrophysics. Prentice Hall of India, 2004.
11. Jayant Narlikar: Introduction to Cosmology. Jones & Bartlett Publishers, Inc, 1998.

Practical Paper AP-451: Photometry & Spectroscopy using IRAF and usage of Archival Data

1) Photometry

a) DS9
b) Ximtool
c) Imexamine
d) Apphot

2) **Spectroscopy**

a) Twodspec
b) Apextract
c) Apall
d) Wavelength calibration
e) Splot

3) Archival Data

a) SIMBAD
b) VIZIER
c) NED
d) HEASARC

Practical AP-452: Project Work

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