M.Sc. (Physics) Optional Papers in A & A - Sample Syllabus

Inter-University Centre for Astronomy and Astrophysics (IUCAA), Pune
These are sample syllabi for three special/optional papers in M.Sc. (Physics). Any two papers may be adopted.

ASTRONOMY and ASTROPHYSICS, Special Paper I

Module I: Solar System and Stars

1. The solar system	5 lectures
Celestial mechanics Elliptical orbits Kepler's laws Virial theorem	2
Earth-moon system Tidal forces Precession of earth's axis Interiors Atmospheres	2
Planets Terrestrial planets Jovian planets	1
2. Observational tools	6 lectures
Blackbody radiation Specific intensity and flux density	1
Stellar parallax Magnitudes Colour index	1
Basic optics and optical telescopes	1
Radio telescopes	1
Infrared, ultraviolet and X-ray telescopes	1

Coordinates and time 1

3. Sta 7 lectures

Classification 2
Formation of spectral lines
Hertzsprung-Russell diagram
Atmosphere 5
Description of the radiation field
Opacities
Radiative transfer
Structure of spectral lines

4. Sun 5 lectures

Interior
Atmosphere
Solar activity
Helioseismology

Module II: Stellar Structure and Evolution

1. Stellar interiors 7 lectures

Hydrostatic equilibrium
Pressure equation of state
Energy sources
Energy transport and convection
Model building
Main sequence

2. Binary stars 5 lectures

Classification
Mass determination
Accretion disks in close binaries

White dwarfs, neutron stars and black holes in binaries

3. Star formation 3 lectures

Interstellar dust and gas
Formation of protostars
Pre-main sequence evolution

4. Post main sequence evolution 3 lectures

Evolution on the main sequence
Late stages of evolution
Fate of massive stars, supernovae

5. Degenerate remnants of stars 4 lectures

White dwarfs
Chandrasekhar limit
Neutron stars
Pulsars

Tutorials will involve problem solving on the topics of the course.

Laboratory Experiments:

1. Polar aligning a telescope and measuring declination of Polaris.
2. Measuring distance to Moon by parallax method.
3. Measuring limb-darkening of Sun.
4. Finding rotation period of Sun by measuring motion of sun-spots.
5. Measuring relative sensitivity of B, V, and R bands of a photometer with Sun and using this to find temperature of filament of a lamp.
6. Measuring colour of a star by differential photometry.
7. Measuring extinction of the atmosphere in B, V, and R bands.
8. Characterising a CCD camera for gain, read-noise, linearity, and flat field.
9. Estimating atmospheric seeing by measuring differential motion.
10. Measuring stellar scintillations for different zenith angles and comparing it with scintillations for planets.

Text books:

1. Modern Astrophysics, B. W. Carroll and D. A. Ostlie, Addison-Wesley Publishing Co.
2. Introductory Astronomy & Astrophysics, M. Zeilik and S. A. Gregory, 4th Edition, Saunders College Publishing.
3. Theoretical Astrophysics, Vol II:Stars and Stellar Systems, T. Padmanabhan, Cambridge University Press.

Other books:

1. The Physical Universe: An Introduction to Astronomy, F. Shu, Mill Valley : University Science Books.
2. Textbook of Astronomy and Astrophysics with Elements of Cosmology, V. B. Bhatia, Pb-New Delhi, Narosa Publishing House.
3. The New Cosmos, A. Unsold and B. Baschek, New York:Springer Verlag.

ASTRONOMY and ASTROPHYSICS, Special Paper II

Module I : High Energy Astrophysics

1. Radiative processes in astrophysics 10 lectures

Synchrotron emission
- for a single particle
- for an ensemble of electrons
Energy loss and electron spectrum
Compton scattering
Multiple Compton scattering
Bremstrahlung
Thermal bremstrahlung

2. Binary stars 7 lectures

White dwarf binaries
Neutron star and black hole binaries
HulseTaylor binary pulsar

3. Accretion discs 5 lectures

Thin accretion discs
Thick accretion discs
Accretion discs in binaries
Accretion discs in galactic nuclei

Module II: Galaxies

1. The Milky Way Galaxy 5 lectures

Distribution of stars
Morphology
Kinematics
Interstellar medium
Galactic Centre

2. Nature of galaxies 4 lectures

Hubble sequence
Spirals and irregular galaxies
Spiral structure
Elliptical galaxies

3. Galactic evolution 4 lectures

Interaction of galaxies
Formation of galaxies

4. Structure of the universe 5 lectures

Extragalactic distance scale
Expansion of the universe
Clusters of galaxies

5. Active galaxies and quasi-stellar objects 5 lectures

Observations
Unified model
Radio lobes and jets
Using QSOs to probe the universe
Gamma ray bursts

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Text books:

1. Quasars and Active Galactic Nuclei, A. K. Kembhavi and J. V. Narlikar, Cambridge University Press.
2. Modern Astrophysics, B. W. Carroll and D. A. Ostlie, Addison-Wesley Publishing Co.
3. Introductory Astronomy & Astrophysics, M. Zeilik and S. A. Gregory, 4th edition, Saunders College Publishing.
4. Theoretical Astrophysics, Vol I:Astrophysical Processes, T. Padmanabhan, Cambridge University Press.

Other books:

1. The Physical Universe: An Introduction to Astronomy, F. Shu, Mill Valley : University Science Books.
2. Textbook of Astronomy and Astrophysics with Elements of Cosmology, V. B. Bhatia, Pb-New Delhi, Narosa Publishing House.
3. The New Cosmos, A. Unsold and B. Baschek, New York:Springer Verlag.
4. Introduction to Cosmology, J. V. Narlikar, 3rd edition, Cambridge University Press.
5. Structure Formation in the Universe, T. Padmanabhan,Cambridge University Press.

ASTRONOMY and ASTROPHYSICS, Special Paper III

Module I: General Relativity (GR)

1. Overview of special relativity 4 lectures

- Principles of special relativity
- Line interval
- Proper time
- Lorentz transformation
- Minkowski spacetime
- Lightcones
- Relativistic momentum
- 4-vectors
- Lorentz transformation of electromagnetic field

2. Conceptual foundations of GR and curved spacetime 12 lectures

- Principle of equivalence
- Connection between gravity and geometry
- Form of metric in Newtonian limit
- Metric tensor and its properties
- Concept of curved spaces and spacetimes
- Tangent space and four vectors
- Tensor algebra
- Tensor calculus
- Covariant differentiation
- Parallel transport
- Riemann curvature tensor
- Geodesics
- Particle trajectories in gravitational field

3. Dynamics of gravitational field 4 lectures

- Einstein's field equations
- Definition of the stress tensor
- Bianchi identities and conservation of the stress tensor
- Einstein's equations for weak gravitational fields
- The Newtonian limit

4. Schwarzschild metric and related topics 5 lectures

Derivation of Schwarzschild metric
Basic properties of Schwarzschild metric coordinate-
systems and nature of R=2M surface
Effective potential for particle orbits in Schwarzschild metric, general properties
Precession of perihelion
Deflection of ultra relativistic particles
Gravitational red-shift

Module II: Applications of GR

1. Gravitational waves 5 lectures

Wave equation in linearised theory
Plane waves
Transverse traceless gauge
Effect on test particles
Principles of detection and generation of gravitational waves
Types of detectors
Landau-Lifshitz formula
Hulse Taylor binary pulsar

2. Cosmology - 15 lectures

Models of the universe 5

Friedmann-Robertson-Walker models
Hubble's law
Angular size
Source counts
Cosmological constant
Horizons

Relics of the big bang 3

The early universe
Thermodynamics of the early universe
Primordial neutrinos
Helium synthesis and other nuclei
Microwave background

Formation of large scale structure 3
Jeans mass in the expanding universe
Growth in the postrecombination era
Observational constraints
Elementary ideas on structure formation

Observations of the cosmological significance 4
Measurement of Hubble's constant
Anisotropy of large-scale velocity fields
Age of the universe
Abundance of light nuclei
Dark matter
Microwave background
Gravitational wave stochastic background.

Tutorials will involve problem solving on the topics of the course.

Text Books:

1. General Relativity and Cosmology, J. V. Narlikar Delhi: Macmillan company of India Ltd.
2. General Relativity, I. R. Kenyon, Oxford university press.
3. Classical Theory of Fields, Vol. 2, L. D. Landau and E. M. Lifshitz, Oxford : Pergamon Press.
4. First course in general relativity, B. F. Schutz Cambridge: Cambridge university press.
5. Introduction to Cosmology, 3rd Edition, J. V. Narlikar, Cambridge University Press.