M. Sc. (Astrophysics)

Scheme & Syllabus

2011-12 Onwards
M.Sc. Programme in Astrophysics

Department of Physics will mentor the M.Sc. Programme in Astrophysics, which is to be introduced from the academic year 2011-12.

Astronomy is one of the oldest fields of scientific enquiry. It is an observational science that studies celestial objects (planets, stars, galaxies ...) that make up the Universe and phenomena that may hold the key to understand their nature, as well as the origin and evolution of the Universe. Astrophysics deals with the physics of the Universe and applies many disciplines of physics, including mechanics, electromagnetism, statistical mechanics, thermodynamics, quantum mechanics, relativity, nuclear and particle physics, and atomic and molecular physics.

Indian astronomers and physicists, in ancient as well as in recent times have made important contributions to Astronomy and Astrophysics. Today, a number of institutions (IIA, IUCAA, ARIES, TIFR, PRL, OU...) and facilities (ground-based optical/infrared telescopes at VBO, Hanle, Girawali, Nainital, Mt. Abu; radio telescopes at Ooty, GMRT, Gauribidanur) for research in astronomy and astrophysics exist in the country. Also, space-based facilities like ASTROSAT, ADITYA for work in X-ray, Ultraviolet/Optical and High-Altitude facilities (HAGAR, MACE..) for work in the Gamma-ray waveband are coming up. India is also planning to join the International Astronomy Community in the development of a Giant Segmented Mirror Telescope (GSMT).

There is, however, an acute shortage of young students with adequate background in basic astronomy/astrophysics who could take up research in astronomy/astrophysics and use these state-of-the-art facilities. In most Indian universities, there are no teaching programmes at the MSc level fully devoted to astronomy/astrophysics. The proposed M.Sc Programme in Astrophysics of the Pondicherry University is intended to bridge this gap and help train bright, motivated, young students to take up research careers in astrophysics.

This M.Sc. programme is designed to impart sound understanding of basic physics, astrophysical processes and the necessary background knowledge of present-day developments in astronomy including practical training in instrumentation and observations at astronomical observatories in the country. The Pondicherry University is planning to introduce M.Sc. Astrophysics from this academic year, 2011-2012.

In addition to main papers covering the core areas in Physics, the programme is planned to cover advanced courses in Astrophysics including the following by experts in the relevant fields.

- Stellar Structure
- Diffuse Matter in Space
- Galactic Structure & Dynamics
- Stellar Evolution
- Physics of Compact Objects
- General Relativity and Cosmology

The students who pass out of this course will have good job and research opportunities.
Details of the programme

Programme Duration:
Two years (Four Semesters); Total number of credits: 77

Eligibility criteria:
B.Sc. Physics/Electronics/Mathematics/Applied Physics with a minimum percentage of 55 marks in part III.

Admission criteria:
Pondicherry University – All India Entrance Examination: The questions will have emphasize in undergraduate level Physics

Intake: 10 students

Teaching and Learning Methods:
Lectures, tutorials and seminars form the main methods of course delivery enhanced by individual and group project work, laboratory work, computing workshops and industrial/Institution visits. Some of the specialized courses will be conducted in coordination with the Faculty of Indian Institute of Astrophysics, Bangalore/ IUCAA, Pune in Pondicherry or Bangalore/Pune.

Assessment Methods:
Assessment will be as per Choice Based Credit System (CBCS) which includes continuous assessment and end semester examinations.

Scheme of Courses and Credits for M.Sc. Astrophysics:

<table>
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<tr>
<th></th>
<th>Odd semester</th>
<th>Even Semester</th>
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</thead>
<tbody>
<tr>
<td><strong>First year</strong></td>
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<tr>
<td>Compulsory subjects</td>
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<td>Elective Subjects</td>
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<td><strong>Second year</strong></td>
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<tr>
<td>Elective Subjects</td>
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<td>Practical – Laboratory</td>
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<td>Project</td>
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</tbody>
</table>

*Depending on Students choice & faculty availability all three or two Groups (A/B/C) will be offered
## PONDICHERRY UNIVERSITY
### 2 year M. Sc (Astrophysics) Programme

### CONTENTS

#### Semester – I

<table>
<thead>
<tr>
<th>S. No</th>
<th>Code</th>
<th>Course Name</th>
<th>Type</th>
<th>Credits</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>APHYS-110</td>
<td>Physics Laboratory</td>
<td></td>
<td>2</td>
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<td>HC</td>
<td>4</td>
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<td>3</td>
<td>APHYS-112</td>
<td>Classical Mechanics</td>
<td>HC</td>
<td>4</td>
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<tr>
<td>4</td>
<td>APHYS-113</td>
<td>Quantum Mechanics - I</td>
<td>HC</td>
<td>4</td>
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<tr>
<td>5</td>
<td>APHYS-114</td>
<td>Electronics</td>
<td>HC</td>
<td>4</td>
<td></td>
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<tr>
<td>6</td>
<td>APHYS-115</td>
<td>Numerical and Transform Techniques</td>
<td>SC</td>
<td>3</td>
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<tr>
<td>7.</td>
<td>APHYS-116</td>
<td>Programming in C and C++</td>
<td>SC</td>
<td>3</td>
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</table>

#### Semester – II

<table>
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<th>S. No</th>
<th>Code</th>
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<th>Type</th>
<th>Credits</th>
<th>Page</th>
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<tbody>
<tr>
<td>1</td>
<td>APHYS-120</td>
<td>Electronics Laboratory</td>
<td></td>
<td>2</td>
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</tr>
<tr>
<td>2</td>
<td>APHYS-121</td>
<td>Statistical Physics</td>
<td>HC</td>
<td>4</td>
<td></td>
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<tr>
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<td>APHYS-122</td>
<td>Electrodynamics</td>
<td>HC</td>
<td>4</td>
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<td>Quantum Mechanics II</td>
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<td>APHYS-124</td>
<td>Nuclear and Particle Physics</td>
<td>HC</td>
<td>4</td>
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<td>APHYS-125</td>
<td>Microprocessors and Applications</td>
<td>SC</td>
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#### Semester – III

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<th>Type</th>
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<th>Page</th>
</tr>
</thead>
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<tr>
<td>1</td>
<td>APHYS-230</td>
<td>Optics Laboratory</td>
<td></td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>APHYS-231</td>
<td>Fundamentals of Astrophysics</td>
<td>HC</td>
<td>4</td>
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<tr>
<td>3</td>
<td>APHYS-232</td>
<td>Radiative Process</td>
<td>HC</td>
<td>4</td>
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</tr>
<tr>
<td>4</td>
<td>APHYS-233</td>
<td>Stellar Physics</td>
<td>HC</td>
<td>4</td>
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<tr>
<td>5</td>
<td>APHYS-234</td>
<td>Fluids and Plasmas</td>
<td>HC</td>
<td>4</td>
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<tr>
<td>6</td>
<td>APHYS-235</td>
<td>Astronomical Techniques</td>
<td>HC</td>
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#### Semester – IV

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<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>APHYS-240</td>
<td>Project work</td>
<td>HC</td>
<td>4</td>
<td></td>
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<tr>
<td>2</td>
<td>APHYS-241</td>
<td>Gen. Relativity and Cosmology</td>
<td>SC</td>
<td>3</td>
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<tr>
<td>3</td>
<td>APHYS-242</td>
<td>Physics of Compact Objects</td>
<td>SC</td>
<td>3</td>
<td></td>
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<td>4</td>
<td>APHYS-243</td>
<td>Diffuse Matters in Space</td>
<td>SC</td>
<td>3</td>
<td></td>
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<tr>
<td>5</td>
<td>APHYS-244</td>
<td>Stellar Atmospheres</td>
<td>SC</td>
<td>3</td>
<td></td>
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<tr>
<td>6</td>
<td>APHYS-245</td>
<td>Galactic Structure</td>
<td>SC</td>
<td>3</td>
<td></td>
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<tr>
<td>7</td>
<td>APHYS-246</td>
<td>Sun and Solar System</td>
<td>SC</td>
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</tr>
</tbody>
</table>
UNIT – I: Linear Algebra
Linear vector spaces – Dual space – Basis sets – Orthogonality and completeness – Hilbert space – Linear operators – Linear dependence and independence

UNIT – II: Vectors and Tensors

UNIT – III: Complex Variables

UNIT – IV: Special Functions

UNIT – V: Differential Equations

Textbooks

Supplementary Reading
### APHYS-112: CLASSICAL MECHANICS

**Unit I:** 15 hours

### Unit II: 15 hours

### Unit III: 15 hours

### Unit IV: 15 hours
Special theory of relativity: Inertial frames – Lorentz transformations – length contraction, time dilation and Doppler effect – Minkowski space – Energy momentum four vectors – Introduction to general relativity.

**Text Book**

**Supplementary Reading**
APHYS-113: QUANTUM MECHANICS -I (4 credits)

Unit I: Quantum theory of spherically symmetric systems 12 hours

Unit II: Symmetry in Quantum Mechanics 6 hours
Symmetries, Conservation laws, and Degeneracies – Discrete symmetries, Parity, or Space Inversion – Lattice translation as a discrete symmetry – Time reversal discrete symmetry.

Unit III: Pictures of Quantum Mechanics 6 hours

Unit IV: Time independent perturbation theory 12 hours

Unit V: Variational Principle and WKB approximation 6 hours
The ground state of helium – The hydrogen molecular ion – WKB approximation – Tunneling through potential barriers.

Quantum theory of scattering 12 hours

Textbooks

Supplementary Reading
2. Dicks and Whike. Introduction to quantum mechanics.
APHYS-114: ELECTRONICS  (4 credits)

Unit I  

Unit II  

Unit III  
Analog circuits: Linear circuits – operational amplifiers – parameters and their importance applications – Summing, difference, inverting, non-inverting, integrating, differentiating amplifiers – Non-linear circuits – absolute rectifiers, Clipping, Clamping circuits, logarithmic amplifiers, Filters, modulation and demodulation circuits, Timers and Phase-locked loop.

Unit IV  
Digital circuits: Combinational logic circuits using standard TTL and CMOS LSI chips- gates, latches, multiplexer/demultiplexer, decoder and encoders, Half and full adder, ALU. Sequential logic circuits – Counters – synchronous, asynchronous, binary and decade, divide by N counters, Shift registers – Serial to parallel and vice-versa.

Unit V  

Textbooks
1. Unit I & III – Integrated Electronics by Millman & Halkias
2. Unit II (first part) – Physics of Semiconductor devices by Simon M.Sze.
3. Unit II (for microwave topics) – Electronic and Radio Engineering by Terman
4. Unit IV – Digital Principles by Malvino & Leach
5. Unit V – Microprocessor Architecture and Programming 8085 by Ramesh S. Gaonker.


Textbooks

Supplementary Reading
APhys – 116: Programming in C and C++ (3 credits)

Unit I: Unix Operating System 12 hours

Unit II: Elements of C Programming Language
Algorithms and flowchart; Structure of a high level language program; Features of C language; constants and variables; expressions; Input and output statements; conditional statements and loop statements; arrays; functions; character strings; structures; pointer data type; list and trees.

Unit III: C++ 12 hours

Unit IV: Laboratory Exercise Session 12 hours

Textbooks

Supplementary Reading
General Experiments
1. Faraday effect using white light.
2. Determination of Lande's g factor of electron by ESR.
4. Thermal diffusivity of brass.
5. Determination of polarization and dipole moment of a liquid.
6. Fourier analysis of a square wave.
7. Study of superconductivity.
11. Study of black body radiation and verification of Wien's law using prism based spectrometer.
12. Determination of wavelengths of H and He spectra using grating based spectrometer.
15. Verification of Coulomb's law.
17. Determination of speed of light in air by Foucault's rotating mirror.
18. Measurement of charge to mass ratio (e/m) of an electron using Helmholtz coil.
19. Hall Effect
20. Band gap measurements with four probe method

Electronics Experiments
1. Integrator and differentiator using operational amplifier.
2. Wein bridge oscillator using operational amplifier.
4. Study of multivibrators using operational amplifier.
5. Logic gates and Boolean algebra.
6. Half and full adder using logic circuits.
7. Decoders using logic circuits.
8. Study of flip flops.

Text Books
**APHYS- 121 – STATISTICAL PHYSICS**  
(4 credits)

**Unit I: Ensemble and equilibrium**  
15 hours  

**Unit II: Partition function and its application**  
15 hours  

**Unit III: Quantum Statistics**  
15 hours  

**Unit IV: Advanced topics**  
15 hours  
Phase transitions- First and second order phase transitions- critical point- order parameter- Scaling hypothesis- critical exponents - ferromagnetic phase transition- Ising model- Bragg William approximation- fluctuations in ensembles- One dimensional random walk- power spectrum- electrical noise- Non-equilibrium statistical mechanics- Onsager reciprocity relations, thermo-electric phenomena.

**Text Book**  

**Supplementary Reading**  
5. F. Mandl. Statistical Physics. ELBS.  
APPHYS – 122: ELECTRODYNAMICS

UNIT – I: Boundary value problems & Special techniques
15 hours
Boundary conditions and uniqueness theorems — Conductors and second uniqueness theorem — Boundary value problems with linear dielectrics — Multipole expansion — Origin of coordinates in multipole expansions.

UNIT – II: Magnetostatics and Electrodynamics
15 hours
Lorentz force law and Biot-Savart law — Scalar and vector potentials — Multipole expansion of vector potential — Calculation of field of a magnetized object — Ampere’s law in magnetized materials and Auxiliary field $H$ — Magnetostatic boundary conditions — Faraday’s law and Lenz’s law — Calculation of energy density in magnetic fields — Electrodynamics before Maxwell — Maxwell’s correction of Ampere’s law — Derivation of Maxwell’s equations in vacuum and in matter.

UNIT – III: Electromagnetic waves
15 hours

UNIT – IV: Potentials and Radiation
15 hours

Textbook

Supplementary Reading
APHYS-123: ATOMIC AND MOLECULAR PHYSICS  (4 credits)

Unit I: Classical Theory of Radiation  12 hours

Unit II: Quantum Theory of Radiation  12 hours

Unit III: Time dependent perturbation theory  12 hours

Unit IV: Microwave Spectroscopy:   12 hours

Unit V: Raman Spectroscopy:  12 hours

Textbooks
T. M. Sugdan and C. N. Kennay. Microwave Spectroscopy of Gases.
Tores and Schawlow. Microwave Spectroscopy, McGraw Hill.
Schnoider and Berstin. High Resolution NMR. McGraw Hill.
Assenheim. Introduction to ESR. Plenum Press.
Unit I: Nuclear Properties and Nuclear Models: 12 hours
Basic nuclear properties: nuclear size, Rutherford scattering, nuclear radius and charge distribution, nuclear form factor, mass and binding energy, Angular momentum, parity and isospin symmetry, Magnetic dipole moment and electric quadrupole moment; Liquid drop model of the nucleus, Bethe-Weizsäcker binding energy/mass formula, Fermi model, Shell model and collective model, super-heavy nuclei.

Unit II: Nuclear Forces – 2-body bound state and scattering: 12 hours
Nature of nuclear forces: charge independence, charge symmetry and isospin invariance of nuclear forces; the Deuteron problem – properties of deuteron, Schrödinger equation and its solution for ground state of deuteron, rms radius; spin dependence of nuclear forces, electromagnetic moment and magnetic dipole moment of deuteron and the necessity of tensor forces; n-p and p-p scattering at low energy, partial wave analysis and phase shifts, scattering length, significance of the sign of scattering length, effective range theory, Wigner's hypothesis, introductory ideas about Bartlett, Majorana and Heisenberg exchange forces, Yukawa meson theory.

Unit III: Nuclear Decay and Nuclear Reactions: 12 hours
Stability of nuclei, β decay and electron capture, gamma decay, Fermi’s theory of allowed β decay, Selection rules for Fermi and Gamow-Teller transitions, Parity non-conservation and Wu’s experiment. Nuclear Reactions: different types of reactions, quantum mechanical theory, resonance scattering and reactions — Breit-Wigner dispersion relation; compound nucleus formation and break-up, statistical theory of nuclear reactions and evaporation probability, optical model; principle of detailed balance, transfer reactions, nuclear fission – cross section, fission products, spontaneous fission; nuclear fusion – thermo-nuclear reactions.

Unit IV: Elementary Particle Physics – Basic concepts: 12 hours
Historical introduction to Elementary Particles: photon and electron, mesons, Dirac equation and antiparticles, neutrinos, strange particles, quark model of hadrons; quarks and leptons as the fundamental constituents of all matter, interactions between fundamental particles – Strong, Electromagnetic and Weak interactions; kinematics of basic particle interaction processes: photon-electron processes – photoelectric, Compton and pair-production processes; low energy weak interactions involving neutrino – Fermi theory; neutrino physics – theory of 2-flavour oscillation, solar and atmospheric neutrino anomalies, neutrino experiments.; basic particle detectors – ionization counters, proportional counters, GM counters, scintillation detectors, Cherenkov detectors.

Unit V: Elementary Particle Physics – Symmetries 12 hours
Symmetries, Groups and Conservation Laws; classification of hadrons by isospin and hypercharge, SU(2) and SU(3); discrete symmetries – parity (P) and charge conjugation (C); CP violation in neutral kaon system; particle decays and conservation laws; CPT theorem (statement only); basic ideas of gauge symmetries – electrodynamics as a gauge theory, non-abelian gauge symmetries as the basis of strong and weak interactions; color quantum number and basic ideas of quantum chromodynamics (QCD), asymptotic freedom, gluons, and jets in electron-positron collisions; basic ideas of spontaneous symmetry breaking, and higgs boson; the basic idea of unification of forces – electro-weak unification, the Standard Model of Particle Physics and Grand Unified Theories; verification of Standard Model with high energy particle colliders.

Text books
2. J.M. Reid, The atomic nucleus (Manchester University Press, 1984)
3. K. Heyde, Basic ideas and concepts in nuclear physics: an introductory approach, 2nd ed. (Institute of Physics, Bristol, 1999).
APHYS-125 MICROPROCESSORS AND APPLICATIONS (3 credits)

Unit I: Architecture of 8 bit Microprocessor 12 hours

Unit II: Assembly Language Programming 12 hours

Unit III: Digital Interfacing 12 hours

Unit IV: Trends in Microprocessor Technology 12 hours

Textbooks
Condensed Matter Physics Experiments:
1. X-ray diffraction.
2. Impedance spectroscopy.
3. Infrared spectroscopy.
4. Differential scanning calorimetry with thermal analysis.
5. UV-VIS-IR spectroscopy.
6. High field magnetic hysteresis using VSM.
7. Superconductivity.
8. Emission spectroscopy.

Electronics Experiments:
1. First order active filters using operational amplifier.
2. Second order active filters using operational amplifier.
3. Counters and registers using logic circuits.
4. Decade counting unit.
5. Study of 8-bit microprocessor.
7. Study of 8051 microcontroller.
8. Study of lockin amplifier.
9. Amplitude modulation.
10. Detection of AM signals.
11. Study and detection of Frequency modulation.
12. Pulse modulation.
15. LabVIEW and Virtual instrumentation laboratory.

LASER Experiments:
1. Numerical aperture of optical fiber and propagation of light through optical fiber.
2. Intensity profile of laser through optical fiber and determination of refractive index profile.
3. Refractive index by Brewster angle setup.
5. Study of electrooptic effect (Pockel effect) with AC modulator.
7. Study of acoustooptic effects.
9. Study of laser beam characteristics (beam divergence, spot size, intensity profile) using He-Ne laser.
10. Digital holography.
11. Fiber optics experiments.
12. Determination of wavelength of He-Ne laser with Michelson interferometer
13. Determination of wavelength of He-Ne laser with Fabry-Peort interferometer
14. Determination of the refractive index of the air and glass slab.
15. To verify the Malus law for light polarization
16. To determine the light intensity vs distance relationship for the point source of light
17. Single slit and double slit diffraction experiment
18. Zeeman Effect

Text Books
APHYS 231- FUNDAMENTALS OF ASTROPHYSICS

9 hours

Unit 1: Introductory astronomy: History of Astronomy; Overview of the major constituents of the universe; Solar System, Planets - laws of motion of planets, inner planets, outer planets; Extrasolar planets- Methods of detection of extrasolar planets; Black body radiation-specific intensity, luminosity; Basics of radiative transfer-emission coefficient, absorption coefficient, source function

9 hours

Unit 2: Stellar Astronomy: Stars-general Distances to stars - trigonometric parallax; Stellar brightness - luminosity, flux, apparent magnitude, magnitude system, distance modulus, colour index, extinction, colour temperature, effective temperature, Stellar masses and radii – measuring masses, binary stars - visual binary, eclipsing binary, spectroscopic binary; Measuring stellar radii; Stellar spectra – colours of stars, Motion of stars-radial velocity, proper motion, spectral classification of stars, luminosity classification of stars, HR diagram, Stellar population- Population I and II, Star clusters-open clusters, globular clusters, Variable stars; Energy generation in stars: PP chain

9 hours

Unit 3: Galactic astronomy: Milky way; Hubble classification of galaxies-Spiral galaxies, Elliptical galaxies, Irregular galaxies, Dwarf galaxies; Masses of galaxies-Rotation curves of galaxies; Dark matter

9 hours

Unit 4: Extragalactic Astronomy: Groups and clusters of galaxies, Interacting galaxies; Active galaxies- Seyfert galaxies, radio galaxies, FRI and FRII sources, Quasars- accretion, accretion efficiency, superluminal motion, Eddington luminosity; radiation mechanisms in active galaxies; gravitational lensing

9 hours

Unit 5: Cosmology: Distances- direct distances-trigonometric parallax; indirect distances-standard candles, main sequence fitting, cepheids variables, RR Lyrae variables, Supernovae, gravitational lensing; Expansion of the universe-Hubble's law, redshift; Newtonian Cosmology; microwave background, early universe

References:
Shu F., The physical universe, University of California, 1982
Harwit M. Astrophysical concepts
Fundamental Astronomy
Radiative processes in Astrophysics, G. B. Rybicki & Lightman A. P.
APHYS 232 RADIATIVE PROCESSES

(3 credits)

9 hours


9 hours


9 hours


9 hours


9 hours


References:
Unit 1: Introduction to stars: HR diagram, a discussion on the variety of stellar phenomena.

Unit 2: Stellar Structure: The equations of stellar structure; stellar opacities; Lane-Emden equation and stellar polytropes.

Unit 3: Energy Generation in Stars: Calculation of thermonuclear reaction rates for resonant, non-resonant and beta-decay reactions; the various reaction chains: pp-I, II, III and CNO cycle; He-burning, C-burning, Si-burning, photo-dissociation. Neutrino emission from stars: The solar neutrino "problem" and its solution, neutrinos from supernovae; terrestrial detection of stellar neutrinos

Unit 4: Stellar degeneracy and Equations of State (EoS): Stellar degeneracy; Chandrasekhar mass, EoS of matter at near-nuclear and nuclear densities

Unit 5: Final stages of stellar evolution: Supernovae (a basic understanding of the core-collapse process and the structure of the progenitor); Neutron stars (NS) - a basic knowledge of NS structure; an overview of the problems associated with determining a unique equation of state for NS; various manifestations of NS.
Unit 1: Fluids and plasmas, the universal states of matter- an overview  
9 hours

Collective and quasi-neutral, electrostatic potential in a plasma, Debye screening, Coulomb collisions, Electric resistivity, Optical properties of a plasma, Coherent radiation, Strongly coupled plasma, Dusty Plasma, Techniques for studying plasmas, Waves and instabilities in plasmas, Plasmas in curved space-time, Neutral fluids, Statistical description of a system of large number of particles: Phase space, Gibb’s ensemble, Liouville equation, Distribution functions, Correlation functions, One particle distribution function, BBGKY hierarchy, Collisionless Boltzmann equation, Self consistent force, Vlasov equation, The Boltzmann collision model, the Krook collision model, The Fokker-Planck collision model, application to stellar systems, The Kinetic and the fluid descriptions, fluid velocity, stress tensor, pressure, shear stresses, Mass, momentum and energy conservation laws, Plasmas as electromagnetic fluids, Maxwell equations, Two-fluid description of a plasma, Magnetohydrodynamics- the single fluid description of a plasma, Mass, momentum and energy conservation laws,

Unit 2: Charged particle motion in electromagnetic and gravitational fields  
9 hours

Why study single particle motion, motion in a uniform magnetic field, in a uniform electric and magnetic fields, in magnetic and gravitational fields, Drift orbit theory, Particle drifts in inhomogeneous magnetic field, grad B parallel B drifts, Van Allen radiation belts, slowly varying fields, Adiabatic invariants, magnetic moment, Magnetic mirror, longitudinal adiabatic invariant, motion in nonuniform electric field, in spatially periodic electric field, motion in time varying electric and magnetic fields, motion of a star in a galaxy, fluid drifts

Unit 3: Magnetohydrodynamics of conducting fluids  
9 hours

Electrically conducting fluids, validity of MHD, equations of MHD, ideal fluids, viscous and resistive fluids, Equilibrium of fluids, hydrostatic equilibrium, MHD equilibrium, MHD waves, dispersion and polarization characteristics, gravitohydrodynamic waves, MHD instabilities, The Rayleigh Taylor Instabilities, The Kelvin-Helmholtz instability, Virial theorem

Unit 4: Two-fluid and kinetic descriptions of Plasmas  
9 hours

Electron and proton plasmas, static equilibrium, radiating and accreting fluids, dynamic equilibrium, waves in two fluids, electron plasma oscillations, ion-plasma oscillations, electron plasma waves in magnetized fluids, ion-plasma waves in magnetized fluids, electromagnetic waves in electron-proton fluids, electromagnetic waves in magnetized plasma fluids, Ambipolar diffusion, Kinetic equilibrium of a plasma, Kinetic description of waves and instabilities

Unit 5: Nonconducting Astrophysical fluids  
9 hours

Whence such fluids, equilibrium of fluids, waves in fluids, instabilities, shocks, turbulence, turbulent flows, quantification of turbulence, flow invariants, Spectral representation, The Kolmogorov-Oboukov law, 2D turbulence, Through Navier- Stokes equations, MHD turbulence and Dynamo

References:

1. Aitchison, Introduction to Fluid dynamics
5. Shu, Physics of Astrophysics: Gas Dynamics
APHYS 235 ASTRONOMICAL TECHNIQUES

(3 credits)

9 hours

Unit I: Celestial Sphere: Coordinate systems (horizon, equatorial, ecliptic, galactic), precession, nutation, aberration, parallax, radial velocity, proper motion, time (JD, LST, UT, hour angle), heliocentric corrections.

9 hours

Unit II: Detectors: Photodetection (photoelectric effect, photosensitive element), Photomultiplier tube, Detectors at different wavelengths and their properties (CCD, CMOS, ICCD, L3CCD, Photon-counting system), spectral response, noise, background, signal to noise ratio, sensitivity, quantum efficiency.

9 hours

Unit III: Astronomical Techniques : Different telescope designs (Refracting and Reflecting telescopes, viz., Newtonian, Cassegrain, coude, Nasmyth, Schmidt), Astrometry (transit circle, observations, analysing astrometric data), photometry (magnitudes, filter systems, photometers, stellar parameters, extinction), Imaging (surface photometry, extended sources), spectroscopy (prisms, gratings, spectrographs, low and high resolution spectroscopy), calibration, polarimetry (polarisers, converters, depolarisers, polarimeters, Stokes parameters, interpretation of polarimetric output).

9 hours

Unit IV: High Resolution Techniques: atmospheric effects on optical imaging, speckle interferometry, aperture synthesis with single telescope, image reconstruction techniques, adaptive optics (Wavefront sensing, wavefront correction, wavefront reconstructions, brief introductions on Fizeau, Michelson stellar interferometry and intensity interferometry, long baseline optical interferometry.

9 hours

Unit V: Detection at other bands: Radio telescope, Brightness and antenna temperatures, Sensitivity, Brightness distribution, Radio interferometer, Fringe visibility, Very long baseline interferometry, neutrino astronomy, gravitational wave astronomy.

9 hours

References:
Christiansen, W.N., & Hogbohm, J.A.: Radio Telescopes
Saha S. K.: Diffraction-limited Imaging with Large and Moderate Telescopes.

Introduction to Optical Stellar Interferometry : A.Lebeyrie, S.G.Lipson & P.Nisension
The Intensity Interferometry : Its Applications to Astronomy : R.H.Brown

Optical Radiation Detectors : E.L.Dereniak & D.G.Crowe
Optical Sources, Detectors & Systems : R.Kingston
Applications of Thermal Imaging : Ed. S.G.Burnay, T.L.Wilman & C.H.Jones
Astronomical Optics : D.J.Sbroeder
Astronomical Techniques : W.A.Hiltner
APHYS 240 RESEARCH PROJECT

I. A list of experiments for Physics Lab (PH419):

II. The student is required to perform any 10 experiments.

1. Verification of the Lorentz formula for force between a current and magnetic field.
2. Determination of the earth's magnetic field from the study of the null point for a bar magnet. Confirmation with a magnetometer.
3. e/m ratio by Thomson's method
4. Wavelength measurement of Na source using Michelson Interferometer
5. Study of Fabry Perot interferometer, for accurate measurement of tiny displacements.
7. Determination of h by Einstein's photoelectric effect formula, using visible and UV light.
8. Coherence and width of spectral lines using Michelson Interferometer.
9. To study magneto-optic rotation.
10. Measurement of the Stefan Constant
11. Black Body curve (limited by the high temperature that can be reached)
12. Maxwell's velocity distribution, using rotating sectors
13. Maxwell's velocity distribution, from the study of spectral lines at difference temperatures (gases in rarefied atmospheres) and deviations as pressure broadening takes over.
14. Brownian motion and verification of the Einstein-Smoluchowski formula
15. Study of Hall parameter of these substances and compare with carrier concentration.
17. Vibration of a suspended simple pendulum, coupled non-linear pendulum.
APHYS 241 GENERAL RELATIVITY AND COSMOLOGY (3 credits)

Unit – I: Review of special theory of relativity: 9 hours

Poincare and Minkowski’s 4-dimensional formulation, geometrical representation of Lorentz transformations in Minkowski’s space and length contraction, time dilation and causality, time-like and space-like vectors, Newton second law of motion expressed in terms of 4-vectors.

Review of tensor calculus:

Idea of Euclidean and non-Euclidean space, meaning of parallel transport and covariant derivatives, Geodesics and autoparallel curves, Curvature tensor and its properties, Bianchi Identities, vanishing of Riemann-Christoffel tensor as the necessary and sufficient condition of flatness, Ricci tensor, Einstein tensor

Unit-II: Einstein’s field equations 9 hours

Inconsistencies of Newtonian gravitation with STR, Principles of equivalence, Principle of general covariance, Metric tensors and Newtonian Gravitational potential, Logical steps leading to Einstein’s field equations of gravitation, Linearised equation for weak fields, Poisson’s equation.

Unit – III: Applications of general relativity: 9 hours

Schwarzschild’s exterior solution, singularity, event horizon and black holes, isotropic coordinates, Birkhoff’s theorem, Observational tests of Einstein’s theory.

Unit-IV: Gravitational Collapse and Black Holes (Qualitative): 9 hours


Unit-V: Cosmology: 9 hours

Introduction, Cosmological Principles, Weyl postulates, Robertson-Walker metric (derivation is not required), Cosmological parameters, Static Universe, Expanding universe, Open and Closed universe, Cosmological red shift, Hubble’s law, Olber’s Paradox. Qualitative discussions on: Big Bang, Early Universe (thermal history and nucleosynthesis), Cosmic Microwave Background Radiation, Event Horizon, Particle Horizon and some problems of Standard Cosmology.

Books Recommended:


Additional references:
APHYS 242 PHYSICS OF COMPACT OBJECTS (3 credits)

Unit I: White dwarfs, neutron stars and black holes (12 hours)
Introduction to Compact objectsFormation of compact objectsphysical properties of white dwarfs, the Chandrasekhar limit comparison with observations: masses and radii-physical properties and, discovery of neutron starsobservation of neutron star masses and maximum mass limit-properties of Schwarzschild black holes

Unit II: Pulsars (12 hours)
Discovery and properties of pulsars, the dispersion measure the magnetic dipole model for pulsars the life history of pulsars, Hulse-Taylor binary pulsar and the evidence for gravitational waves

Unit III: X-ray binaries (12 hours)
Introduction to X-ray binaries high and low mass X-ray binaries, X-ray pulsars mass flow in binary systems, Roche lobe overflow and wind accretion the binary X-ray pulsar: Her X1 and the black hole system: Cygnus X1

Unit IV: Accreting compact objects (12 hours)
Nonrelativistic spherical accretion -- standard accretion disk theory – accretion disk spectra, accretion onto Neutron stars - the magnetosphere emission from accreting neutron stars White dwarf accretion Active Galactic Nuclei – types of AGN multi wavelength spectra of AGN

Textbooks
3. An Introduction to Active galactic Nuclei, B.M.Peterson, Cambridge University Press, 1977
APHYS 243 DIFFUSE MATTER IN SPACE  (3 credits)

Unit I: Introduction and general properties of the Interstellar Medium; 8 hours

Discovery of interstellar gas and dust - Galactic distribution of ISM, the "Oort Limit" - Phases of ISM, pressure equilibrium - Models of the ISM: Thermal Stability & Equilibrium, two-phase models, the coronal hot gas and Multi-Phase Models.

Unit II: Neutral Atomic Gas (HI Regions) 8 hours

Interstellar absorption lines: Radiative Transfer, line formation, equivalent widths, curve of growth, gas-phase abundances in the ISM - The HI 21cm hyperfine structure line: excitation, absorption & emission - HI clouds.

Unit III: Ionized Gas (HII Regions) 8 hours

Photoionization equilibrium, Ionization Structure, HII nebulae (Strömgren Spheres) - Thermal Structure of Nebulae: Heating, Cooling (recombination, free-free, and collisional excitation), thermal Equilibrium - Spectra of HII regions.

Unit IV: Coronal Gas 8 hours


Unit V: Interstellar Dust and Molecules 8 hours

Scattering, absorption, extinction and polarization by interstellar dust - Optical and material properties of dust: Grain sizes and shapes, Grain Materials, Grain Mixture Models - Grain Formation & Destruction - Interstellar CO and other tracer molecules, H2 formation.

Unit VI: Sources and Sinks of ISM 8 hours

Mass loss from stars: stellar winds, planetary nebulae and supernovae - formation of shells, supershells and clouds-star formation in molecular clouds- galactic chemical evolution

Text Books

Unit 1: Spectral line formation and causes of line broadening


Unit 2: Equation of transfer


Unit 3: Continuous spectra of stars


Unit 4: Formation of absorption and emission lines


REFERENCES

1) L.H.Aller: Astrophysics.
2) J.Greenstein(Ed): Stellar Atmospheres.
3) Hynek: Astrophysics.
4) Mihalas: Stellar Atmospheres.2nd edition
5) E.Ambartzumian: Theoretical Astrophysics.
6) K.D.Abhyankar: Astrophysics Stars and Galaxies.
7) David F. Gray; Observations and Analysis of Stellar Photospheres, 3rd edition.
APHYS 245 GALACTIC STRUCTURE & DYNAMICS (3 Credits)

Unit-I 12 hours

Structure of our Galaxy - Distribution of stars, gas, and chemical elements in the disk and spheroid. Other galaxies: surface profile, photometric, spectroscopic, and morphological properties, fundamental plane. Stellar kinematics - solar Motion, standards of rest, velocities and velocity dispersions of disk and spheroid stars.

Unit-II 12 hours

Viral theorem, Galaxy collisions, Dynamical friction in galaxy – collisions, Methods of distance determination, Spectra and redshift, Clusters of galaxies-different types of galaxy clusters, galaxy-galaxy encounters, Radio galaxies and quasars, Active galactic nuclei.

Unit-III 12 hours

Galactic rotation curves, Differential rotation, Velocity dispersion of galaxies, galaxy clusters and gravitational lensing, Cosmic microwave background, Recent status of CMBR, Supermassive black holes in galaxies, Dark matter and Dark energy.

Unit-IV 12 hour


Text Books

5. Astronomy by R. H. Baker
APHYS 246 SUN AND SOLAR SYSTEM (3 credits)

Unit 1 The Sun

Unit 2 Planets and their Satellites

Unit 3 Asteroids, Meteors and Meteorites

Unit 4 Comets

References