Semester-IV

Course No. MPC-456

(Credit-4)

Astrophysics

Lectures: 50

Full marks: 50

1. **Basic concept of Astronomy:** (10)

(i) Celestial sphere and related topics.
(ii) Celestial coordinate systems.
(iii) Explanation of astronomical events.
(iv) Distance measurement in astronomy.

2. **Stellar Structure and Evolution:** (12)

(i) Star formation, stellar magnitudes, H-R diagram.
(ii) Virial theorem, gravitational energy, equations of stellar structure and evolution.
(iii) Pre-main sequence evolution, evolution on the main sequence, post main sequence evolution, degeneracy of stellar matter, models of red giants, late stages of stellar evolution, brown dwarfs. Stellar explosions: Nova, Super-nova, Neutron star, White dwarf, Black hole.

3. **Nuclear Astrophysics and Beyond:** 28

(i) Thermonuclear reactions in stars, pp chains and the solar neutrino problem, the CNO cycle, subsequent thermonuclear reactions, helium burning, nucleosynthesis beyond iron, r and s processes.

Static spherically symmetric spacetime: Physical interpretation of metric terms; energy at infinity, gravitational redshift.

Perfect Fluid: Equation of state, equation of motion, TOV equation, stars of uniform density, limit of mass to radius ratio.

Newtonian Stars: Hydrostatic equilibrium, Polytropic equation of state, Lane-Emden equation and its analytic solutions

White dwarf: Electron degeneracy pressure, Chandrasekhar limit.

Neutron Stars: TOV equation applied to neutron stars, Neutron degeneracy pressure, Maximum mass, schematic structure of neutron stars. Pulsars.

Black Holes, Introduction: Creation of black holes, black hole binaries, observational evidence.

Black Hole space-time: Conserved quantities, symmetries and Killing vectors, Schwarzschild black hole, Event Horizon and its nature, infinite red shift, Light cone, Removal of coordinate singularity, Eddington-Finkelstein and Kruskal-Szekres coordinates, Penrose diagram. No hair theorem (statement only)

Kerr metric in Boyer-Lindquist coordinates, event horizons, Ergosphere, Penrose Process, energy extraction from BH, irreducible mass, Dragging of inertial frames

Black Hole Mechanics: Hawking Area Theorem (statement only), surface gravity, four laws of BH thermodynamics, Hawking Radiation (qualitative discussion), BH evaporation.

References:

1) Text book of astronomy and astrophysics with elements of cosmology, V.B.Bhatia, Narosa publishing house, 2001.
2) Astrophysics- stars and galaxies, K.D. Abhyankar, Universities press, 2001.
3) Black holes, white dwarfs and neutron stars, S.L. Shapiro and S.A.Teukolsky, John Wiley, 1983.
4) An introduction to the study of stellar structure, S. Chandrasekhar, Dover.
5) The classical theory of fields, L.D. Landau and E.M. Lifshitz, Pergamon, 1975.
6) Relativistic astrophysics, Ya B. Zel'dovich and I.D. Novikov, Vol.-I, University of Chicago press.
7) Theoretical astrophysics, Vol.-I, II and III, T. Padmanabhan, Cambridge.
8) Gravitation and Cosmology: Principles and applications of the General Theory of Relativity- S. Weinberg, John Wiley, 1972.
9) Gravitation: T Padmanabhavan
10) Gravity: Hartle (Pearson Education)
11) A First Course in general relativity – B F Schutz (CUP)
12) General Relativity : R M Wald
13) Lecture notes on general relativity: Sean Carroll, gr-qc/9712019
14) Introduction to General Relativity : G t'Hooft (Freely available)
15) Lecture notes on General Relativity: Mathew Blau (http://www.unine.ch/phys/string/Lecturenotes.html)