



Syllabus

Third Semester Courses in MSc Physics (June 2024 onwards)

- **Core Courses:**
 - PSPHY6501CR1 Relativistic Transient Astrophysics
 - PSPHY6501CR1PR Relativistic Transient Astrophysics Practical
 - PSPHY6502CR1 Stellar Physics
 - PSPHY6502CR1PR Stellar Physics Practical
 - PSPHY6503CR1 Astrophysics of Galaxies
 - PSPHY6503CR1PR Astrophysics of Galaxies Practical
 - PSPHY6504CR1 Interstellar and Intergalactic Medium
 - PSPHY6504CR1PR Interstellar and Intergalactic Medium Practical
- **Elective Courses:**
 - PSPHY6501EL1 General Relativity and Cosmology
 - PSPHY6501EL1PR General Relativity and Cosmology Practical
 - PSPHY6502EL1 Atmospheric Physics
 - PSPHY6502EL1PR Atmospheric Physics Practical
- **Research Project:**
 - PSPHY6501RP1 Research Proposal for Dissertation
- **Evaluation and Assessment guidelines**

APPROVED SYLLABUS



PRINCIPAL
ST. XAVIER'S COLLEGE
AUTONOMOUS
MUMBAI - 400 001.



Syllabus

Third Semester Courses in MSc Physics (June 2024 onwards)

- **Core Courses:**

- PSPHY6501CR1 Relativistic Transient Astrophysics
- PSPHY6501CR1PR Relativistic Transient Astrophysics Practical
- PSPHY6502CR1 Stellar Physics
- PSPHY6502CR1PR Stellar Physics Practical
- PSPHY6503CR1 Astrophysics of Galaxies
- PSPHY6503CR1PR Astrophysics of Galaxies Practical
- PSPHY6504CR1 Interstellar and Intergalactic Medium
- PSPHY6504CR1PR Interstellar and Intergalactic Medium Practical

- **Elective Courses:**

- PSPHY6501EL1 General Relativity and Cosmology
- PSPHY6501EL1PR General Relativity and Cosmology Practical
- PSPHY6502EL1 Atmospheric Physics
- PSPHY6502EL1PR Atmospheric Physics Practical

- **Research Project:**

- PSPHY6501RP1 Research Proposal for Dissertation

- **Evaluation and Assessment guidelines**

MSc-II in Physics		
Course Title: Relativistic Transient Astrophysics		
Course Code: PSPHY6501CR1		
Credits 3: 45 hr (Theory)		
Prerequisite: Students who have completed a Four-Year Bachelor Degree in Science with Physics Major or a postgraduate diploma in Physics (Level 6); Proficiency in Python programming is mandatory.		
No.	Course Objectives	
1	To study radiative processes in matter and its applications.	
2	To study highly energetic particle acceleration processes and their applications.	
3	To study stellar end products.	
CO	Course Outcomes On completing the course, the learner will be able to	Bloom's Taxonomy Level (BT level)
1	Possess knowledge of the radiative processes that occur in the presence of matter.	Remembering
2	Understand the fundamental theoretical model of particle acceleration.	Understanding
3	Demonstrate how radiative transfer occurs through a medium, viz. bremsstrahlung, synchrotron radiation and Compton scattering.	Applying
4	Explain the observational and underlying models of astroparticle physics.	Analyzing
5	Compare the different kinds of stellar remnants.	Evaluating
6	Develop the phenomenological understanding of the fundamental physical process of high energy sources, viz. accretion and ejection around the compact objects.	Creating

- UNIT I Fundamentals of Radiative Transfer and Radiative Processes (15)**
- A. Fundamentals of Radiative Transfer**
1. (Review: The Electromagnetic Spectrum; Elementary Properties of Radiation, Radiative Flux), The Specific Intensity and Its Moments, Radiative Transfer, Thermal Radiation, The Einstein Coefficients, Scattering Effects; Radiative Diffusion
- B. Bremsstrahlung**
1. Emission from single-speed electrons, Thermal Bremsstrahlung Emission (free-free absorption). Relativistic Bremsstrahlung.
- C. Synchrotron Radiation**
1. Cyclotron to synchrotron emission. Single particle synchrotron emissivity, thermal and non-thermal synchrotron spectrum. Synchrotron absorption.
- D. Compton Scattering**
1. Inverse Compton scattering, Comptonization, Kompaneet's equation.
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- UNIT II High Energy Particles and Astroparticle Physics (15)**
- A. Particle Acceleration**
1. Gravity, electromagnetic wave, and Fermi acceleration. Relativistic shock waves and blast waves – internal shocks and jump conditions, recollimation and collisionless shock and particle acceleration, blast waves (impulsive radiative and adiabatic), forward and reverse shock, Introductory relativistic magnetohydrodynamics and their application in Jets and winds.
- B. Astroparticle Physics**
1. Gamma-ray astronomy – tools, techniques and astrophysical phenomena. Gamma-ray bursts – observations and physical theories. Ultra-high energy cosmic ray physics – hadronic processes and neutrino production.
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- UNIT III The End States of Stellar Evolution (15)**
- A. The Degenerate Remnants of Stars**
1. White Dwarfs, The Physics of Degenerate Matter, The Chandrasekhar Limit, The cooling of white dwarfs.

B. White Dwarf, Neutron Star, and Black Hole in Binary Star systems and their Evolution

1. Gravity in close binary star system, Accretion disks, White dwarfs in semi-detached binaries, Type Ia supernovae, Accretion process in Neutron stars and Black holes in Binaries (X-ray Binaries) – Accretion of plasma, theory of thin and thick accretion disks.

C. Pulsing Sources

1. Neutron Stars – structural properties; Radio and X-ray Pulsars; Cataclysmic variables.

Reference Books:

1. Carroll, B.W., & Ostlie, D.A. (2014). *An Introduction to Modern Astrophysics* (2nd ed.). Pearson New International Edition.
2. Kolb, U. (2010). *Extreme Environment Astrophysics*. Cambridge University Press.
3. Melia, F. (2009). *High-Energy Astrophysics*. Princeton University Press.
4. Rybicki, G. B., & Lightman, A. P. (2004). *Radiative Processes In Astrophysics*. Wiley-VCH Verlag, Weinheim.
5. van Putten, M. H., P., M., & Levinson, A. (2012). *Relativistic Astrophysics of the Transient Universe*. Cambridge University Press.

Evaluation of Theory Course (PSPHY6501CR1):

Total marks – 100

- I. Formative Assessment ‘for’ Learning
(continuous internal assessment - CIA to improve learning).
CIA - 40 marks
CIA 1: Written test -20 marks
CIA 2: Field trip/ Sit-in exams/ Research article review/ Assignments/ Presentations/ MCQs/ as prescribed -20 marks
- II. Summative Assessment ‘of’ Learning
(focus on outcomes, quantitative data for outcomes of instruction).
End Semester Examination – 60 marks

Distribution of Bloom’s Taxonomy levels for theory course assessment

Learning Levels	Remember	Understand	Apply	Analyze	Evaluate	Create
Percentage	5-10%	20-30%	20-30%	15-20%	10-20%	0-5%

MSc-II in Physics		
Course Title: Relativistic Transient Astrophysics Practical		
Course Code: PSPHY6501CR1PR		
Credits 1: 30 hr (Practicum)		
Prerequisite: Students who have completed a Four-Year Bachelor Degree in Science with Physics Major or a postgraduate diploma in Physics (Level 6); Proficiency in Python programming is mandatory.		
No.	Course Objectives	
1	To study radiative processes in matter and its applications.	
2	To study highly energetic particle acceleration processes and their applications.	
3	To study stellar end products.	
CO	Course Outcomes On completing the course, the learner will be able to	Bloom's Taxonomy Level (BT level)
1	Recall fundamental concepts necessary to perform practical exercises and projects related to relativistic transient astrophysics.	Remembering
2	Demonstrate understanding of experimental and/or computational methods relevant to relativistic transient astrophysics.	Understanding
3	Execute these methods with efficient management of time and other resources.	Applying
4	Analyze the outcome of the applied methods to draw inferences.	Analyzing
5	Assess the significance of the results in a larger context and defend the results scientifically.	Evaluating
6	Design coherent structures for communication such as project proposals, lab reports, project reports, presentations, etc.	Creating

Practical Syllabus

A. Minimum four practicals in the complete semester from the following list:

1. The plotting of a lightcurve of celestial objects, viz. X-ray binaries.
2. Fourier analysis of X-ray binaries: accretion powered pulsars and black hole binaries.
3. Spectral analysis black hole binary system - study of thermal and non-thermal emissions (viz. Comptonization).
4. Simulation of particle acceleration.
5. Simulation of Compton scattering.

B. Project:

In a complete semester, a student must perform one project related to the course.

Evaluation of Practical Course (PSPHY6501CR1PR):

Total marks - 50

Project work with report – 20 marks

End semester practical examination – 20 marks

Journal – 5 marks

Co-curricular activity – 5 marks

Distribution of Bloom's Taxonomy levels for practical course assessment

Learning Levels	Remember	Understand	Apply	Analyze	Evaluate	Create
Percentage	0-5%	5-10%	20-25%	25-30%	20-25%	20-25%

MSc-II in Physics		
Course Title: Stellar Physics		
Course Code: PSPHY6502CR1		
Credits 3: 45 hr (Theory)		
Prerequisite: Students who have completed a Four-Year Bachelor Degree in Science with Physics Major or a postgraduate diploma in Physics (Level 6); Proficiency in Python programming is mandatory.		
No.	Course Objectives	
1	To study stellar models, the structure of the stellar interior and its atmosphere.	
2	To study the life cycle of stars from formation to death.	
CO	Course Outcomes On completing the course, the learner will be able to	Bloom's Taxonomy Level (BT level)
1	List the properties of different kinds of stars.	Remembering
2	Understand a star's life cycle - from formation to death.	Understanding
3	Apply mathematical tools and physics laws to understand the structure of the stellar interior and its atmosphere.	Applying
4	Infer the physics of pulsating stars based on observations.	Analyzing
5	Evaluate the conditions governing the stability of stars.	Evaluating
6	Elaborate on the formation of stars.	Creating

UNIT I Stars and their Properties (15)

A. Stars and their Observational Properties

1. Observational Stellar Astronomy: The brightness of the stars, The HR diagrams: Colour-magnitude, colour-colour diagrams, The luminosities of the stars, Angular radii of stars, Effective temperatures of stars. Spectral classification, Understanding stellar spectra, Stellar population, Population II stars, Stellar rotation, Stellar magnetic fields, Stars with peculiar spectra.

B. Binary Stars

1. Gravitationally bound system of stars, masses and radii of stars, Classification of binary star systems, Luminosity-mass law, Multiple star systems bound by gravity, introduction to stellar clusters.

C. Variable Stars

1. Classifications and properties of different types of variabilities in stars.

UNIT II Stellar Models and Star Formation (15)

A. Protostars

1. The Formation of Protostars, Pre-Main-Sequence Evolution, Hayashi tracks, Henyey tracks on the HR-diagram. Protostellar accretion disks and jets.

B. Stellar Atmospheres

1. The Description of the Radiation Field, Stellar Opacity, Radiative Transfer, The Transfer Equation.

C. The Interiors of Stars

1. Hydrostatic Equilibrium, Pressure Equation of State, Stellar Energy Sources, Energy Transport and Thermodynamics, Stellar Model Building, The Main Sequence.

D. Stability of Stars

1. Equilibrium Stellar Configurations and simple models, The stability of Stars and the Thermal, Dynamical and Convective instabilities.

UNIT III Stellar Evolution (15)

A. Main Sequence and Post-Main-Sequence Stellar Evolution

1. Evolution on the Main Sequence, Late Stages of Stellar Evolution, Stellar Clusters.

B. Stellar Pulsation

1. Observations of Pulsating Stars, The Physics of Stellar Pulsation, Modelling Stellar Pulsation, Non-radial Stellar Pulsation, Helioseismology and Asteroseismology, Pulsating stars.

C. The Fate of Massive Stars

1. Post-Main-Sequence Evolution of Massive Stars, The Classification of Supernovae, Core-Collapse Supernovae.

Reference Books:

1. Bohm-Vitense, E. (1989). *Introduction to Stellar Astrophysics*. Cambridge University Press.
2. Carroll, B.W., & Ostlie, D.A. (2014). *An Introduction to Modern Astrophysics* (2nd ed.). Pearson New International Edition.
3. Kippenhahn, R., Weigert, A., & Weiss, A. (2012). *Stellar Structure and Evolution* (2nd ed.). Springer.
4. Prialnik, D. (2011). *An Introduction to the Theory of Stellar Structure and Evolution* (2nd ed.). Cambridge University Press.

Evaluation of Theory Course (PSPHY6502CR1):

Total marks – 100

- I. Formative Assessment ‘for’ Learning
(continuous internal assessment - CIA to improve learning).
CIA - 40 marks
CIA 1: Written test -20 marks
CIA 2: Field trip/ Sit-in exams/ Research article review/ Assignments/ Presentations/ MCQs/ as prescribed -20 marks
- II. Summative Assessment ‘of’ Learning
(focus on outcomes, quantitative data for outcomes of instruction).
End Semester Examination – 60 marks

Distribution of Bloom’s Taxonomy levels for theory course assessment

Learning Levels	Remember	Understand	Apply	Analyze	Evaluate	Create
Percentage	5-10%	20-30%	20-30%	15-20%	10-20%	0-5%

MSc-II in Physics		
Course Title: Stellar Physics Practical		
Course Code: PSPHY6502CR1PR		
Credits 1: 30 hr (Practicum)		
Prerequisite: Students who have completed a Four-Year Bachelor Degree in Science with Physics Major or a postgraduate diploma in Physics (Level 6); Proficiency in Python programming is mandatory.		
No.	Course Objectives	
1	To study stellar models, the structure of the stellar interior and its atmosphere.	
2	To study the life cycle of stars from formation to death.	
CO	Course Outcomes On completing the course, the learner will be able to	Bloom's Taxonomy Level (BT level)
1	Recall fundamental concepts necessary to perform practical exercises and projects related to stellar physics.	Remembering
2	Demonstrate understanding of experimental and/or computational methods relevant to stellar physics.	Understanding
3	Execute these methods with efficient management of time and other resources.	Applying
4	Analyze the outcome of the applied methods to draw inferences.	Analyzing
5	Assess the significance of the results in a larger context and defend the results scientifically.	Evaluating
6	Design coherent structures for communication such as project proposals, lab reports, project reports, presentations, etc.	Creating

Practical Syllabus

A. Minimum four practicals in the complete semester from the following list:

1. Simulation of binary star light curves.
2. Analysis and classification of various variable stars.
3. Plotting of the H-R diagram for selected sources.
4. Querying stellar databases.

B. Project:

In a complete semester, a student must perform one project related to the course.

Evaluation of Practical Course (PSPHY6502CR1PR):

Total marks - 50

Project work with report – 20 marks

End semester practical examination – 20 marks

Journal – 5 marks

Co-curricular activity – 5 marks

Distribution of Bloom's Taxonomy levels for practical course assessment

Learning Levels	Remember	Understand	Apply	Analyze	Evaluate	Create
Percentage	0-5%	5-10%	20-25%	25-30%	20-25%	20-25%

MSc-II in Physics		
Course Title: Astrophysics of Galaxies		
Course Code: PSPHY6503CR1		
Credits 3: 45 hr (Theory)		
Prerequisite: Students who have completed a Four-Year Bachelor Degree in Science with Physics Major or a postgraduate diploma in Physics (Level 6); Proficiency in Python programming is mandatory.		
No.	Course Objectives	
1	To study observational facts about the Milky Way and its galactic neighbourhood.	
2	To study structures of different types of galaxies and their evolution.	
3	To study the large-scale structure of the Universe.	
CO	Course Outcomes On completing the course, the learner will be able to	Bloom's Taxonomy Level (BT level)
1	Have knowledge of the properties of the Milky Way and different types of galaxies in the expanse of the Universe.	Remembering
2	Understand how properties of different galaxies are deduced based on astrophysical and cosmological observations.	Understanding
3	Apply mathematical tools and physics laws to understand the formation, structure and evolution of galaxies.	Applying
4	Use analytical skills to solve problems pertaining to different galaxies.	Analyzing
5	Evaluate current knowledge about different galaxies, their properties, and how these structures have evolved over time.	Evaluating
6	Develop an overarching understanding of structure in the Universe from the Galactic to cosmological scales.	Creating

- UNIT I Milky Way and Local Group (15)**
- A. Introduction**
1. Galaxies, Hubble expansion, overview of thermal history of the Universe, structure formation and galaxy evolution.
- B. Milky Way**
1. Structure and components of the galaxy, kinematics, rotation curve, microlensing, Galactic Centre, Poisson equation and gravitational potential, strong and weak encounters, Orbits of disk stars, Stars as an ensemble: collisionless Boltzmann equation.
- C. Local Group**
1. Galaxies in the Local Group, Satellites of the Milky Way, Properties of the Local Group spiral galaxies, Dwarf galaxies in the Local Group.
- UNIT II The World of Galaxies (15)**
- A. Galaxy Classification**
1. Hubble sequence and bimodal colour distribution of galaxies, Properties of different types of galaxies, Brightness profile, Stellar orbits in triaxial galaxies, Schmidt-Kennicutt law of star formation, scaling relations, luminosity function, galaxies as gravitational lenses.
- B. Active Galactic Nuclei**
1. Structure and components of an active galactic nucleus (AGN), types of AGN, Eddington luminosity, properties of AGN population.
- C. Galaxies at High Redshift**
1. Lyman-break galaxies, photometric redshift and other selection techniques, starburst galaxies, extremely red objects, Lyman-alpha blobs, properties of high-redshift galaxies, cosmic star-formation history.
- UNIT III Galaxy Evolution and Large Scale Structure (15)**
- A. Galaxy Evolution**
1. Dark matter halos, halo collapse and cooling of gas, reionization of the Universe, formation of disk and elliptical galaxies, feedback processes, cosmic downsizing.
- B. Clusters and Groups of Galaxies**
1. Abell catalogue, morphology and classification, X-ray radiation, cooling flows, Sunyaev-Zeldovich effect, Scaling relations, clusters as gravitational lenses, properties of galaxy population in clusters, evolutionary effects.

Reference Books:

1. Binney, J., & Tremaine, S. (2008). *Galactic Dynamics* (2nd ed.). Princeton University Press.
2. Jones, M. H., Lambourne, R. J. A., & Serjeant, S. (Eds.). (2015). *An Introduction to Galaxies and Cosmology* (2nd ed.). Cambridge University Press.
3. Mo, H., Van Den Bosch, F., & White, S. (2010). *Galaxy Formation and Evolution*. Cambridge University Press.
4. Schneider, P. (2015). *Extragalactic Astronomy and Cosmology* (2nd ed.). Springer.
5. Sparke, L., & Gallagher, J. (2007). *Galaxies in the Universe: An Introduction* (2nd ed.). Cambridge University Press.

Evaluation of Theory Course (PSPHY6503CR1):

Total marks – 100

- I. Formative Assessment ‘for’ Learning
(continuous internal assessment - CIA to improve learning).
CIA - 40 marks
CIA 1: Written test -20 marks
CIA 2: Field trip/ Sit-in exams/ Research article review/ Assignments/ Presentations/ MCQs/ as prescribed -20 marks
- II. Summative Assessment ‘of’ Learning
(focus on outcomes, quantitative data for outcomes of instruction).
End Semester Examination – 60 marks

Distribution of Bloom’s Taxonomy levels for theory course assessment

Learning Levels	Remember	Understand	Apply	Analyze	Evaluate	Create
Percentage	5-10%	20-30%	20-30%	15-20%	10-20%	0-5%

MSc-II in Physics		
Course Title: Astrophysics of Galaxies Practical		
Course Code: PSPHY6503CR1PR		
Credits 1: 30 hr (Practicum)		
Prerequisite: Students who have completed a Four-Year Bachelor Degree in Science with Physics Major or a postgraduate diploma in Physics (Level 6); Proficiency in Python programming is mandatory.		
No.	Course Objectives	
1	To study observational facts about the Milky Way and its galactic neighbourhood.	
2	To study structures of different types of galaxies and their evolution.	
3	To study the large-scale structure of the Universe.	
CO	Course Outcomes On completing the course, the learner will be able to	Bloom's Taxonomy Level (BT level)
1	Recall fundamental concepts necessary to perform practical exercises and projects related to astrophysics of galaxies.	Remembering
2	Demonstrate understanding of experimental and/or computational methods relevant to astrophysics of galaxies.	Understanding
3	Execute these methods with efficient management of time and other resources.	Applying
4	Analyze the outcome of the applied methods to draw inferences.	Analyzing
5	Assess the significance of the results in a larger context and defend the results scientifically.	Evaluating
6	Design coherent structures for communication such as project proposals, lab reports, project reports, presentations, etc.	Creating

Practical Syllabus

- A.** Minimum four practicals in the complete semester from the following list:
1. Galaxy surface brightness profile through photometric analysis
 2. Simple machine learning techniques for galaxy classification
 3. Modelling galaxy orbits or rotation curves
 4. Determining the distance to galaxy clusters
 5. Analysis of galaxy spectral energy distribution
- B.** Project:
- In a complete semester, a student must perform one project related to the course.

Evaluation of Practical Course (PSPHY6503CR1PR):

Total marks - 50

- Project work with report – 20 marks
- End semester practical examination – 20 marks
- Journal – 5 marks
- Co-curricular activity – 5 marks

Distribution of Bloom's Taxonomy levels for practical course assessment

Learning Levels	Remember	Understand	Apply	Analyze	Evaluate	Create
Percentage	0-5%	5-10%	20-25%	25-30%	20-25%	20-25%

MSc-II in Physics		
Course Title: Interstellar and Intergalactic Medium		
Course Code: PSPHY6504CR1		
Credits 3: 45 hr (Theory)		
Prerequisite: Students who have completed a Four-Year Bachelor Degree in Science with Physics Major or a postgraduate diploma in Physics (Level 6); Proficiency in Python programming is mandatory.		
No.	Course Objectives	
1	To understand the different phases of the interstellar and intergalactic media.	
2	To understand the tools and techniques used to probe the diffuse Universe.	
CO	Course Outcomes On completing the course, the learner will be able to	Bloom's Taxonomy Level (BT level)
1	Have knowledge of the phases and constituents of the interstellar, circumgalactic and intergalactic media.	Remembering
2	Understand interstellar, circumgalactic and intergalactic features and phenomena, along with the fundamentals of spectroscopy.	Understanding
3	Apply mathematical tools and the laws of physics to explain the onset of star formation and chemical evolution of galaxies.	Applying
4	Use analytical skills to constrain physical properties of interstellar and circumgalactic regions on the basis of spectroscopy.	Analyzing
5	Evaluate current knowledge and tools to probe interstellar, circumgalactic and intergalactic environments.	Evaluating
6	Integrate the physical understanding of the diffuse Universe into a multidisciplinary approach involving chemistry and biology.	Creating

- UNIT I Interstellar Medium and the Onset of Star Formation (15)**
- A. Phases of the Interstellar Medium**
1. Constituents and phases of the ISM, properties of H II regions, H I regions, molecular clouds, the hot ionized medium, heating and cooling in different phases of the ISM, types of nebulae, interstellar medium in other galaxies.
- B. Dust Grains**
1. Extinction, optical depth, types of dust grains and their significance, origin of interstellar dust.
- C. The Onset of Star Formation**
1. Jeans criterion for collapse of dense molecular clouds, homologous collapse and fragmentation.
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- UNIT II Circumgalactic and Intergalactic Media (15)**
- A. Circumgalactic and Intergalactic Media**
1. Properties of the circumgalactic and intergalactic media, Gunn-Peterson effect, quasar absorption lines, damped Lyman-alpha systems and their significance, absorption line spectroscopy towards other distant sources, warm-hot intergalactic medium, intracluster gas.
- B. Galactic Chemical Evolution**
1. Equations of galactic chemical evolution, mixing processes in the interstellar medium, G-dwarf problem, inflows, outflows and recycling, abundances of different elements, chemical evolution in different types of galaxies.
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- UNIT III Tools and Techniques to probe the Diffuse Universe (15)**
- A. Basics of Astronomical Spectroscopy**
1. Line emission and absorption, equivalent width and column density, line broadening mechanisms, profiles of spectral lines, curve of growth.
- B. Instruments for High Resolution Spectroscopy**
1. Echelle gratings, overview of past, present and future generation instruments.
- C. Important Interstellar Transitions**
1. Important atomic and molecular transitions: H I 21 cm, [C II] 158 micron, CO emission, etc., radiative and collisional processes, constraining physical properties on the basis of spectroscopic observations, common software tools.

D. Astrochemistry

1. Inventory of molecules in the interstellar medium, gas-grain chemistry, laboratory astrophysics, introduction to astrobiology.

Reference Books:

1. Carroll, B.W., & Ostlie, D.A. (2014). *An Introduction to Modern Astrophysics* (2nd ed.). Pearson New International Edition.
2. Draine, B. (2011). *Physics of the Interstellar and Intergalactic Medium*. Princeton University Press.
3. Dyson, J. E., & Williams, D. A. (2021). *The Physics of the Interstellar Medium* (3rd ed.). CRC Press.
4. Kitchin, C. R. (2014). *Astrophysical Techniques* (6th ed.). CRC Press.
5. Kwok, S. (2007). *Physics and Chemistry of the Interstellar Medium*. University Science Books.
6. Muñoz Caro, G. M., & Escribano, R. (Eds.). (2018). *Laboratory Astrophysics*. Springer.
7. Osterbrock, D. E., & Ferland, G. J. (2006). *Astrophysics of Gaseous Nebulae and Active Galactic Nuclei* (2nd ed.). University Science Books.
8. Pagel, B. E. J. (2009). *Nucleosynthesis and Galactic Chemical Evolution* (2nd ed.). Cambridge University Press.
9. Ryden, B. & Pogge, R. (2021). *Interstellar and Intergalactic Medium*. Cambridge University Press.
10. Schneider, P. (2015). *Extragalactic Astronomy and Cosmology* (2nd ed.). Springer.
11. Tielens, A. G. G. M. (2005). *The Physics and Chemistry of the Interstellar Medium*. Cambridge University Press.
12. Tielens, A. G. G. M. (2020). *Molecular Astrophysics*. Cambridge University Press.

Evaluation of Theory Course (PSPHY6504CR1):

Total marks – 100

- I. Formative Assessment ‘for’ Learning
(continuous internal assessment - CIA to improve learning).
CIA - 40 marks
CIA 1: Written test -20 marks
CIA 2: Field trip/ Sit-in exams/ Research article review/ Assignments/ Presentations/ MCQs/ as prescribed -20 marks
- II. Summative Assessment ‘of’ Learning
(focus on outcomes, quantitative data for outcomes of instruction).
End Semester Examination – 60 marks

Distribution of Bloom’s Taxonomy levels for theory course assessment

Learning Levels	Remember	Understand	Apply	Analyze	Evaluate	Create
Percentage	5-10%	20-30%	20-30%	15-20%	10-20%	0-5%

MSc-II in Physics		
Course Title: Interstellar and Intergalactic Medium Practical		
Course Code: PSPHY6504CR1PR		
Credits 1: 30 hr (Practicum)		
Prerequisite: Students who have completed a Four-Year Bachelor Degree in Science with Physics Major or a postgraduate diploma in Physics (Level 6); Proficiency in Python programming is mandatory.		
No.	Course Objectives	
1	To understand the different phases of the interstellar and intergalactic media.	
2	To understand the tools and techniques used to probe the diffuse Universe.	
CO	Course Outcomes On completing the course, the learner will be able to	Bloom's Taxonomy Level (BT level)
1	Recall fundamental concepts necessary to perform practical exercises and projects related to the interstellar and intergalactic media.	Remembering
2	Demonstrate understanding of experimental and/or computational methods relevant to the interstellar and intergalactic media.	Understanding
3	Execute these methods with efficient management of time and other resources.	Applying
4	Analyze the outcome of the applied methods to draw inferences.	Analyzing
5	Assess the significance of the results in a larger context and defend the results scientifically.	Evaluating
6	Design coherent structures for communication such as project proposals, lab reports, project reports, presentations, etc.	Creating

Practical Syllabus

- A.** Minimum four practicals in the complete semester from the following list:
1. Modelling the Gaussian, Lorentzian and Voigt line profiles
 2. Spectroscopic analysis of quasar absorption lines
 3. Temperature determination based on molecular excitation diagrams
 4. Moment maps of neutral gas in emission
 5. Analysing the effect of interstellar dust grains
- B.** Project:
- In a complete semester, a student must perform one project related to the course.

Evaluation of Practical Course (PSPHY6504CR1PR):

Total marks - 50

- Project work with report – 20 marks
- End semester practical examination – 20 marks
- Journal – 5 marks
- Co-curricular activity – 5 marks

Distribution of Bloom's Taxonomy levels for practical course assessment

Learning Levels	Remember	Understand	Apply	Analyze	Evaluate	Create
Percentage	0-5%	5-10%	20-25%	25-30%	20-25%	20-25%

MSc-II in Physics		
Course Title: General Relativity and Cosmology		
Course Code: PSPHY6501EL1		
Credits 3: 45 hr (Theory)		
Prerequisite: Students who have completed a Four-Year Bachelor Degree in Science with Physics Major or a postgraduate diploma in Physics (Level 6); Proficiency in Python programming is mandatory.		
No.	Course Objectives	
1	To understand the relation of gravitation to curvature of space-time.	
2	Applications of Einstein's field equations to gravitational waves, black holes etc.	
3	Applications of general relativity to classical cosmology.	
CO	Course Outcomes On completing the course, the learner will be able to	Bloom's Taxonomy Level (BT level)
1	Recall the algebra of tensors on curved manifolds.	Remembering
2	Understand the relation of gravity to the curvature of space-time.	Understanding
3	Apply mathematical tools and physics laws to understand the nature of massive objects such as neutron stars and black holes.	Applying
4	Deduce the early history of the Universe according to classical cosmology.	Analyzing
5	Interpret the results of the observational studies that support general relativity.	Evaluating
6	Adapt the elements of relativity to understand the cosmological framework.	Creating

UNIT I Curved Space-Time and Gravitation (15)

A. Preface to Curvature

1. On the relation of gravitation to curvature, Tensor algebra in polar coordinates, Tensor calculus in polar coordinates, Christoffel symbols and the metric, Non coordinate bases.

B. Curved Manifolds

1. Differentiable manifolds and tensors, Riemannian manifolds, Covariant differentiation, Parallel-transport, geodesics, and curvature, The curvature tensor, Bianchi identities: Ricci and Einstein tensors, Curvature in perspective.

C. Physics in a Curved Spacetime

1. The transition from differential geometry to gravity, Physics in slightly curved spacetimes, Curved intuition, Conserved quantities – Killing vector formulation, Geodesic deviation.

UNIT II General Relativity and its Applications (15)

A. The Einstein Field Equations

1. Purpose and justification of the field equations, Einstein's equations, Einstein's equations for weak gravitational fields, Newtonian gravitational fields.

B. Experimental Tests of General Relativity

1. Precession of Mercury orbit, Bending of light, Gravitational lenses, cosmological redshift, qualitative discussion on gravitational waves.

C. Spherical Solutions for Stars

1. Coordinates for spherically symmetric spacetimes, Static spherically symmetric spacetimes.

D. Schwarzschild geometry and black holes

1. Nature of the surface $r = 2M$, Kruskal coordinates, Trajectories in the Schwarzschild spacetime, General black holes, Real black holes in astronomy, Reissner-Nordstrom metric, Kerr metric, structure of Kerr ergosphere and horizon, Penrose process.

UNIT III Classical Cosmology (15)

A. The Isotropic Universe

1. The Robertson–Walker metric, Friedmann equation and solution, Dynamics of the expansion, Common big bang misconceptions, Observations in cosmology.

B. The Age and Distance Scales

1. The distance scale and the age of the universe, Methods for age determination, Large-scale distance measurements, The local distance scale, Direct distance determinations.

C. Early History of the Universe

1. Thermal History and cosmic microwave background. inflation, primordial nucleosynthesis, recombination and decoupling.

Reference Books:

1. Carroll, S. (2003). *Introduction to General Relativity: Spacetime and Geometry*. Pearson.
2. d’Inverno, R. (1992). *Introducing Einstein’s Relativity*. Clarendon Press.
3. Peacock, J. A. (1998). *Cosmological Physics*. Cambridge University Press.
4. Schutz, B. F. (2012). *A First Course in General Relativity* (2nd ed.). Cambridge University Press.

Evaluation of Theory Course (PSPHY6501EL1):

Total marks – 100

- I. Formative Assessment ‘for’ Learning
(continuous internal assessment - CIA to improve learning).
CIA - 40 marks
CIA 1: Written test -20 marks
CIA 2: Field trip/ Sit-in exams/ Research article review/ Assignments/ Presentations/ MCQs/ as prescribed -20 marks
- II. Summative Assessment ‘of’ Learning
(focus on outcomes, quantitative data for outcomes of instruction).
End Semester Examination – 60 marks

Distribution of Bloom’s Taxonomy levels for theory course assessment

Learning Levels	Remember	Understand	Apply	Analyze	Evaluate	Create
Percentage	5-10%	20-30%	20-30%	15-20%	10-20%	0-5%

MSc-II in Physics		
Course Title: General Relativity and Cosmology Practical		
Course Code: PSPHY6501EL1PR		
Credits 1: 30 hr (Practicum)		
Prerequisite: Students who have completed a Four-Year Bachelor Degree in Science with Physics Major or a postgraduate diploma in Physics (Level 6); Proficiency in Python programming is mandatory.		
No.	Course Objectives	
1	To understand the relation of gravitation to curvature of space-time.	
2	Applications of Einstein's field equations to gravitational waves, black holes etc.	
3	Applications of general relativity to classical cosmology.	
CO	Course Outcomes On completing the course, the learner will be able to	Bloom's Taxonomy Level (BT level)
1	Recall fundamental concepts necessary to perform practical exercises and projects related to general relativity and cosmology.	Remembering
2	Demonstrate understanding of experimental and/or computational methods relevant to general relativity and cosmology.	Understanding
3	Execute these methods with efficient management of time and other resources.	Applying
4	Analyze the outcome of the applied methods to draw inferences.	Analyzing
5	Assess the significance of the results in a larger context and defend the results scientifically.	Evaluating
6	Design coherent structures for communication such as project proposals, lab reports, project reports, presentations, etc.	Creating

Practical Syllabus

A. Minimum four practicals in the complete semester from the following list:

1. Manipulation of covariant and contravariant indices
2. Geodesics in Schwarzschild background
3. Visualising precession in Schwarzschild spacetime
4. Ricci tensor and scalar curvature calculations

B. Project:

In a complete semester, a student must perform one project related to the course.

Evaluation of Practical Course (PSPHY6501EL1PR):

Total marks - 50

Project work with report – 20 marks

End semester practical examination – 20 marks

Journal – 5 marks

Co-curricular activity – 5 marks

Distribution of Bloom's Taxonomy levels for practical course assessment

Learning Levels	Remember	Understand	Apply	Analyze	Evaluate	Create
Percentage	0-5%	5-10%	20-25%	25-30%	20-25%	20-25%

MSc-II in Physics		
Course Title: Atmospheric Physics		
Course Code: PSPHY6502EL1		
Credits 3: 45 hr (Theory)		
Prerequisite: Students who have completed a Four-Year Bachelor Degree in Science with Physics Major or a postgraduate diploma in Physics (Level 6); Proficiency in Python programming is mandatory.		
No.	Course Objectives	
1	To learn about the physical processes that govern the Earth's atmosphere.	
2	To understand the implications of atmospheric processes for Earth's climate.	
CO	Course Outcomes On completing the course, the learner will be able to	Bloom's Taxonomy Level (BT level)
1	Describe the composition and layers of Earth's atmosphere.	Remembering
2	Summarize the physical processes underlying the Earth's atmosphere.	Understanding
3	Apply mathematical tools to understand motion and radiative transfer within the atmosphere.	Applying
4	Compare the properties of Earth's ionosphere and magnetosphere.	Analyzing
5	Evaluate disparate observational techniques and their applicability to probe different aspects of the atmosphere.	Evaluating
6	Develop understanding of the significance and implications of climate change in the context of the solar-terrestrial environment.	Creating

- UNIT I Physics of the Earth's Atmosphere (15)**
- A. Composition of the Atmosphere**
1. Primary and greenhouse gases, aerosols, variations with height, latitude, season and time, mass and layers of the atmosphere, energy transfer within the Earth-Sun system: effect of various factors, vertical temperature profile.
- B. Atmospheric Motion and Radiative Transfer**
1. Laws of horizontal motion, divergence, vertical motion and vorticity, local winds, radiative transfer in planetary atmospheres.
- C. Physics of Space Plasma**
1. Physics of magnetoplasma, radio waves in an ionized medium, radio propagation through an irregular plasma, instabilities.
- UNIT II Earth's Ionosphere and Magnetosphere (15)**
- A. Earth's Ionosphere**
1. Physical and chemical aeronomy, airglow, charged particle motions and electrical conductivity, behaviour of low, mid and high-latitude ionosphere, ionospheric electric currents, storms, aurora.
- B. Earth's Magnetosphere**
1. The geomagnetic cavity, circulation of the magnetosphere, particles in the magnetosphere, van Allen particles, magnetospheric current systems, substorms, pulsations.
- UNIT III Weather and Climate on the Earth (15)**
- A. Observational Techniques in Space Physics**
1. Direct and indirect sensing, Radiation sensors, remote sensing, radar techniques, applications in communications and forecasting.
- B. Weather**
1. Evaporation, condensation and precipitation, features of tropical weather and weather at middle and higher latitudes, introduction to general circulation models.
- C. Climate Dynamics**
1. History of Earth's climate, Present-day climate, climate variability, equilibria and feedbacks, greenhouse warming, climate monitoring and prediction.

Reference Books:

1. Barry, R. & Chorley, R. (2010). Atmosphere, Weather and Climate (9th ed.), Routledge.
2. Hargreaves, J. K. (1995). *The Solar-Terrestrial Environment: An Introduction to Geospace*. Cambridge University Press.
3. Kivelson, M. G. & Russell, C. T. (Eds.). (1996). *Introduction to Space Physics*. Cambridge University Press.
4. Wallace, J. M. & Hobbs, P. V. (2006). *Atmospheric Science: An Introductory Survey* (2nd ed.). Elsevier.

Evaluation of Theory Course (PSPHY6502EL1):

Total marks – 100

- I. Formative Assessment ‘for’ Learning
(continuous internal assessment - CIA to improve learning).
CIA - 40 marks
CIA 1: Written test -20 marks
CIA 2: Field trip/ Sit-in exams/ Research article review/ Assignments/ Presentations/ MCQs/ as prescribed -20 marks
- II. Summative Assessment ‘of’ Learning
(focus on outcomes, quantitative data for outcomes of instruction).
End Semester Examination – 60 marks

Distribution of Bloom’s Taxonomy levels for theory course assessment

Learning Levels	Remember	Understand	Apply	Analyze	Evaluate	Create
Percentage	5-10%	20-30%	20-30%	15-20%	10-20%	0-5%

MSc-II in Physics		
Course Title: Atmospheric Physics Practical		
Course Code: PSPHY6502EL1PR		
Credits 1: 30 hr (Practicum)		
Prerequisite: Students who have completed a Four-Year Bachelor Degree in Science with Physics Major or a postgraduate diploma in Physics (Level 6); Proficiency in Python programming is mandatory.		
No.	Course Objectives	
1	To learn about the physical processes that govern the Earth's atmosphere.	
2	To understand the implications of atmospheric processes for Earth's climate.	
CO	Course Outcomes On completing the course, the learner will be able to	Bloom's Taxonomy Level (BT level)
1	Recall fundamental concepts necessary to perform practical exercises and projects related to atmospheric physics.	Remembering
2	Demonstrate understanding of experimental and/or computational methods relevant to atmospheric physics.	Understanding
3	Execute these methods with efficient management of time and other resources.	Applying
4	Analyze the outcome of the applied methods to draw inferences.	Analyzing
5	Assess the significance of the results in a larger context and defend the results scientifically.	Evaluating
6	Design coherent structures for communication such as project proposals, lab reports, project reports, presentations, etc.	Creating

Practical Syllabus

- A.** Minimum four practicals in the complete semester from the following list:
1. Study of equatorial jet currents
 2. Identification of quiet and disturbed days
 3. Determination of disturbance storm index
 4. Study of geomagnetic pulsations
 5. Simple numerical models of atmospheres/climate systems
- B.** Project:
- In a complete semester, a student must perform one project related to the course.

Evaluation of Practical Courses (PSPHY6502EL1PR):

Total marks - 50

- Project work with report – 20 marks
- End semester practical examination – 20 marks
- Journal – 5 marks
- Co-curricular activity – 5 marks

Distribution of Bloom's Taxonomy levels for practical course assessment

Learning Levels	Remember	Understand	Apply	Analyze	Evaluate	Create
Percentage	0-5%	5-10%	20-25%	25-30%	20-25%	20-25%

MSc-II in Physics		
Course Title: Research Proposal for Dissertation		
Course Code: PSPHY6501RP1		
Credits 2: 60 hr		
Prerequisite: Students who have completed a Four-Year Bachelor Degree in Science with Physics Major or a postgraduate diploma in Physics (Level 6); Proficiency in Python programming is mandatory.		
No.	Course Objectives	
1	To initiate a research project in the area of physics and/or astrophysics through literature survey and develop a coherent research proposal.	
CO	Course Outcomes On completing the course, the learner will be able to	Bloom's Taxonomy Level (BT level)
1	Identify areas of interest in physics and/or astrophysics for carrying out research.	Remembering
2	Understand the state of existing knowledge in the chosen research area through literature review.	Understanding
3	Apply information about active researchers in the field to seek collaborations.	Applying
4	Analyze the literature in the field and define a suitable research problem under the guidance of an academic advisor.	Analyzing
5	Evaluate multiple approaches and plan appropriate methodology for execution of the project within the available time-frame.	Evaluating
6	Develop a research proposal outlining the various aspects of the project and its expected outcomes.	Creating

Evaluation of Research Project Course (PSPHY6501RP1):**Total marks - 50**

CIA – 20 marks

Mode of CIA: Reports/Presentations

End Semester Examination – 30 marks

Distribution of Bloom's Taxonomy levels for research project course assessment

Learning Levels	Remember	Understand	Apply	Analyze	Evaluate	Create
Percentage	0-5%	15-20%	20-30%	20-30%	10-20%	5-10%
