DEPARTMENT OF MATHEMATICS
&
ASTRONOMY
UNIVERSITY OF LUCKNOW

PROPOSED STRUCTURE
OF
UG ASTRONOMY SYLLABUS
(CBCS)

Developed by

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Lucknow

SEMESTER-WISE TITLES OF THE PAPERS IN UG ASTRONOMY COURSE

SEMESTER-WISE TITLES OF THE PAPERS IN UG ASTRONOMY COURSE					
Year	**Semester**	**Course Code**	**Paper Title**	**Theory/ Practical**	**Credit**
CERTIFICATE IN BASIC ASTRONOMY					
First Year	I	P1	Spherical Astronomy & Spherical Trigonometry	Theory	4
		P2	Practical-I	Practical	4
	II	P3	General Astronomy-Paper I	Theory	4
		P4	Practical-II	Practical	4
DIPLOMA IN FUNDAMENTALS OF ASTRONOMY					
Second Year	III	P5	Spherical Astronomy	Theory	4
		P6	Practical-III	Practical	4
	IV	P7	General Astronomy-Paper II	Theory	4
		P8	Practical-IV	Practical	4
DEGREE IN BACHLOR OF SCIENCE					
Third Year	V	P9	Stellar Astronomy-Paper I	Theory	4
		P10	Practical-V	Practical	4
		P11x	Stellar Astronomy-Paper II	Theory	4
		P11y	Stellar Astronomy-Paper III	Theory	4
	VI	P12	Introduction to Binaries	Theory	4
		P13	Practical-VI	Practical	4
		P14x	Variable Stars	Theory	4
		P14y	The Milkyway Galaxy	Theory	4
RESEARCH IN BACHLOR OF SCIENCE					
Fourth Year	VII	P15	Interstellar Medium	Theory	4
		P16	Quantum Chemistry	Theory	4
		P17	Practical-VII	Practical	4
		P18x	Basic Stellar Physics	Theory	4
		P18y	Introduction to Galaxies	Theory	4
		P19x	Extraterrestrial Intelligences	Theory	4
		P19y	Bio-Astronomy	Theory	4
	VIII		Major Project		24

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SUBJECT PREREQUISTIES
To study the subject a student must have had the subjects Physics & Mathematics in Class 12th.
PROGRAMME OUTCOMES (POs)
Department of Mathematics and Astronomy, University of Lucknow, is one of the few Universities in India offering Astronomy subjects at the Undergraduate level. Developed to nurture the interest and intrigue the scientific thinking of future generations, this program in Astronomy covers the basic and intermediate, and advanced level of course. Astronomy is one of the fundamental science subjects, and it explains the origin of the cosmos. It covers a broad range of topics, such as planetary science, stellar evolution, galaxy evolution and formation, the origin of the Universe, and many more. With the recent advent in the field, Astronomical instrumentation is also developing at an accelerated pace. Therefore, to bridge the gap and cover the fundamental concepts in Astronomy, this program starts with basics concepts of Astronomy and leads to an advanced level. In addition to a wide course structure, this program includes concept of small seminar to present and discuss current scientific issues. Moreover it allows to carry out short research projects, learning to novice training of research exposure The main goals and outcome of this course are summarized as follows: • The **First-Year Certificate Course** is developed for introducing the fundamental terminology used in Astronomy. Completing this course, students will have basic knowledge of the field and can acquire and perform amateur level of astronomical observations. • The **Second-Year Diploma Course** consists of an intermediate level of knowledge of introductory Astronomy. It covers a broad range of topics, from studying the solar system formation to space missions. After completing this course, the student will be eligible to work in Planetariums and assist in observatories. • The **Third-Year Degree Course** is developed to teach advanced concepts in Astronomy. In final year, students will perform short research projects, providing a first exposure of research experience. • The **Fourth-Year Research Course**, students will learn about different subfields of Astronomy, with the final aim to learn and pursue research in Astronomy at higher-level studies. After completing this course, students can pursue postgraduate-level studies in Astronomy and establish their Astronomy and Astrophysics scientific research careers.

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PROGRAMME SPECIFIC OUTCOMES (PSOs)	
CERTIFICATE IN BASIC ASTRONOMY	
First Year	Astronomy is one of the fundamental subjects explaining the origin and evolution of the cosmos. To lay down the foundation and ignite students' interest, this program introduces the basics of Astronomy. This program introduces the essential trigonometrical tools needed for doing observations in Astronomy at a beginner level. Starting with a coordinate system, this course gradually teaches students about the Astronomical phenomenon. At the end of the first semester, a student is expected to have gained and learn to explain the observational phenomenon in Astronomy, such as the rising and setting of stars, handling Sextants, and performing simple observations. General Astronomy, the second course of this program, presents the details about our home solar system. In particular, the second semester introduces the formation and physical properties of the solar system planets. At the end of the entire certificate course, the student is expected to have learned the basics of Astronomy with knowledge of the Astronomical coordinate system; one is expected to carry his own set of Amateur level Astronomical observations.
DIPLOMA IN FUNDAMENTALS OF ASTRONOMY	
Second Year	The diploma in Fundamentals of Astronomy program brings the intermediate level of knowledge of Astronomy for students. With current and new advancements going on in Astronomy, this program set a broader class of understanding among students. Combined with a set of experiments, this program teaches the physics behind the observed Astronomical phenomenon. In the second semester of this diploma course, students learn the formation and evolution of our solar system. With this course, a student is expected to have gained a sufficient understanding of Astronomy to work and assist in Astronomical observatories

DEGREE IN BACHLOR OF SCIENCE	
Third Year	In the current time, Astronomy is at the forefront of the scientific research world. This final stage of the bachelor's program in Astronomy is meant to develop an advanced level of understanding of Astronomy. It builds the base for future research-level studies in Astrophysics. This program introduces various subjects of Astronomy, such as stellar Astronomy and stellar spectroscopy & evolution, Galaxies, etc. This program also presents the technique behind Astronomical instrumentation. These subjects are of extreme importance to learn and carry higher studies in Astronomy. Combined with theoretical and practical experiments, this program brings the scientific temperament to pursue higher research studies. Moreover, after completing this course, the student will be eligible to work as a scientific assistant in research labs and observatories
RESEARCH IN BACHLOR OF SCIENCE	
Fourth Year	The fourth year of this course introduces the various subfields of Astronomy. In addition to topics such as interstellar medium, radio astronomy, subjects like Quantum Chemistry and Astrobiology are covered in the last year of this program. Last semester is dedicated to pursuing a major research project based on student interest. This introduction to various subjects and a major research project will be crucial for students to decide their specialization for carrying out future research careers.

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First Year

Detailed syllabus For

CERTIFICATE
IN
BASIC ASTRONOMY

***First Year-Certificate Course (Semester I & II)

YEAR	SEM	COURSE CODE	PAPER	PAPER TITLE	UNIT TITLE	CREDIT
	CERTIFICATE IN BASIC ASTRONOMY					
FIRST YEAR	**SEMESTER I**	**P1**	Theory Paper	**Spherical Astronomy & Spherical Trigonometry**	I. Coordinate Systems II. Diurnal Motion, Twilight, Refraction & Time III. Kepler's Laws, Planetary Phenomenon IV. Spherical Trigonometry	**4**
		P2	Practical Paper	**Practical-I**	• List of Experiments • Online Virtual Lab Experiment List/Link	**4**
	SEMESTER II	**P3**	Theory Paper	**General Astronomy- Paper I**	I. The Earth II. The Moon III. Terrestrial Planets & Dwarfs Planets IV. Jovian Planets	**4**
		P4	Practical Paper	**Practical-II**	• List of Experiments • Online Virtual Lab Experiment List/Link	**4**

Semester I (Theory Paper) P1

Subject: **Astronomy**	Programme/Class**: Certificate**	Year: **First**	Semester: **First**

Title of the Paper: Spherical Astronomy & Spherical Trigonometry
Course Code: P1 [Theory]
Credit: 4

Course Outcomes (COs)

1. To understand the different Coordinate systems to locate the celestial object in space.
2. Learn and use new vocabulary words (Great circle, Small circles, Spherical Angle, Spherical Triangle, Vertical circles, Zenith, Nadir, Cardinal points etc.).
3. To learn the diurnal/annual motion of Earth and Sun, Concept of twilight, Rising & setting of celestial objects, Effect of the refraction phenomena for the celestial objects.
4. Understand the surface features, phases and origin of moon.
5. Discover facts about Spherical triangles & applications of Trigonometrical formulas over the sphere.
6. Understand Kepler's Laws of Planetary Motion.
7. To understand the importance of the mother planet and its atmosphere
8. To explore the Terrestrial, Jovian and Dwarf planets and their missions.

Title of the Paper: Spherical Astronomy & Spherical Trigonometry

Unit	Topics
I	**Coordinate Systems** The Celestial sphere, The Coordinate systems: Azimuth & Altitude, Right Ascension & Declination, Longitude & Latitude; Hour angle; Altitude of the pole, Equinoxes, Conversion of Coordinates from one System to another, Geocentric Celestial sphere.
II	**Diurnal Motion, Twilight, Refraction & Time** Earth's Diurnal Motion & Annual Motion, Time of Transit, Rising and Setting of Celestial Bodies, Motion of the Sun, Morning & Evening Twilight, Dip of the horizon. Laws of Refraction, Atmospheric Refraction, Sidereal Time, Mean Time, Equation of Time, Universal Time, Mean Sun.
III	**Kepler's Laws & Planetary Phenomenon** Kepler's laws, Relations in Elliptical Motion, True, Eccentric & Mean Anomalies, Kepler's Equation, Direct & Retrograde Motion, Geocentric Motion of a Planet, Elongation, Phases of a Celestial body, Brightness of the Planet.
IV	**Spherical Trigonometry** Geometry of the Sphere: Definitions and properties of Great circle, Small circle, Spherical triangle, Spherical Triangles, Polar Triangles, Astronomical Triangles, Co-lunar & Antipodal Triangle and their properties, Statements and Derivations of Sine, Cosine, Cotangent and Sine-Cosine formula, Napier Analogy and its application in solving problems.

References

- **Text Books**

1. W. M. Smart, 1977, Textbook on Spherical Astronomy, Cambridge University Press.
2. Gorakh Prasad, 2006, Textbook on Spherical Astronomy, Pothishala, Allahabad.
3. Todhunter, 1914, Spherical trigonometry, The MacMillan Company, London.
4. Robin M. Green, 1999, Spherical Astronomy, Cambridge University Press.
5. John D. Cook, Introduction to Spherical Trigonometry.

- **Suggested Readings**

1. https://www.classcentral.com/subject/astronomy
2. NPTEL : https://nptel.ac.in/courses/115/105/115105046/
3. Coursera : https://www.coursera.org/search?query=astronomy
4. Edx. : https://www.edx.org/learn/astronomy
5. Udemy : https://www.udemy.com/courses/search/?q=astronomy
6. OpenLearnhttps://www.open.edu/openlearn/science-maths-technology/free-courses/?filter=date/grid/671/all/all/all/

- **Web References**

1. http://star-www.st-and.ac.uk/~fv/webnotes/index.html
2. http://aprsa.villanova.edu/files/Smart-SphericalAstronomy.pdf
3. https://www.google.co.in/books/edition/Spherical_Astronomy/wOpaUFQFwTwC?hl=en&gbpv=1&dq=spherical+Astronomy&printsec=frontcover
4. The Project Gutenberg EBook of Spherical Trigonometry, by I. Todhunter, https://www.gutenberg.org/files/19770/19770-pdf.pdf
5. ePg Pathshala https://epgp.inflibnet.ac.in/Home
6. NEPTEL http://www.nptelvideos.in/2012/12/astrophysics-cosmology.html
7. Uttar Pradesh Higher Education Digital Library, http://heecontent.upsdc.gov.in/SearchContent.aspx
8. http://www.astronomynotes.com/

Further Suggestions

The Institution may add/modify/change the contents time to time for advancement and up-gradation.

***Practical Paper (Practical-I) P2

Subject: A**stronomy**	Programme/Class**: Certificate**	Year: **First**	Semester: **First**

Title of the Paper: Practical-I
Course Code: P2 [Practical]
Credit: 4

Course Outcomes (COs)

1. Learn to handle the Astronomical data.
2. Learn the positions of the celestial bodies on the Celestial Sphere for northern latitudes.
3. Know the time concept and its conversion.
4. Conceptual knowledge of daily Astronomical phenomenon.

Unit	Topics
	Lab Experiment List
	1. Usages and handling the Astronomical Data through Astronomical Ephemeris. 2. Draw the Celestial Spheres for a given place in Northern latitude, showing therein Sun, Moon, a Planet, and Star. 3. Draw the Celestial Spheres for a place on the equator, showing therein the Sun, Moon, Planet, and Star. 4. Calculate the Shortest Distance between two Places on the Surface of the Earth. 5. Calculate of the Time of Rising and Setting of the sun. 6. Calculate of the Duration of Morning Twilight at Lucknow. 7. Calculate of the Duration of Morning Twilight at any given Place. 8. Calculate of the Duration of Evening twilight at Lucknow. 9. Calculate of the Duration of Evening Twilight at any given Place. 10. Conversion of Sidereal Time to Mean Time at any given Place. 11. Conversion of Mean Time to Sidereal Time at any given Place. Problems on Converting from one Coordinate System to another.
	On line Virtual Lab Experiment List/Link
	1. http://va-iitk.vlabs.ac.in/?page=objectives. 2. http://astro.physics.uiowa.edu/ITU. 3. http://astronomy.nmsu.edu/geas/labs/html/home.shtml 4. https://astro.unl.edu/nativeapps/

References

- **Text Books**

1. W. Schroeder, 1965, Practical Astronomy, Philosophical Library.
2. J.J. Nassau, 1948, Practical Astronomy, McGraw Hill Text; 2nd Edition.
3. George L. Hosmer & James M. Robbins, 1963, Practical Astronomy, John Wiley and Sons Inc.

- **Suggested Readings**

1. Peter Duffett-Smith,1988, Practical Astronomy with your Calculator, Cambridge University Press.

2. Gorakh Prasad, 2006, Textbook on Spherical Astronomy, Pothishala, Allahabad.

- **Web References**

1. http://va-iitk.vlabs.ac.in/?page=objectives.
2. http://astro.physics.uiowa.edu/ITU.
3. http://astronomy.nmsu.edu/geas/labs/html/home.shtml
4. https://astro.unl.edu/nativeapps/

Further Suggestions

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*** Semester II (Theory Paper) P3

Subject: **Astronomy**	Programme/Class**: Certificate**	Year: **First**	Semester: **Second**

Title of the Paper: General Astronomy-Paper I
Course Code: P3 [Theory]
Credit: 4

Course Outcomes (COs)

1. Understand the importance of the home Planet.
2. Understand the Earth's Diurnal, Annual motions, and its Atmosphere.
3. Understand the surface features of Moon, viz., Lunar Mountains, Lunar Maria, Lunar Craters etc.
4. Explore Lunar Librations, Tides and Waxing and Waning of the moon and various Theories for the formation of Moon.
5. Utility of Titus-Bode's Law.
6. Explore the Terrestrial & Jovian planets.
7. Study the Morphology, Orbital properties, Surface features, Ring systems, Satellites and Atmosphere of the Planets.
8. Understand the definition, discovery and properties of the Dwarf Planets.
9. Information & Finding of various Planetary Missions.

Title of the Paper: General Astronomy-Paper I

Unit	Topics
I	**The Earth** The shape, size, rotation, and revolution of the Earth its atmosphere. Green House effect, Aurora; Geomagnetic field, Van Allen Radiation Belts, Trapped radiation. Origin, Appearance, and duration of Zodical Light, Origin of Gagenschein Light.
II	**The Moon** General Introduction, Surface features, Motion of the Moon, Lunar Phases, Tides, Lunar Librations, Origin of the Moon.
III	**Terrestrial Planets** Terrestrial Planets- (Mercury, Venus & Mars): Classifications of the Planets, General introduction, discovery, orbital properties, surface features, interior, polar caps, atmospheres, magnetic fields and satellites, Past, Present & Future Missions and their findings for the Terrestrial Planets. Titus-Bode Law and its Importance. Dwarfs Planets- Pluto, Ceres, Eris, Makemake, Haumea. General Introduction, Discovery, Orbital Properties, Surface & Atmosphere, Satellites, Exploration.
IV	**Jovian Planets** Jovian Planets: Jupiter, Saturn Uranus & Neptune, General Introduction, Discovery, Orbital Properties, Surface Features, Interior, Atmosphere, Magnetic Fields, Ring Systems and Satellites.

References

- **Text Books**

1. Eric Chaisson & Steve MacMillan, 1996, Astronomy Today, Prentice Hall, New Jersey.
2. John D Fix, 1995, Astronomy-Journey to the Cosmic Frontier, Mosby, New York.
3. R.H. Fredrick and L. W Baker, 1968, Introduction of Astronomy by D. Van Nostrand Co.; Unabridged. Edition.
4. C. Payne Gaposhkin, 1956, Introduction to Astronomy, Eyre & Spottiswoode; First British ed. Edition.

- **Suggested Readings**

1. Baidyanath Basu, Tanuka Chattopadhyay & Sudhindra Nath Biswas, 2010, An Introduction to Astrophysics
2. https://www.classcentral.com/subject/astronomy
3. NPTEL : https://nptel.ac.in/courses/115/105/115105046/
4. Coursera : https://www.coursera.org/search?query=astronomy
5. Edx. : https://www.edx.org/learn/astronomy
6. Udemy : https://www.udemy.com/courses/search/?q=astronomy
7. OpenLearnhttps://www.open.edu/openlearn/science-maths-technology/free-courses/?filter=date/grid/671/all/all/all/

- **Web References**

1. NEPTEL http://www.nptelvideos.in/2012/12/astrophysics-cosmology.html
2. http://www.astronomynotes.com/
3. https://www.enchantedlearning.com/subjects/astronomy/
4. http://astronomyonline.org/
5. https://astronomy.swin.edu.au/cosmos/
6. http://repository.iucaa.in:8080/jspui/handle/11007/4241
7. Jet Propulsion Laboratory-NASA: California Institute of Technology, https://www.jpl.nasa.gov/
8. Uttar Pradesh Higher Education Digital Library, http://heecontent.upsdc.gov.in/SearchContent.aspx
9. CliffNotes https://www.cliffsnotes.com/study-guides/astronomy
10. https://www.open.edu/openlearn/science-maths-technology/science/physics-and-astronomy/astronomy
11. http://www.space.com
12. http://www.nasa.gov
13. Astronomy notes https://www.astronomynotes.com/index.html
14. http://www.esa.int/

Further Suggestions

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***Practical Paper (Practical-II) P4

Subject: A**stronomy**	Programme/Class**: Certificate**	Year: **First**	Semester: **Second**

Title of the Paper: Practical-II
Course Code: P4 [Practical]
Credit: 4

Course Outcomes (COs)

1. Learn to handle the Astronomical data through Ephemeris.
2. Learn the locations of the celestial bodies on the Celestial Sphere for Southern latitudes.
3. Understand the conversion of coordinate system.
4. Calculations of Lunar phases at different times.
5. Observations through Sextant.
6. Observing Seasonal features of night Sky.

Unit	Topics
	Lab Experiment List
	1. Draw the Celestial Spheres for a given place in Southern latitude, showing therein the Sun, Moon, Planets and Stars. 2. Draw the Celestial Spheres in Southern latitude for a place on the equator, showing therein Sun, Moon, Planets and Stars. 3. Calculate of the time of rising and setting of the given Star for any given latitude. 4. Calculate of the Duration of Visibility of a given Star at any given latitude. 5. Calculation of lunar phases and brightness. 6. Problems on converting from one coordinate system to another. 7. Determination of the semi-diameter of the Sun by Sextant. 8. Sky Watching. 9. Project Work.
	Online Virtual Lab Experiment List/Link
	1. http://va-iitk.vlabs.ac.in/?page=objectives. 2. http://astro.physics.uiowa.edu/ITU. 3. http://astronomy.nmsu.edu/geas/labs/html/home.shtml 4. https://astro.unl.edu/nativeapps/

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- **Text Books**

1. W. Schroeder, 1965, Practical Astronomy, Philosophical Library.
2. J.J. Nassau, 1948, Practical Astronomy, McGraw Hill Text; 2nd edition.
3. George L. Hosmer & James M. Robbins, 1963, Practical Astronomy, John Wiley and Sons Inc.

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2. Gorakh Prasad, 2006, Textbook on Spherical Astronomy, Pothishala, Allahabad.

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2. http://astro.physics.uiowa.edu/ITU.
3. http://astronomy.nmsu.edu/geas/labs/html/home.shtml
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Further Suggestions

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Second Year

Detailed syllabus For

Diploma
IN
FUNDAMENTALS OF ASTRONOMY

*** Second Year-Diploma Course (Semester III & IV)

YEAR	SEM	COURSE CODE	PAPER	PAPER TITLE	UNIT TITLE	CREDIT
DIPLOMA IN FUNDAMENTALS OF ASTRONOMY						
SECOND YEAR	**SEMESTER III**	**P5**	Theory Paper	**Spherical Astronomy**	I. Parallax II. Precession & Nutation, Eclipses of Sun & Moon III. Aberration IV. Proper Motions of Stars Determination of Position, Occultations of Stars, Binary Orbits	4
		P6	Practical Paper	**Practical-III**	• List of Experiments • Online Virtual Lab Experiment List/Link	4
	SEMESTER IV	**P7**	Theory Paper	**General Astronomy-Paper II**	I. Modeling for the Origin of Solar System, II. Various Theories for the Formation of Solar System III. Asteroids, Meteoroids, Meteors & Meteorites IV. Comets & Cometary Missions	4
		P8	Practical Paper	**Practical-IV**	• List of Experiments • Online Virtual Lab Experiment List/Link	4

*** Semester III (Theory Paper) P5

Subject: A**stronomy**	Programme/Class**: Diploma**	Year: **Second**	Semester: **Third**

Title of the Paper: Spherical Astronomy
Course Code: P5 [Theory]
Credit: 4

Course Outcomes (COs)

1. Understand the Phenomenon of Parallax in the Celestial Objects.
2. Effect of the Aberration in Celestial Objects.
3. Causes of the Precessional Motion of the Earth.
4. Learn the Precession and Nutation effect.
5. Understand the phenomenon of the Solar and Lunar Eclipses.
6. Determination the positions of the places and to learn Techniques to determine the Longitudes and Latitudes of the place.
7. Study of the Binaries, its formation and detecting techniques.
8. Usages and Theory of the Astronomical Transit Instruments.
9. Understand the phenomena of Occultation.

Title of the Paper: Spherical Astronomy

Unit	Topics
I	**Parallax** Introduction, Shape of the Earth, Angle of the Vertical, Geocentric Parallax, Annual parallax, Parallax of Moon, Parallax of the Sun, Planets & Stars. Derivations for the Lunar Parallax in Right Ascension & Declination, Derivation for Stellar Parallax in Right Ascension & Declination and Longitude & Latitude.
II	**Precession & Nutation & Eclipses of Sun & Moon** Introduction, Physical Causes of Precession & Nutation, Derivations for Precession in Right Ascension & Declination, & Derivations for Nutation in Right Ascension & Declination, Independent Day Numbers. General Introduction, Eclipses of the Sun and the Moon, Ecliptic Limits, Greatest and Least number of Eclipses in one year.
III	**Aberration** Introduction, Diurnal Aberration, Annual Aberration, Planetary Aberration, Apex of the Earth Motion. Derivations of Aberration in Longitude & Latitude, Effect of Aberration in Right Ascension & Declination, Independent Day Numbers.
IV	**Proper Motions of Stars, Determination of Position & Occultation of Stars, Binary Orbits** General Introduction, Proper Motion in Right ascension & Declination, Motion of the Sun, Parallactic Motion in Right Ascension & Declination. Determination of the Longitude & Latitude, The Sextant, Theodolite, The Zenith Telescope, Dip of the Horizon. General Introduction, Occultation of Stars, Besselian elements of Occultation. Binary system, Wide binaries, Close binaries, Elements of the orbit, Detecting techniques of the binaries: Zwier's Method, Lehmann-Filhes Method

References

- **Text Books**

1. W. M. Smart, 1977, Textbook on Spherical Astronomy, Cambridge University Press.
2. Gorakh Prasad, 2006, Textbook on Spherical Astronomy, Pothishala, Allahabad.
3. Robin M. Green, 1999, Spherical Astronomy, Cambridge University Press.

- **Suggested Readings**

1. https://www.classcentral.com/subject/astronomy
2. NPTEL : https://nptel.ac.in/courses/115/105/115105046/
3. Coursera : https://www.coursera.org/search?query=astronomy
4. Edx. : https://www.edx.org/learn/astronomy
5. Udemy : https://www.udemy.com/courses/search/?q=astronomy
6. OpenLearnhttps://www.open.edu/openlearn/science-maths-technology/free-courses/?filter=date/grid/671/all/all/all/

- **Web References**

1. http://star-www.st-and.ac.uk/~fv/webnotes/index.html
2. http://aprsa.villanova.edu/files/Smart-SphericalAstronomy.pdf
3. https://www.google.co.in/books/edition/Spherical_Astronomy/wOpaUFQFwTwC?hl=en&gbpv=1&dq=spherical+Astronomy&printsec=frontcover
4. ePg Pathshala- https://epgp.inflibnet.ac.in/Home
5. NEPTEL http://www.nptelvideos.in/2012/12/astrophysics-cosmology.html
6. Uttar Pradesh Higher Education Digital Library, http://heecontent.upsdc.gov.in/SearchContent.aspx
7. http://www.astronomynotes.com/

Further Suggestions

The Institution may add/modify/change the contents time to time for advancement and up-gradation.

***Practical Paper (Practical-III) P6

Subject: A**stronomy**	Programme/Class**: Diploma**	Year: **Second**	Semester: **Third**

Title of the Paper: Practical-III
Course Code: P6 [Practical]
Credit: 4

Course Outcomes (COs)

1. Methods to calculate physical properties of the stellar objects.
2. Learn the concept of various magnitudes of stars.
3. Understand the mass-luminosity relationship.
4. Uses of Precession & Nutation table for deterring the stellar position at an Epoch.
5. Computation of the elements of the True orbit of a Visual binary by Zwier's method.
6. Observations with the help of Sextant.
7. Observing Seasonal features of the Night Sky.

Unit	Topics
	Lab Experiment List
	1. Determination of absolute magnitude of a star given its apparent magnitude and parallax. 2. Problem on mass-luminosity relationship. 3. Determination of combined magnitude of a binary system. 4. Calculation of relative brightness of one star with respect to other given their magnitudes. 5. Calculation of bolometric magnitude, diameter, distance and the mass of a star. 6. Determination of stellar position at an epoch, given its position at another epoch, applying corrections for precession for northern objects. 7. Computation of the elements of the true orbit of a Visual binary by Zwier's method. 8. Determination of time from the altitude of the Sun by Sextant. 9. Determination of the latitude of the place from observations of the meridian transit of the Sun by Sextant. 10. Sky Watching.
	Online Virtual Lab Experiment List/Link
	1. http://va-iitk.vlabs.ac.in/?page=objectives. 2. http://astro.physics.uiowa.edu/ITU. 3. http://astronomy.nmsu.edu/geas/labs/html/home.shtml 4. https://astro.unl.edu/nativeapps/

References

- **Text Books**

1. W. Schroeder, 1965, Practical Astronomy, Philosophical Library.
2. J.J. Nassau, 1948, Practical Astronomy, McGraw Hill Text; 2nd Edition.
3. George L. Hosmer & James M. Robbins, 1963, Practical Astronomy, John Wiley & Sons Inc.

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1. Peter Duffett-Smith,1988, Practical Astronomy with your Calculator, Cambridge University Press.
2. Gorakh Prasad, 2006, Textbook on Spherical Astronomy, Pothishala, Allahabad.

- **Web References**

1. http://va-iitk.vlabs.ac.in/?page=objectives.
2. http://astro.physics.uiowa.edu/ITU.
3. http://astronomy.nmsu.edu/geas/labs/html/home.shtml
4. https://astro.unl.edu/nativeapps/

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*** Semester IV (Theory Paper) P7

Subject: A**stronomy**	Programme/Class**: Diploma**	Year: **Second**	Semester: **Fourth**

Title of the Paper: General Astronomy-Paper II
Course Code: P7 [Theory]
Credit: 4

Course Outcomes (COs)

1. Understand the major features that a theory of Solar system origin has to explain.
2. Learn the process of cooling & condensation process in Solar Nebula.
3. Knowledge of various theories of origin of the Solar System.
4. Knowledge of orbital, physical and chemical properties of Asteroids.
5. Distinguish the terms Meteor, Meteoroid & Meteorite & their properties
6. Learn the characteristics, composition, structure and classification and tail formation of Comets.
7. Knowledge of Kuiper Belt & Oorts Cloud.
8. Learn the various missions and their findings for Comets & Asteroids.

Title of the Paper: General Astronomy-Paper II

Unit	**Topics**
	Formation of Solar System
I	**Modeling for the Origin of the Solar System** Modeling, Model Requirements, Solar Nebula, Chemical Condensation Sequence in Solar Nebula, Pre-existing Solar Nebula: Mass, Size and age.
II	**Various Theories for the Formation of Solar System** Laplace Theory, Condensation Theories, Nebular Theories, Planetesimal Theory, Proto-planet & Accretion Theory, Whipple theory etc.
III	**Asteroids, Meteoroids, Meteors & Meteorites** Introduction, Discovery, Orbital properties, Asteroids Belt, Classes of Asteroids, Earth Crossing Asteroids, Asteroids Collision. General Introduction, difference between Meteoroid, Meteorite and Meteors, Meteor Showers, Meteorites its Ages and kinds.
IV	**Comets & Cometary Missions** Introduction, Cometary Structure & its Orbit, Classification of Comets, Origin of Comets: Oorts Cloud & Kupier Belt, Future of Comets, Cometary Impact & its consequences, Importance & Astrobiological Relevance. General Introduction, Types of Space Exploration Missions: Flyby, Orbiter, Lander, Rover, Penetrator, Atmospheric, Observatory, Communications & Navigation spacecraft. Knowledge & Findings of some important missions of Comets & Asteroids

References

- **Text Books**

1. Eric Chaisson & Steve MacMillan, 1996, Astronomy Today, Prentice Hall, New jersey.
2. John D Fix, 1995, Astronomy-Journey to the Cosmic Frontier, Mosby, New York.

3. R.H. Fredrick and L. W Baker, 1968, Introduction of Astronomy by D. Van Nostrand Co.; Unabridged. Edition.
4. C. Payne Gaposhkin, 1956, Introduction to Astronomy, Eyre & Spottiswoode; First British ed. Edition.

- **Suggested Readings**

- https://www.classcentral.com/subject/astronomy
- NPTEL : https://nptel.ac.in/courses/115/105/115105046/
- Coursera : https://www.coursera.org/search?query=astronomy
- Edx. : https://www.edx.org/learn/astronomy
- Udemy : https://www.udemy.com/courses/search/?q=astronomy
- OpenLearnhttps://www.open.edu/openlearn/science-maths-technology/free-courses/?filter=date/grid/671/all/all/all/

- **Web References**

1. NEPTEL http://www.nptelvideos.in/2012/12/astrophysics-cosmology.html
2. http://www.astronomynotes.com/
3. https://www.enchantedlearning.com/subjects/astronomy/
4. http://astronomyonline.org/
5. https://astronomy.swin.edu.au/cosmos/
6. http://repository.iucaa.in:8080/jspui/handle/11007/4241
7. Jet Propulsion Laboratory-NASA: California Institute of Technology, https://www.jpl.nasa.gov/
8. Uttar Pradesh Higher Education Digital Library, http://heecontent.upsdc.gov.in/SearchContent.aspx
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10. https://www.open.edu/openlearn/science-maths-technology/science/physics-and-astronomy/astronomy
11. http://www.space.com
12. http://www.nasa.gov
13. Astronomy notes https://www.astronomynotes.com/index.html
14. http://www.esa.int/
15. https://solarsystem.nasa.gov/solar-system/our-solar-system/overview/
16. https://solarsystem.nasa.gov/basics/chapter9-1/#surface

Further Suggestions

The Institution may add/modify/change the contents time to time for advancement and up-gradation.

***Practical Paper (Practical-IV)P8

Subject: **Astronomy**	Programme/Class**: Diploma**	Year: **Second**	Semester: **Fourth**

Title of the Paper: Practical-IV
Course Code: P8 [Practical]
Credit: 4

Course Outcomes (COs)

1. Calculate the Transit time and the Altitude of stellar objects.
2. Learn the Concept of various magnitudes of Stars.
3. Understand the Empirical Mass-Luminosity relationship.
4. Uses of Precession & Nutation table for deterring the stellar position at an Epoch for Southern Objects.
5. Computation of the elements of the true orbit of a spectroscopic binary by Lehman-Filhes Method.
6. Observations with the help of Theodolite.
7. Observing Seasonal features of the Night Sky.

Unit	Topics
	Lab Experiment List
	1. Determination of time of transit of a given star (Betelgeuse) at any place and find its altitude at the time of transit. 2. Calculate how much brighter is the star Sirius than a star of a given magnitude. 3. Compute the absolute visual magnitude, diameter and luminosity of ϵ-Eridani in term of the Sun. 4. Estimate the mass from the Empirical-mass Luminosity relation and compute the surface gravity of ϵ-Eridani. 5. Estimate the position of a star for no displacement due to annual Parallax and also for the greatest annual parallax. 6. Determination of stellar position at an epoch, given its position at another epoch, applying corrections for precession for southern objects. 7. Computation of the elements of the true orbit of a spectroscopic binary by Lehman-Filhes method. 8. Determination of Azimuth of the Sun from its altitude by Theodolite, the Latitude of the place being known. 9. Determination of Azimuth of the Sun from its altitude by Theodolite, the time being known. 10. Sky Watching
	Online Virtual Lab Experiment List/Link
	1. http://va-iitk.vlabs.ac.in/?page=objectives. 2. http://astro.physics.uiowa.edu/ITU. 3. http://astronomy.nmsu.edu/geas/labs/html/home.shtml 4. https://astro.unl.edu/nativeapps/

References

- **Text Books**

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2. J.J. Nassau, 1948, Practical Astronomy, McGraw Hill Text; 2nd Edition.
3. George L. Hosmer & James M. Robbins, 1963, Practical Astronomy, John Wiley and Sons Inc.

- **Suggested Readings**

1. Peter Duffett-Smith,1988, Practical Astronomy with your Calculator, Cambridge University Press.
2. W. M. Smart, 1977, Textbook on Spherical Astronomy, Cambridge University Press.

- **Web References**

1. http://va-iitk.vlabs.ac.in/?page=objectives.
2. http://astro.physics.uiowa.edu/ITU.
3. http://astronomy.nmsu.edu/geas/labs/html/home.shtml
4. https://astro.unl.edu/nativeapps/

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Third Year

Detailed syllabus For

DEGREE
IN
BACHELOR OF SCIENCE

***Third Year-Degree Course (Semester V & VI)

YEAR	SEM	COURSE CODE	PAPER	PAPER TITLE	UNIT TITLE	CREDIT
DEGREE IN BACHLOR OF SCIENCE						
THIRD YEAR	**SEMESTER V**	**P9**	Theory Paper	**Stellar Astronomy-Paper I**	I. Basic Properties of the Sun II. Solar Interior III. Solar Atmosphere IV. Sun Spots & Solar Cycle	**4**
		P10	Practical Paper	**Practical-V**	• List of Experiments • Online Virtual Lab Experiment List/Link	**4**
		P11x	Theory Paper	**Stellar Astronomy-Paper II**	I. Formation of Stars II. Pre-Main sequence Evolution III. Post-Main sequence Evolution IV. Degenerate Remnants	**4**
		P11y	Theory Paper	**Stellar Astronomy-Paper III**	I. Formation of Spectral Lines, Laws of Radiation & HR Diagram II. Characteristic of Stellar Spectra III. Astronomical Utility of Various Laws IV. Astronomical Instruments	**4**
	SEMESTER VI	**P12**	Theory Paper	**Introduction to Binaries**	I. Introduction II. Formation & Evolution III. Accretion Discs in Binaries IV. X-Rays Binaries	4
		P13	Practical Paper	**Practical-VI**	• List of Experiments • Online Virtual Lab Experiment List/Link	4
		P14x	Theory Paper	**Variable Stars**	I. R-R Lyre Stars II. Cepheid Variables III. Mira Type Stars IV. Novae & Super Novae	4
		P14y	Theory Paper	**The MilkyWay Galaxy**	I. Introduction II. Structure & Morphology III. Kinematics IV. Evidence of Dark Matter	4

*** Semester V (Theory Paper-1) P9

Subject: **Astronomy**	Programme/Class**: Degree**	Year: **Third**	Semester: **Fifth**

Title of the Paper: Stellar Astronomy-Paper I
Course Code: P9 [Theory]
Credit: 4

Course Outcomes (COs)

1. Define and use content-specific vocabulary.
2. Understand the overall Properties of the Sun.
3. Understand the Standard Solar Model and its importance.
4. Learn the Sunspots and Solar Cycle.

Title of the Paper: Stellar Astronomy-Paper I	
Unit	**Topics**
I	**Basic Properties of the Sun** Physical Properties of the Sun, Solar Constant, Luminosity of the Sun, Helioseismology, Solar Energy Production, Sun's life Time
II	**Solar Interior** Modeling the Structure of the Sun, Standard Solar Model, Core, Radiation zone, Convective Zone, Photosphere, Energy Transport, and Granulations.
III	**Solar Atmosphere** Composition of the Solar Atmosphere, Chromospheres, Transition Zone, Corona, solar Wind, Coronal hole, Coronal Mass Ejections (CME), Solar Flares.
IV	**Sun Spots & Solar Cycle** General Introduction, Active regions, Formation of Sun Spots, Solar Magnetism, Solar Cycle.

References:

- **Text Books**

1. Eric Chaisson & Steve Macmillion, 1996, Astronomy Today, Prentice Hall, New Jersey.
2. John D Fix, 1995, Astronomy-Journey to the Cosmic Frontier, Mosby, New York.
3. R.H. Fredrick and L. W Baker, 1968, Introduction of Astronomy by D. Van Nostrand Co.; Unabridged. Edition.
4. Payne Gaposhkin, 1956, Introduction to Astronomy, Eyre & Spottiswoode; First British ed. Edition.

- **Suggested Readings**

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2. K.S.Krishna Swamy, 2010, Astrophysics: a Modern Perspective, New Age International Pvt. Ltd.
3. https://www.classcentral.com/subject/astronomy
3. NPTEL : https://nptel.ac.in/courses/115/105/115105046/
4. Coursera : https://www.coursera.org/search?query=astronomy
5. Edx. : https://www.edx.org/learn/astronomy

6. Udemy : https://www.udemy.com/courses/search/?q=astronomy
7. OpenLearnhttps://www.open.edu/openlearn/science-maths-technology/free-courses/?filter=date/grid/671/all/all/all/

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2. https://solarsystem.nasa.gov/basics/chapter9-1/#surface
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16. http://www.esa.int/

Further Suggestions

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***Practical Paper (Practical-V) P10

Subject: Astronomy	Programme/Class**: Degree**	Year: **Third**	Semester: **Fifth**

Title of the Paper: Practical-V
Course Code: P10 [Practical]
Credit: 4

Course Outcomes (COs)

1. Learn the handling & Mounting of a Solar Telescope.
2. Observations with the Solar Telescope.
3. Uses of Astronomical Software in handling telescope (Stellarium, Starry night, Celestia).
4. Solve problems related to the Stars and Novae.
5. Experiment/Instruments demonstration Presentations.

Unit	**Topics**
	Lab Experiment List
	1. Learn the Mounting and the Handling of the Solar Telescope. 2. Determination of the angular size of the Sun with the help of the Telescope. 3. Spotting the features of the Sun with the help of a telescope. 4. Uses of Astronomical software in handling telescope. (Stellarium, Starry night, Celestia). 5. To find the distance of a Cepheid Variable Stars if absolute (M) and Apparent magnitude (m) are known. 6. Calculation of the brightness of the Supernova in the night sky. 7. Calculation of the duration of life-time of a given star in the Main Sequence. 8. Estimation of the Schwarzschild radius. 9. Project Work/PPT Presentation.
	Online Virtual Lab Experiment List/Link
	1. http://va-iitk.vlabs.ac.in/?page=objectives. 2. http://astro.physics.uiowa.edu/ITU. 3. http://astronomy.nmsu.edu/geas/labs/html/home.shtml 4. https://astro.unl.edu/nativeapps/

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- **Suggested Readings**

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Further Suggestions
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*** Semester V (Theory Paper) P11x

Subject: **Astronomy**	Programme/Class**: Degree**	Year: **Third**	Semester: **Fifth**

Title of the Paper: Stellar Astronomy-Paper II
Course Code: P11x [Theory]
Credit: 4

Course Outcomes (COs)

1. Learn the Life Cycle & Formation of Stars.
2. Understand the Hertzprung-Russell Diagram.
3. Learn Pre-Post Main Sequence Evolution of Stars.
4. Learn the Degenerate Remnants.

Title of the Paper: Stellar Astronomy-Paper II

Unit	Topics
I	**Formation of Stars** Introduction, Star Formation Regions, Different Stages of Star Formation Stage I to Stage VII), Life of the Star.
II	**Pre-Main Sequence Evolution** General Introduction, Giant Molecular Cloud, Proto-Stars, T-Tauri stars Ae/Be Stars.
III	**Post-Main Sequence Evolution** Introduction of Main Sequence Stars, Core fusion, He flash, Giants Super Giants, Planetary Nebula
IV	**Degenerate Remnants** A brief Introduction of White Dwarfs, Neutron Stars & Black Holes

References:

- **Text Books**

1. Eric Chaisson & Steve Macmillion, 1996, Astronomy Today, Prentice Hall, New Jersey.
2. John D Fix, 1995, Astronomy-Journey to the Cosmic Frontier, Mosby, New York.
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Further Suggestions

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*** Semester V (Theory Paper) P11y

Subject: **Astronomy**	Programme/Class**: Degree**	Year: **Third**	Semester: **Fifth**

Title of the Paper: Stellar Astronomy-Paper III
Course Code: P11y [Theory]
Credit: 4

Course Outcomes (COs)

1. Learning of stellar spectra and stellar radiations with its applications.
2. Study of variation of Stellar Luminosities with Stellar Classes and Life cycle of a star.
3. To know the effect of Temperature on Stellar Spectra and basics of its quantitative analysis.
4. Understand the variation in frequencies of light with the observer and its applications. To study the importance of Stellar Magnetic fields, Stellar Populations and their classification.
5. Knowledge of Astronomical Instrument, Telescopes, its Mountings and image defects.
6. Elementary idea of Dispersion and Resolution via Spectrograph, Prisms and Grating and Photoelectric Photometers.

Title of the Paper: Stellar Astronomy-Paper III

Unit	Topics
I	**Formation of Spectral Line, Laws of Radiation & HR Diagram** Elementary ideas about formation of spectral lines, spectra, Laws of radiation and their application. Spectral classification, Luminosity classification, HR diagram, Elementary ideas about stellar evolution.
II	**Characteristics of Stellar Spectra** Characteristics of stellar spectra, Description of peculiar stellar spectra, Effects of temperature and luminosity, Explanation on the basis of Saha and Boltzman equations
III	**Astronomical Utility of Various Laws** Astronomical utility of Doppler effect, Astronomical utility of Zeeman effect, Measurements of Stellar magnetic fields, Polarization measurements, Causes of polarization, Stellar populations: their classification and characteristics.
IV	**Astronomical Instruments:** **Telescopes, Prism & Gratings, Spectrographs & Photometers** Telescopes: Properties & its kinds, Types of Foci, Mountings, Light Gathering Power, Magnifying Power and Resolving power of Telescope, Defects of Telescope Images: Chromatic, spherical, and Astigmatism. Properties of Prism & Grating, Dispersion of Light, Resolving power & Magnification power, Types of Grating, Formation of Spectra. Spectrograph, its Resolving power, Dispersion, Spectral Resolution, Speed of Spectrograph; Dispersion and Resolving Power of Prism and Grating Spectrograph. Photoelectric photometers, astronomical filters, Photomultiplier Tubes (PMT), Charge Coupled Device (CCD).

References:

- **Text Books:**

1. Eric Chaisson & Steve Macmillion, 1996, Astronomy Today, Prentice Hall, New jersey.
2. John D Fix, 1995, Astronomy-Journey to the Cosmic Frontier, Mosby, New York.
3. R.H. Fredrick and L. W Baker, 1968, Introduction of Astronomy by D. Van Nostrand Co.; Unabridged. Edition.
4. C. Payne Gaposhkin, 1956, Introduction to Astronomy, Eyre & Spottiswoode; First British ed. Edition.
5. K.D. Abhyankar, 2002, Astrophysics: Stars and Galaxies, Universities Press

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2. K.S.Krishna Swamy, 2010, Astrophysics: a Modern Perspective, New Age International Pvt. Ltd.
3. K.D. Abhyankar, 2002, Astrophysics: Stars and Galaxies, Universities Press
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Further Suggestions

The Institution may add/modify/change the contents time to time for advancement and up-gradation.

*** Semester VI (Theory Paper) P12

Subject: **Astronomy**	Programme/Class**: Degree**	Year: **Third**	Semester: **Sixth**

Title of the Paper: Introduction to Binaries
Course Code: P12 [Theory]
Credit: 4

Course Outcomes (COs)

1. Basic properties of Binary System their Classifications and Detecting Techniques.
2. Knowledge of Origin and Evolution of Binary System and its Importance for finding Mass of a Star.
3. Learning about the formation of Accretion Disc in Binary systems
4. Lean the properties of the X-rays binaries and their Evolution.
5. Learn the process of Mass exchange in Stars.

Course Title: Introduction to Binaries

Unit	Topics
I	**Introduction** General Introduction of the Binary stars, Classification of the Binaries, Properties of the Visual, Spectroscopic & Eclipsing Binaries and their delectating techniques. Importance of the Binary system.
II	**Formation & Evolution** Discovery and Evolution of the Binaries, Theories for the formation of Binaries: Capture Theory, McMillan Theory, Fission Theory.
III	**Accretion Discs in Binaries** Mass Transfer in close binary systems: Roche lobe, Zone of Influence, Lagrange Point & Contact Binary.
IV	**X-Ray Binaries** X Rays Binary Systems and their basic properties, Classification of X-Rays Binaries, Mass Exchange in the X-Ray Binaries.

References:

- **Text Books:**

1. Eric Chaisson & Steve MacMillan, 1996, Astronomy Today, Prentice Hall, New jersey.
2. John D Fix, 1995, Astronomy-Journey to the Cosmic Frontier, Mosby, New York.
3. R.H. Fredrick and L. W Baker, 1968, Introduction of Astronomy by D. Van Nostrand Co.; Unabridged. Edition.
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- **Web Links**

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13. http://www.space.com
14. http://www.nasa.gov
15. Astronomy notes https://www.astronomynotes.com/index.html
16. http://www.esa.int/

Further Suggestions

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***Practical Paper (Practical-VI) P13

Subject: Astronomy	Programme/Class**: Degree**	Year: **Third**	Semester: **Sixth**

Title of the Paper: Practical-VI
Course Code: P13 [Practical]
Credit: 4

Course Outcomes (COs)

1. Learn the handling & Mounting of a Reflector.
2. Observations with the Reflecting Telescope.
3. Uses of Astronomical Software in handling telescope. (Stellarium, Starry night, Celestia)
4. Deep Night Sky Observation with the help of a Reflecting Telescope.
5. Solve problems related to the galaxies.
6. Dissertation (Short Research Project).

Title of the Paper: Practical -VI

Unit	**Topics**
	Lab Experiment List
	1. Learn the Mounting and Handling of the Reflecting Telescope. 2. Deep Night Sky Observation with the help of a Telescope. 3. Determination of the Angular size of the Moon with the help of the Telescope. 4. Uses of Astronomical Software in handling telescope. (Stellarium, Starry Night, Celestia). 5. Estimation of the Schwarzschild radius. 6. Estimation of the distance of the Galaxy. 7. Calculation of the Hubble Constant for a given galaxy. 8. Find the velocity of the Galaxy due to expansion of the Universe from the given data. 9. Find the Mass of the Galaxy from the given data. 10. Evaluate the type of the Galaxy from the given data. 11. Evaluate the red shift in a Galaxy from the given data. 12. Dissertation (Short Research Project).
	Online Virtual Lab Experiment List/Link
	1. http://va-iitk.vlabs.ac.in/?page=objectives. 2. http://astro.physics.uiowa.edu/ITU. 3. http://astronomy.nmsu.edu/geas/labs/html/home.shtml 4. https://astro.unl.edu/nativeapps/

References:

- **Text Books**

1. W. Schroeder, 1965, Practical Astronomy, Philosophical Library.
2. J.J. Nassau, 1948, Practical Astronomy, McGraw Hill Text; 2nd Edition.
3. George L. Hosmer & James M. Robbins, 1963, Practical Astronomy, John Wiley and Sons Inc.

- **Suggested Readings**

1. Peter Duffett-Smith,1988, Practical Astronomy with your Calculator, Cambridge University Press.
2. W. M. Smart, 1977, Textbook on Spherical Astronomy, Cambridge University Press.

- **Web References**

1. http://va-iitk.vlabs.ac.in/?page=objectives.
2. http://astro.physics.uiowa.edu/ITU.
3. http://astronomy.nmsu.edu/geas/labs/html/home.shtml
4. https://astro.unl.edu/nativeapps/

Further Suggestions

The Institution may add/modify/change the contents time to time for advancement, up- gradation and availability of the Apparatus/Equipments.

*** Semester VI (Theory Paper) P14x

Subject: **Astronomy**	Programme/Class**: Degree**	Year: **Third**	Semester: **Sixth**

Title of the Paper: Variable Stars
Course Code: P14x [Theory]
Credit: 4

Course Outcomes (COs)

1. Learn the basic knowledge of Variable stars.
2. Knowledge of difference between Extrinsic & Intrinsic variable Stars.
3. Knowledge of Intrinsic Variable Stars and their types.
4. Knowledge of the Binary system that leads to a Nova/Super Novae event.
5. Learn the importance of Period Luminosity Relation.

Course Title: Variable Stars

Unit	Topics
I	**R-R Lyrae Stars** Brief introduction about classification of Variable Stars, Introduction of R-R Lyre star. Light cure of R-R Lyre Stars. Period Luminosity relation and its importance.
II	**Cepheid Variables** Basic properties of Cepheid Variables, Classification of Cepheid Variable Stars and their Properties, Light cure of Cepheid Variables, Cepheid Variable as distance indicator.
III	**Mira Type Stars** Basic Properties of Long Period Variable Stars, Period-Luminosity Relation, Period Spectral Relation.
IV	**Novae & Super Novae** General Introduction of Nova & Super Novae and their properties, Binary system that leads to a Nova/Super Novae event, Type of Super Novae and their basic characteristics .

References:

- **Text Books:**

1. Eric Chaisson & Steve MacMillan, 1996, Astronomy Today, Prentice Hall, New Jersey.
2. John D Fix, 1995, Astronomy-Journey to the Cosmic Frontier, Mosby, New York.
3. R.H. Fredrick and L. W Baker, 1968, Introduction of Astronomy by D. Van Nostrand Co.; Unabridged. Edition.
4. C. Payne Gaposhkin, 1956, Introduction to Astronomy, Eyre & Spottiswoode; First British ed. Edition

- **Suggested Readings**

1. B. Basu, T. Chattopadhyay, S.N. Biswas, 2010, An Introduction to Astrophysics, PHI learning Private Ltd.
2. K.S.Krishna Swamy, 2010, Astrophysics: a Modern Perspective, New Age International Pvt. Ltd.

3. https://www.classcentral.com/subject/astronomy.
4. OpenLearnhttps://www.open.edu/openlearn/science-maths-technology/free-courses/?filter=date/grid/671/all/all/all/
5. NPTEL : https://nptel.ac.in/courses/115/105/115105046/
6. Coursera : https://www.coursera.org/search?query=astronomy
7. Edx. : https://www.edx.org/learn/astronomy
8. Udemy : https://www.udemy.com/courses/search/?q=astronomy

- **Web Links**

1. https://solarsystem.nasa.gov/solar-system/our-solar-system/overview/
2. https://solarsystem.nasa.gov/basics/chapter9-1/#surface
3. NEPTEL http://www.nptelvideos.in/2012/12/astrophysics-cosmology.html
4. http://www.astronomynotes.com/
5. https://www.enchantedlearning.com/subjects/astronomy/
6. http://astronomyonline.org/
7. https://astronomy.swin.edu.au/cosmos/
8. http://repository.iucaa.in:8080/jspui/handle/11007/4241
9. Jet Propulsion Laboratory-NASA: California Institute of Technology, https://www.jpl.nasa.gov/
10. Uttar Pradesh Higher Education Digital Library, http://heecontent.upsdc.gov.in/SearchContent.aspx
11. CliffNotes https://www.cliffsnotes.com/study-guides/astronomy
12. https://www.open.edu/openlearn/science-maths-technology/science/physics-and-astronomy/astronomy
13. http://www.space.com
14. http://www.nasa.gov
15. Astronomy notes https://www.astronomynotes.com/index.html
16. http://www.esa.int/

Further Suggestions

The Institution may add/modify/change the contents time to time for advancement, up- gradation and availability of the Apparatus/Equipments.

*** Semester VI (Theory Paper) P14y

Subject: **Astronomy**	Programme/Class**: Degree**	Year: **Third**	Semester: **Sixth**

Title of the Paper: The MilkyWay Galaxy
Course Code: P14y [Theory]
Credit: 4

Course Outcomes (COs)

1. Understanding of basic properties of Galaxies and its modification.
2. Understand the overall structure and Formation of the Milkyway Galaxy
3. Comprehending the kinematics and stellar population of the Milky way Galaxy.
4. Understand the evidence of dark matter and possible dark matter candidates.

Title of the Paper: The MilkyWay Galaxy

Unit	Topics
I	**Introduction** Introduction of our Home Galaxy, Historical models of the Milkyway Galaxy, Formation of Milkyway, Center of the Galaxy, Black Hole at the Center.
II	**Structure & Morphology** Spiral Structure of the Milkyway, Size, Shape and Mass of the Milkyway, Star Counting, Distribution of Stars, Structure of the thin and thick disk, Galactic Halo, Age-Metallicity Relation.
III	**Kinematics** Galactic Coordinate system, Conversion between Equatorial and Galactic coordinates, Stellar population, Rotation of the Milky, Space Velocity, Differential Rotation and Oorts Constant, The Central Star System, Hypervelocity Stars.
IV	**Evidence of Dark Matter** Hydrogen 21-cm line, HI Flat Rotation curve, Evidence of Dark Matter, Keplerian Rotation, Dark matter models, Dark matter candidates.

References:

- **Test Books**

1. B. Basu, T. Chattopadhyay, S.N. Biswas, 2010, An Introduction to Astrophysics, PHI Learning Private Ltd.
2. Eric Chaisson & Steve MacMillian, 1996, Astronomy Today, Prentice Hall, New Jersey.
3. John D Fix, 1995, Astronomy-Journey to the Cosmic Frontier, Mosby, New York.
4. R.H. Fredrick and L. W Baker, 1968, Introduction of Astronomy by D. Van Nostrand Co.; Unabridged. Edition.
5. C. Payne Gaposhkin, 1956, Introduction to Astronomy, Eyre & Spottiswoode; First British ed. Edition.

- **Suggested Readings**

1. K.D. Abhyankar, 2002, Astrophysics: Stars and Galaxies, Universities Press
2. N. Subrahmanyam, Brij Lal, M. N. Avadhanulu, 2015, A Text Book of Optics (m.e.), S. Chand Limited
3. https://www.classcentral.com/subject/astronomy

4. K.S.Krishna Swamy, 2010, Astrophysics: a Modern Perspective, New Age International Pvt. Ltd.
5. NPTEL : https://nptel.ac.in/courses/115/105/115105046/
6. Coursera : https://www.coursera.org/search?query=astronomy
7. Edx. : https://www.edx.org/learn/astronomy
8. Udemy : https://www.udemy.com/courses/search/?q=astronomy
9. OpenLearnhttps://www.open.edu/openlearn/science-maths-technology/free-courses/?filter=date/grid/671/all/all/all/

- **Web references**

1. https://solarsystem.nasa.gov/solar-system/our-solar-system/overview/
2. https://solarsystem.nasa.gov/basics/chapter9-1/#surface
3. NEPTEL http://www.nptelvideos.in/2012/12/astrophysics-cosmology.html
4. http://www.astronomynotes.com/
5. https://www.enchantedlearning.com/subjects/astronomy/
6. http://astronomyonline.org/
7. https://astronomy.swin.edu.au/cosmos/
8. http://repository.iucaa.in:8080/jspui/handle/11007/4241
9. Jet Propulsion Laboratory-NASA: California Institute of Technology, https://www.jpl.nasa.gov/
10. Uttar Pradesh Higher Education Digital Library, http://heecontent.upsdc.gov.in/SearchContent.aspx
11. CliffNotes https://www.cliffsnotes.com/study-guides/astronomy
12. https://www.open.edu/openlearn/science-maths-technology/science/physics-and-astronomy/astronomy
13. http://www.space.com
14. http://www.nasa.gov
15. Astronomy notes https://www.astronomynotes.com/index.html
16. http://www.esa.int/

Further Suggestions

The Institution may add/modify/change the contents time to time for advancement and up-gradation.

Fourth Year

Detailed syllabus For

Research
IN
BACHELOR OF SCIENCE

***Fourth Year-Research Course (Semester VII & VIII)

YEAR	SEM	COURSE CODE	PAPER	PAPER TITLE	UNIT TITLE	CREDIT
RESEARCH IN BACHLOR OF SCIENCE						
FOURTH YEAR	**SEMESTER VII**	**P15**	Theory Paper	**Interstellar Medium**	I. Introduction to Interstellar Medium II. Interstellar Physical & Chemical Processes III. Formation of Molecules in ISM IV. Hydrogen Regions & Detection Techniques	4
		P16	Theory Paper	**Quantum Chemistry**	I. Introduction to Quantum Chemistry II. Methods of Quantum Chemistry III. Gaussian Observables IV. Reaction Mechanism & Gaussian	4
		P17	Practical Paper	**Practical-VII**	• List of Experiments • Online Virtual Lab Experiment List/Link	4
		P18x	Theory Paper	**Basic Stellar Physics**	I. Stellar Radiations II. Stellar Atmosphere III. Stellar Interiors IV. Radiative Process in Stars	4
		P18y	Theory Paper	**Introduction to Galaxies**	I. Hubble Classification II. Formation and Evolution of Galaxy III. Active Galactic Nuclei IV. Galaxy Clusters	4
		P19x	Theory Paper	**Extra-terrestrial Intelligences**	I. Early Life II. Theories of Origin of Life III. Possibility of Life in Space IV. Fermi Paradox & SETI	4
		P19y	Theory Paper	**Bio-Astronomy**	I. Rise of Life II. Habitable Zone III. Extra-solar Planets IV. Evolution of Exoplanets	4
	SEM-VIII			**Major Project**		24

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Semester VII (Theory Paper) P15

Subject: **Astronomy**	Programme/Class**: Research**	Year: **Fourth**	Semester: **Seventh**

Title of the Paper: Interstellar Medium
Course Code: P15 [Theory]
Credit: 4

Course Outcomes (COs)

1. To understand the importance of studying Interstellar Medium.
2. To analyze the various chemical processes in interstellar medium.
3. To study the composition of different regions of interstellar medium.
4. To study the formation of molecules in various interstellar regions of interstellar medium.
5. To learn the detection techniques of molecules in interstellar medium.
6. To study the ionized and neutral hydrogen regions of interstellar medium.

Title of the Paper: Interstellar Medium

Unit	Topics
I	**Introduction to Interstellar Medium** Introduction, Interstellar Objects, Components of Interstellar Medium (ISM), Milky Way Galaxy & its structure, Energy sources, Classifications: Diffuse clouds, Dense clouds, Hot molecular cores, Circumstellar envelops, Planetary Nebulae
II	**Interstellar Physical & Chemical Processes** Physics & chemistry of ISM, Gas Phase Chemical process, Grain Surface chemistry, Gas-Grain interaction, Solid surface interstellar chemistry, Gas phase interstellar chemistry
III	**Formation of Molecules in ISM** Formation of organic molecules in Diffuse clouds, Dense clouds, Hot molecular Cores, Circumstellar envelops, Planetary Nebulae, Formation of molecules in meteorites and comets
IV	**Hydrogen Regions & Detection Techniques** Atomic and molecular hydrogen, 21-cm line of neutral hydrogen, HII regions, Expansion of HII regions, Molecules detected in ISM, Interstellar PAHs, Techniques to detect molecules in interstellar medium.

References

- **Text Books**

1. A. G. G. M. Tielens, 2005,The Physics and Chemistry of the Interstellar Medium, Cambridge University Press.
2. James Lequeux, E. Falgarone, C. Ryter, 2005,The Interstellar Medium, Physica-Verlag.
3. Jonathan P. Williams, 2021, Introduction to the Interstellar Medium, Wiley.

- **Suggestive Readings**

1. Dieter Rehder, 2011, Chemistry in Space, From Interstellar Matter to the Origin of Life, Wiley
2. Lyman Spitzer, Jr. · 2008, Physical Processes in the Interstellar Medium, Wiley

3. Satoshi Yamamoto, Introduction to Astrochemistry, Chemical Evolution from Interstellar Clouds to Star and Planet Formation, Wiley
4. http://www.astronomy.ohio-state.edu/~pogge/Ast871/Notes/Intro.pdf
5. http://www.astronomy.ohio-state.edu/~pogge/Ast871/Notes/
6. Coursera: https://www.coursera.org/lecture/astronomy/interstellar-medium-rZT9w
7. PNAS: Interstellar chemistry: https://www.pnas.org/content/103/33/12232

- **Web References**

1. Harvard-Smithsonian Center for Astrophysics' Colloquium (CfA)- CfA Colloquium : https://www.youtube.com/channel/UCApHNlZLkxmiV95A0ChueYg
2. The Interstellar Medium online tutorial: http://www-ssg.sr.unh.edu/ism/what1.html
3. Lumen Learning: https://courses.lumenlearning.com/astronomy/chapter/the-interstellar-medium/
4. Astronomy Notes: http://astronomynotes.com/
6. Astrophysics & Astrochemistry: Science and people http://www.astrochemistry.eu/ac/astrochem_lecture.html

Further Suggestions

The Institution may add/modify/change the contents time to time for advancement and up-gradation.

Semester VII (Theory Paper) P16

Subject: **Astronomy**	Programme/Class**: Research**	Year: **Fourth**	Semester: **Seventh**

Title of the Paper: Quantum Chemistry
Course Code: P16 [Theory]
Credit: 4

Course Outcomes (COs)

1. To understand the effect of different quantum chemical methods on the chemical reactivities.
2. To analyze the thermo-chemistry of the chemical model.
3. To interpret the various physical properties viz. ground state energy, stable geometry, stationary points, local maxima, minima etc. of the final molecular structure.
4. To learn different methods to find the transition state and find the intrinsic reaction coordinates.
5. To explore the idea of selecting the feasible and appropriate reaction path.
6. To calculate the anharmonic and distortion constants.
7. To calculate local and global reactivity descriptors.
8. To estimate the difference between gas phase and solvation effect on reaction mechanism.

Title of the Paper: Quantum Chemistry

Unit	Topics
I	**Introduction to Quantum Chemistry** Introduction, Postulates of quantum mechanics, Approximations: Born-Oppenheimer, LCAO, Electron correlation, Interaction of electrons, Schrodinger Wave Equation, Application of Schrodinger Equation to chemistry by Huckel, Applications in Astronomy
II	**Methods of Quantum Chemistry** Computational Quantum Chemistry, Molecular Mechanics, Semi empirical calculations, Electron Correlation Theory, *ab-initio* methods, Density functional theory, Moller Plesset perturbation Theory, Configuration Interaction Method, Coupled Cluster Method
III	**Gaussian Observables** Gaussian Functions, Basis Sets & its types, Computable Quantities: Potential Energy Surface, Geometry optimization, Stationary points, Symmetry, Ground state energy, Thermodynamic properties, Effect of solvent
IV	**Reaction Mechanisms & Gaussian** Transition state theory, RRKM theory, Studying chemical reactions & Reactivity, Gaussian & its application in computational quantum chemistry

References

- **Text Books**

1. Christopher J. Cramer, 2013, Essentials of Computational Chemistry: Theories and Models, Wiley.
2. Errol Lewars, 2007, Computational Chemistry, Introduction to the Theory and Applications of Molecular and Quantum Mechanics, Springer US.

- **Suggestive Readings**

1. Jerzy Leszczynski, 2012, Handbook of Computational Chemistry, Springer
2. David Young, 2004, Computational Chemistry: A Practical Guide for Applying Techniques to Real World Problems, Wiley
3. https://www.freebookcentre.net/chemistry-books-download/Lecture-Notes-in-Computational-Chemistry.html
4. NPTEL: https://nptel.ac.in/courses/104/101/104101095/
5. Coursera: https://www.coursera.org/learn/density-functional-theory

- **Web References**

1. The Sherrill Group: http://vergil.chemistry.gatech.edu/notes/
2. https://www.internetchemistry.com/chemistry/computational-chemistry.htm
3. http://pollux.chem.umn.edu/8021/Lectures/
4. https://www.chem.uzh.ch/dam/jcr:ffffffff-8715-1fca-ffff-ffffd43f2167/pcv.pdf
5. http://www.ccl.net/cca/documents/dyoung/topics-orig/compchem.html

Further Suggestions

The Institution may add/modify/change the contents time to time for advancement and up-gradation.

Semester VII (Practical-VII) P17

Subject: Astronomy	Programme/Class**: Research**	Year: **Fourth**	Semester: **Seventh**

Title of the Paper: Practical-VII
Course Code: P17 [Practical]
Credit: 4

Course Outcomes (COs)

1. Learn the installation of software.
2. Learn to optimize a molecule by atoms.
3. Analyze the physical properties of molecules.
4. Learn the effect of basis sets and theories on the energies of a molecule.
5. Learn to calculate the energies of a molecule in gas phase.
6. Learn to calculate energies in solvent and PCM model.
7. Learn to perform a reaction between two molecules.

Title of the Paper: Practical-VII

Unit	**Topics**
	Lab Experiment List
	1. Optimize the ground state geometry of a molecule and calculate its energy. 2. Calculate the bond distances, angles and dihedral angles of a molecule and compare from experimental data. 3. Calculate the zero point vibrational energy, Gibbs energy, Enthalpy, entropy of a molecule. 4. Calculate the properties of a molecule with different basis sets. 5. Calculate the properties of a molecule with different theories. 6. Calculate the properties of a molecule in gas phase and PCM. 7. Run the program to perform a reaction between two molecules.
	Online Virtual Lab Experiment List/Link
	1. Pchem Lab : https://www.youtube.com/c/PchemLab/videos 2. Gaussian: https://gaussian.com/expchem3/ 3. Gaussian: https://gaussian.com/videos/

References

- **Text Book**

1. J. B. Foresman and Æ Frisch, 2015, Exploring Chemistry with Electronic Structure Methods, 3rd ed., Gaussian, Inc.: Wallingford, CT.ISBN: 978-1-935522-03-4

- **Suggested Readings**

1. https://barrett-group.mcgill.ca/tutorials/Gaussian%20tutorial.pdf
2. https://guides.libraries.uc.edu/c.php?g=222784&p=1473460

- **Web References**

1. Pchem Lab : https://www.youtube.com/c/PchemLab/videos
2. Gaussian: https://gaussian.com/expchem3/
3. Gaussian: https://gaussian.com/videos/

Further Suggestions

The Institution may add/modify/change the Experiments time to time for advancement and up-gradation and availability of the Apparatus/Equipment.

Semester VII (Theory Paper) P18x

Subject: **Astronomy**	Programme/Class**: Research**	Year: **Fourth**	Semester: **Seventh**

Title of the Paper: : Basic Stellar Physics
Course Code: P18x [Theory]
Credit: 4

Course Outcomes (COs)

1. Understand the basics of black body radiations.
2. Understand the Concept of hydrostatic equilibrium.
3. Explore the Radiative transfer mechanism in stars.
4. Understand the energy transport modes in the stellar interiors.
5. Study the pressure equation of state in stars.
6. To understand the different radiative processes in stars.
7. To explore the H-R Diagram and its utility.
8. Learn about the Main sequence stars.

Title of the paper: Basic Stellar Physics

Unit	Topics
I	**Stellar Radiations** Applications of Laws of Radiation: Rayleigh Jeans law, Planck's law, Wein's Law, Stefan Boltzmann Law, Specific intensity and flux density, Stellar parallax Magnitudes, Colour index, Basic optics, Classification, Study of spectral lines,
II	**Stellar Atmosphere** Atmospheres, Description of the radiation field, Opacities, Radiative transfer, Structure of spectral lines, Main Sequence stars, pre main sequence stars, post main sequence stars
III	**Stellar Interiors** Hydrostatic equilibrium, Solar central Pressure, solar Central temperature, Structure of a star in equilibrium, Simple Stellar Models, Pressure equation of state, Energy sources, Energy transport and convection,
IV	**Radiative Processes in stars** Photoelectric Effect, Synchrotron emission, Energy loss and electron spectrum, Compton scattering, Inverse Compton Scattering, Bremsstrahlung, Thermal Bremsstrahlung. Photo Ionization

References

- **Text Books**

1. T. Padmanabhan, 2000, Theoretical Astrophysics, Vol I: Astrophysical Processes, Cambridge, University Press.
2. B. W. Carroll and D. A. Ostlie, 1984, Modern Astrophysics, Addison-Wesley Publishing Co.
3. George B. Rybicki, Alan P. Lightman · 2008, Radiative Processes in Astrophysics, Wiley
4. R.H. Fredrick and L. W Baker, 1968, Introduction of Astronomy by D. Van Nostrand Co.; Unabridged. Edition.
5. C. Payne Gaposhkin, 1956, Introduction to Astronomy, Eyre & Spottiswoode; First British ed. Edition.
6. B. Basu, T. Chattopadhyay, S.N. Biswas, 2010, An Introduction to Astrophysics, PHI learning Private Ltd.

- **Suggestive Readings**

1. Eric Chaisson & Steve MacMillan, 1996, Astronomy Today, Prentice Hall, New jersey.
2. John D Fix, 1995, Astronomy-Journey to the Cosmic Frontier, Mosby, New York.
3. Nouredine Zettili · 2009, Quantum Mechanics, Concepts and Applications, Wiley
4. Carl J. Hansen, Steven D Kawaler, Virginia Trimble · 2012, Stellar Interiors, Physical Principles, Structure, and Evolution, Springer New York
5. https://jila.colorado.edu/~pja/astr3730/

- **Web References**

1. http://www.astronomynotes.com/
2. http://astronomyonline.org/
3. https://astronomy.swin.edu.au/cosmos/
4. http://repository.iucaa.in:8080/jspui/handle/11007/4241
5. Uttar Pradesh Higher Education Digital Library, http://heecontent.upsdc.gov.in/SearchContent.aspx
6. https://www.open.edu/openlearn/science-maths-technology/science/physics-and-astronomy/astronomy
7. Astronomy notes https://www.astronomynotes.com/index.html
8. ePg Pathshala- https://epgp.inflibnet.ac.in/Home
9. https://www.classcentral.com/subject/astronomy

Further Suggestions

The Institution may add/modify/change the contents time to time for advancement and up-gradation.

Semester VII (Theory) ***P18y***

Subject: **Astronomy**	Programme/Class**: Research**	Year: **Third**	Semester: **Seventh**

Title of the Paper: :Introduction to Galaxies
Course Code: P18y [Theory]
Credit: 4

Course Outcomes (COs)

1. Understanding of basic properties of Galaxies..
2. Learn about the galactic coordinate system.
3. Knowledge of the various galaxies and their properties.
4. Understanding important scaling relations of between physical parameters of galaxies.
5. Comprehending the Active galactic nuclei system.
6. Learning properties of galaxy cluster.

Title of the Paper: Introduction to Galaxies

Unit	Topics
I	**Hubble Classification** Morphological classification, Other types of galaxies, Elliptical galaxies, Spiral galaxies, Tully-Fisher relation, Faber-Jackson relation, Fundamental plane.
II	**Formation and Evolution of Galaxies** Formation theories of galaxies, Evidence of interactions, Rapid encounters, Starburst galaxies, Mergers of spiral and elliptical systems.
III	**Active Galactic Nuclei (AGN)** Brief history of AGN, Properties of AGN, Seyfert galaxies, Radio galaxies, Components of AGN, Central engine, Broad emission lines and Narrow lines.
IV	**Galaxy Clusters** Local group, Spatial distribution of galaxies, Dynamical mass of clusters, Nearby galaxy groups, Morphology-density relation.

References:

- **Test Books**

1. B. Basu, T. Chattopadhyay, S.N. Biswas, 2010, An Introduction to Astrophysics, PHI Learning Private Ltd.
2. Eric Chaisson & Steve MacMillian, 1996, Astronomy Today, Prentice Hall, New Jersey.
3. John D Fix, 1995, Astronomy-Journey to the Cosmic Frontier, Mosby, New York.
4. R.H. Fredrick and L. W Baker, 1968, Introduction of Astronomy by D. Van Nostrand Co.; Unabridged. Edition.
5. C. Payne Gaposhkin, 1956, Introduction to Astronomy, Eyre & Spottiswoode; First British ed. Edition.

- **Suggested Readings**

1. K.D. Abhyankar, 2002, Astrophysics: Stars and Galaxies, Universities Press
2. N. Subrahmanyam, Brij Lal, M. N. Avadhanulu, 2015, A Text Book of Optics (m.e.), S. Chand Limited
3. K.S.Krishna Swamy, 2010, Astrophysics: a Modern Perspective, New Age International Pvt. Ltd.

4. https://www.classcentral.com/subject/astronomy
5. NPTEL : https://nptel.ac.in/courses/115/105/115105046/
6. Coursera : https://www.coursera.org/search?query=astronomy
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8. Udemy : https://www.udemy.com/courses/search/?q=astronomy
9. OpenLearnhttps://www.open.edu/openlearn/science-maths-technology/free-courses/?filter=date/grid/671/all/all/all/

- **Web references**

1. https://solarsystem.nasa.gov/solar-system/our-solar-system/overview/
2. https://solarsystem.nasa.gov/basics/chapter9-1/#surface
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8. http://repository.iucaa.in:8080/jspui/handle/11007/4241
9. Jet Propulsion Laboratory-NASA: California Institute of Technology, https://www.jpl.nasa.gov/
10. Uttar Pradesh Higher Education Digital Library, http://heecontent.upsdc.gov.in/SearchContent.aspx
11. CliffNotes https://www.cliffsnotes.com/study-guides/astronomy
12. https://www.open.edu/openlearn/science-maths-technology/science/physics-and-astronomy/astronomy
13. http://www.space.com
14. http://www.nasa.gov
15. Astronomy notes https://www.astronomynotes.com/index.html
16. http://www.esa.int/

Further Suggestions

The Institution may add/modify/change the contents time to time for advancement and up-gradation.

Semester VII (Theory) P19x

Subject: **Astronomy**	Programme/Class**: Research**	Year: **Fourth**	Semester: **Seventh**

Title of the Paper: Extra-terrestrial Intelligence
Course Code: P19x [Theory]
Credit: 4

Course Outcomes (COs)

1. To learn the possibility of origin of life in the space.
2. To understand the Fermi Paradox.
3. To learn the possibility of civilization in the universe.
4. To explore the existence of extra-terrestrial life.
5. To learn about the theories of origin of life.
6. To understand the biochemical evolution of life.

Title of the Paper: Extra-terrestrial Intelligence

Unit	Topics
I	**Early Life** Elements of Life, Early Life, atmosphere and chemical composition, Life is complex, self-organizing, adaptive chemical system, Life requires energy sources, Life exhibits Darwinian Evolution, Versatility of Carbon in the formation of life
II	**Theories of origin of life** Origin of life, Life under extreme conditions, Theories of origin of life: Panspermia, Icy worlds, Possibility of Life on: Titan Enceladus, Europa, Biochemical Origin of Life.
III	**Possibility of life in space** Urey-Miller Experiment & Mass Extinctions, Search for Extraterrestrial civilizations
IV	**Fermi paradox & SETI** Fermi Paradox & Solutions, SETI - Search for Extraterrestrial Intelligence: Radio SETI, Optical SETI,

References

- **Text Books**

1. B. Basu, T. Chattopadhyay, S.N. Biswas, 2010, An Introduction to Astrophysics, PHI learning Private Ltd.
2. I. Gilmour and M.A. Sephton, 2004, An introduction to Astrobiology by Cambridge University Press.
3. Dieter Rehder, 2011, Chemistry in Space, From Interstellar Matter to the Origin of Life, Wiley

- **Suggestive Readings**

1. Pascale Ehrenfreund, William Irvine, 2005, Astrobiology: Future Perspectives, Springer
2. Muriel Gargaud, Bernard Barbier, Herve Martin & Jacques Reisse, 2005, Lectures in astrobiology Vol I, Springer
3. Muriel Gargaud, Bernard Barbier, Herve Martin & Jacques Reisse, 2007, Lectures in astrobiology Vol II, Springer.
4. Akihiko Yamagishi, Takeshi Kakegawa, Tomohiro Usui, 2019, Astrobiology: From the Origins of Life to the Search for Extraterrestrial Intelligence, Springer Singapore

5. Alan Longstaff, 2014, Astrobiology-An Introduction, CRC Press
6. COURSERA: https://www.coursera.org/learn/astrobiology
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- **Web References**

1. https://www.seti.org/
2. http://www.phy.olemiss.edu/~luca/astr/Topics-Extrasolar/SETI-N.html
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4. TEDx: https://www.youtube.com/user/TEDxTalks/search?query=extraterrestrial
5. Talks at Google: https://www.youtube.com/c/talksatgoogle/search?query=extraterrestrial
6. https://www.jpl.nasa.gov/news/free-lectures-on-search-for-extraterrestrial-life

Further Suggestions

The Institution may add/modify/change the contents time to time for advancement and up-gradation.

Semester VII (Theory) P19y

Subject: **Astronomy**	Programme/Class**: Research**	Year: **Fourth**	Semester: **Seventh**

Title of the Paper: Bio-Astronomy
Course Code: P19y [Theory]
Credit: 4

Course Outcomes (COs)

1. To explore the possibility of extra-terrestrial life.
2. To learn about the evidences of life in the space.
3. To understand the hypothesis and mathematical calculations of the origin of life.
4. To learn the extra solar planetary systems.
5. To learn about the habitable planets.
6. To know the possibility of habitability elsewhere in the universe.

Title of the Paper: Bio-Astronomy

Unit	Topics
I	**Rise of Life** Introduction, Drake Equation, Rare Earth Hypothesis, Prebiotic reactions, RNA world, Alternatives to carbon and oxygen, other probable processes, constraints of physics, biology and chemistry on possibilities. Environmental influences on Life: gravity, temperature, pressure, atmospheric composition, radiation
II	**Habitable Zones** Planetary Habitability, Greenhouse effect, Factors of habitability, Habitable Zone, The Circumstellar Habitable Zone, The Inner limit and outer limit of HZ, Continuous Habitable Zone, Galactic Habitable Zone,
III	**Extrasolar planets** Exoplanets and its types, atmosphere, Chemical composition of exoplanets, Detection techniques of exoplanets: radial velocity, transit method, gravitational microlensing, direct imaging, Astrometry, Super Earths
IV	**Evolution of Exoplanets** Properties of known exoplanets, exoplanet surveys, formation, interior and evolution of planets, brown dwarf exoplanets connection, close orbiting exoplanets, multiple planet systems, planets in binary systems, moons of exoplanets, Kepler Mission

References

- **Text Books**

1. B. Basu, T. Chattopadhyay, S.N. Biswas, 2010, An Introduction to Astrophysics, PHI learning Private Ltd.
2. John W Mason, 2008, Exoplanets: Detection, Formation, Properties and Habitability Springer
3. Cassen, Patrick, Guillot, Tristan, Quirrenbach, A. Queloz, D.; Udry, S.; Mayor, M.; Benz, W. (Eds.), 2006, Extrasolar Planets by SAAS Fee Advance Course 31, Springer
4. I. Gilmour and M.A. Sephton, 2004, An introduction to Astrobiology by Cambridge University Press.

- **Suggestive Readings**

1. Pascale Ehrenfreund, William Irvine, 2005, Astrobiology: Future Perspectives, Springer
2. Muriel Gargaud, Bernard Barbier, Herve Martin & Jacques Reisse, 2005, Lectures in astrobiology Vol I, Springer
3. Muriel Gargaud, Bernard Barbier, Herve Martin & Jacques Reisse, 2007, Lectures in astrobiology Vol II, Springer.
4. Alessandro Sozzetti, Luigi Mancini, Valerio Bozza, 2016, Methods of Detecting Exoplanets: 1st Advanced School on Exoplanetary Science, Springer International Publishing
5. https://www.esa.int/Science_Exploration/Space_Science/How_to_find_an_extrasolar_planet

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3. https://exoplanets.nasa.gov/search-for-life/habitable-zone/
4. https://planetary-science.org/astrobiology/planetary-habitability/
5. https://www.space.com/17738-exoplanets.html
6. https://exoplanets.nasa.gov/what-is-an-exoplanet/overview/
7. https://www.paulanthonywilson.com/exoplanets/exoplanet-detection-techniques/
8. https://exoplanets.nasa.gov/alien-worlds/ways-to-find-a-planet/

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