Indian Institute of Technology Indore

Curriculum and Courses of Study
for
Bachelor of Technology
in Astronomy, Astrophysics and Space Engineering

October 2025

[After incorporating decisions of 57th meeting of the Senate held on October 17, 2025]

CONTENTS

Sections and Course structure of 1st year BTech (from AY 2023-24 onwards)

Section-A (CSE+CE+MEMS+CH+EP)				Section-B (EE+ME+MC+SSE)			
Semester-I	**Autumn Semester**			**Semester-I**	**Autumn Semester**		
Course Code	**Course Title**	**Weekly Contact Hours (L-T-P)**	**Credits**	**Course Code**	**Course Title**	**Weekly Contact Hours (L-T-P)**	**Credits**
EE 101	Basic Electrical Engineering	1-1-0	2	EE 101	Basic Electrical Engineering	1-1-0	2
ME 101	Engineering Mechanics	2-0-0	2	ME 101	Engineering Mechanics	2-0-0	2
PH 107	Basics of Physics	2-1-0	3	CH 105	Chemistry	3-0-0	3
PH 157	Physics Lab- I	0-0-2	1	CH 155	Chemistry Lab	0-0-2	1
MA 101N	Calculus-I (half Semester)	3-1-0 (=4/2)	2	MA 101N	Calculus-I (half Semester)	3-1-0 (=4/2)	2
MA 103N	Calculus-II (half Semester)	3-1-0 (=4/2)	2	MA 103N	Calculus-II (half Semester)	3-1-0 (=4/2)	2
HS 109	Language and Composition	2-0-0	2	HS 109	Language and Composition	2-0-0	2
HS XXX	Flexible Elective (HSS)	1-0-0	1	HS XXX	Flexible Elective (HSS)	1-0-0	1
IC 152	Makerspace	1-0-6	4	CS 103	Computer Programming	2-0-0	2
CS 103	Computer Programming	2-0-0	2	IC 151	Computer Programming Lab	0-0-3	1.5
IC 151	Computer Programming Lab	0-0-3	1.5	NO 101	National Sports Organization (NSO)	0-0-0	P/NP
NO 101	National Sports Organization (NSO)	0-0-0	P/NP				

Total	**14-3-11**	**22.5**

Total	**14-2-5**	**18.5**

Semester-II	Spring Semester		
Course Code	Course Title	Weekly Contact Hours (L-T-P)	Credits
BSE 102	Biosciences	2-1-0	3
MA 102N	Linear Algebra (half Semester)	2-1-0 (=3/2)	1.5
MA 104N	Differential Equations-I (half Semester)	2-1-0 (=3/2)	1.5
ES 102	Environmental Studies: Scientific and Engineering Aspects (half Semester)	2-1-0 (=3/2)	1.5
HS 102	Environmental Studies: Social Aspects (half Semester)	2-1-0 (=3/2)	1.5
HS 104	Fundamentals of Economics	2-0-0	2
CH 105	Chemistry	3-0-0	3
CH 155	Chemistry Lab	0-0-2	1
ZZ XXX	Flexible Elective	1-0-0	1
ZZ XXX	Flexible Elective	1-0-0	1
ZZ XXX	Flexible Elective (HSS)	1-0-0	1

Semester-II	Spring Semester		
Course Code	Course Title	Weekly Contact Hours (L-T-P)	Credits
BSE 102	Biosciences	2-1-0	3
MA 102N	Linear Algebra (half Semester)	2-1-0 (=3/2)	1.5
MA 104N	Differential Equations-I (half Semester)	2-1-0 (=3/2)	1.5
ES 102	Environmental Studies: Scientific and Engineering Aspects (half Semester)	2-1-0 (=3/2)	1.5
HS 102	Environmental Studies: Social Aspects (half Semester)	2-1-0 (=3/2)	1.5
HS 104	Fundamentals of Economics	2-0-0	2
IC 152	Makerspace	1-0-6	4
PH 107	Basics of Physics	2-1-0	3
PH 157	Physics Lab- I	0-0-2	1
ZZ XXX	Flexible Elective	1-0-0	1
ZZ XXX	Flexible Elective	1-0-0	1

NO 102	National Sports Organization (NSO)	0-0-0	P/NP
	Total	**14-3-2**	**18**

ZZ XXX	Flexible Elective (HSS)	1-0-0	1
NO 102	National Sports Organization (NSO)	0-0-0	P/NP
	Total	**14-4-8**	**22**

Curriculum of 2nd year BTech in Space Science and Engineering
From AY 2024-25 onwards (Batch admitted in and after AY 2023-24)
Semester III

Course Code	Course Name	Weekly Contact Hours L-T-P	Credit
ZZ 2XX	Course -I for Minor Program	X-X-X	3
MA 205	Complex Analysis	3-1-0 (½ semester)	2
MA 207	Differential Equation -II	3-1-0 (½ semester)	2
AA 203/ PH 203	Classical Mechanics	2-1-0	3
AA 205/ PH 205	Electronic Devices and Circuits I	2-1-0	3
AA 207/ PH 207	Wave Phenomena and Optics	2-1-0	3
AA 209/ PH 209	Fundamental Concepts of Solid-State Engineering	2-1-0	3
AA 251/ PH 251	Engineering Physics Lab I	0-0-3	1.5
AA 255/ PH 255	Electronic Devices and Circuits Lab I	0-0-3	1.5
AA 2XX	Department Elective - I	x-x-x	3
		Total	**22/ 25**

Semester IV
From AY 2024-25 onwards (Batch admitted in and after AY 2023-24)

Course Code	Course Name	Weekly Contact Hours L-T-P	Credit
ZZ 2XX	Course II for Minor Program	X-X-X	3
MA 204	Numerical Methods	2-0-2	3
AA 206/ PH 206	Electronic Devices and Circuits II	2-1-0	3
AA 208/ PH 208	Electrodynamics	2-0-0	2
AA 210/ PH 210	Fundamentals of Quantum Mechanics	2-1-0	3
AA 212/ PH 212	Thermal Physics	2-1-0	3

AA 252/ PH 252	Scientific Computing Lab	0-0-2	1
AA 256/ PH 256	Electronic Devices and Circuits Lab - II	0-0-3	1.5
AA 2XX	Department Elective II	x-x-x	3
ZZ 2XX	Institute Elective I	x-x-x	**3**
		Total	**22.5/ 25.5**

3rd Year BTech in Space Science and Engineering
From AY 2025-26 onwards (Batch admitted in and after AY 2023-24)

Semester V

Course Code	Course Name	Weekly Contact Hours L-T-P	Credit
ZZ XXX	Course III - Minor Program	X-X-X	3
AA 307	Space Systems - Orbits and Payloads	2-1-0	3
AA 309	Space Instrument Design	2-1-0	3
AA 311	Statistical Physics and Radiative Transfer	2-1-0	3
AA 313	Fluid Dynamics	2-1-0	3
AA 315	Data Analytics and Visualization for Space	0-1-4	3
AA XXX	Departmental Elective III	2-1-0	3
ZZ XXX	Institute Elective-II	2-1-0	3
	Total	**13-5-4**	**20/23**

Semester VI
From AY 2025-26 onwards (Batch admitted in and after AY 2023-24)

Course Code	Course Name	Weekly Contact Hours L-T-P	Credit
ZZ XXX	Course IV - Minor Program	X-X-X	3
AA 306	Signals & Communication in Space	2-0-2	3

AA 312	Atmospheric Physics and Remote Sensing	2-1-0	3
AA 308	Guidance, Navigation and Control	2-1-0	3
AA 304	Radiowave Propagation & Antenna Applications	2-0-2	3
AA XXX	Departmental Elective IV	2-0-2	3
AA XXX	Departmental Elective V	2-1-0	3
ZZ XXX	Institute Elective - III	2-1-0	3
	Total	**14-4-6**	**21/24**

4th Year BTech in Space Science and Engineering
From AY 2026-27 onwards (Batch admitted in and after AY 2023-24)

Semester VII

Course Code	Course Name	Weekly Contact Hours L-T-P	Credit
ZZ XXX	Course-V for Minor Program /field study/white paper/domain comprehension (Seminar)/Lab course	x-x-x	2
ZZ 493N	B. Tech Project (BTP)	0-0-32	16
ZZ 495 ZZ XXX	Internship **OR** Professional/ Societal-Connect basket course	x-x-x	1.5
	Total		**17.5/19.5**

Semester VIII
From AY 2026-27 onwards (Batch admitted in and after AY 2023-24)

Course Code	Course Name	Weekly Contact Hours L-T-P	Credit
AA XXX	Departmental Elective - VI	2-1-0	3
AA XXX	Departmental Elective - VII	2-1-0	3

ZZ XXX	Institute Open Elective - IV	2-1-0	3
ZZ XXX	Institute Open Elective - V	2-1-0	3
ZZ XXX	Institute Open Elective - VI	2-1-0	3
	Total	**10-5-0**	**15**

Departmental Electives for Semester III*

Course Code	Course Name	Weekly Contact Hours L-T-P	Credit
AA 201	Introduction to Astronomy	2-1-0	3
AA 203	Introduction to Atmospheric and Earth Sciences	2-1-0	3

Departmental Electives for Semester IV*

Course Code	Course Name	Weekly Contact Hours L-T-P	Credit
AA 204	Introduction to Space Exploration	2-1-0	3
AA 202N	Astronomical Techniques	2-1-0	3
AA 214	Stellar and Planetary Science	2-1-0	3
AA 216	Flight mechanics and classical control	2-1-0	3

Departmental Electives for Semester V*

Course Code	Course Name	Weekly Contact Hours L-T-P	Credit
AA 317	Galaxies and Cosmology	2-1-0	3
AA 303	IoT for Space Applications	2-1-0	3
AA 319	Launch Vehicle and Propulsion Systems	2-1-0	3

Departmental Electives for Semester VI*

Course Code	Course Name	Weekly Contact Hours L-T-P	Credit
AA 310	Satellite Imaging	2-0-2	3
AA 318	Meteorology and Climate Modelling	2-0-2	3
AA 320	Detectors for Space - II	2-0-2	3
AA 322	Computational Electromagnetics	2-1-0	3
AA 301	High Energy Astrophysics and Transient Sky	2-1-0	3
AA 301N	High Energy Astrophysics and Transient Sky	2-1-0	3
AA 324	Space Informatics	2-0-2	3
AA 374	Computational Fluids and Structures	2-1-0	3

Departmental Electives for Semester VIII*

Course Code	Course Name	Weekly Contact Hours L-T-P	Credit
AA 476/676	Satellite Based Navigation Systems	2-0-2	3
AA 414/614	Cosmology	2-1-0	3
AA 412/612	Microwave Remote Sensing	2-1-0	3
AA 408N/608N	Astrostatistics	2-1-0	3
AA 474N/674N	Radio Astronomy	2-1-0	3
AA 472N/672N	Galactic and Extragalactic Astronomy	2-1-0	3
AA404/604	Spacecraft Attitude Control and Dynamics	2-0-2	3

DAASE courses listed as institute open electives for Semester VIII**

Course Code	Course Name	Weekly Contact Hours L-T-P	Credit
AA 413/613	Electrodynamics and Radiative Processes	2-1-0	3
AA 415/615	Quantum Mechanics and Spectroscopy	2-1-0	3
AA 417/617	Electronic Devices and Control	2-1-0	3
AA 401/601	Astrophysical Fluids and Plasma	2-1-0	3
AA 407/AA 607	Remote sensing for Atmospheric and Space Sciences	2-0-2	3
AA 403/AA 603	Space Engineering Systems	2-0-2	3
AA 405/ AA 605	*Detectors and Sensors for Space Observations	2-0-2	3
AA 411/ AA 611	Advanced Optics	2-0-2	3
AA 409/609	Computational Methods in Astronomy and Space Sciences	2-0-2	3
AA 607/407	Remote sensing for Atmospheric and Space Sciences	2-0-2	3
AA 473 / 673	Classical Mechanics and Relativity	2-1-0	3
AA 416/ 616	Stellar Evolution and planets	2-1-0	3
AA4XX/6XX	Advanced IoT for Space	2-0-2	3
AA4XX/6XX	Advanced Optical Instrumentation	2-0-2	3
AA 4XX/6XX	Space Economics, Policy & Space Act and Benefits	2-1-0	3

*The list of departmental electives will be updated as and when new courses get approved for the same.
**The list of DAASE courses listed as institute open electives will be updated as and when new courses get approved for the same.

Structure of the Minor programs [from AY 2014-15 to AY 2020-21]

A student has to register and pass at least FIVE courses (three core courses and two elective courses) as prescribed for a minor program in order to get a minor degree in that specialization along with the regular BTech degree in his/her engineering Department. A minor program will run only when at least TEN students register for it. Following minor programs are available from AY 2014-15 onwards.

1. Minor program in Biosciences and Biomedical Engineering (BSBE): To get a minor degree in BSBE, a student needs to register and pass **at least FIVE prescribed** courses ***excluding the core course*** BSE 101 Bio-Sciences for successful minor degree in BSBE.

2. MINOR PROGRAM IN CHEMISTRY: To get a minor degree in Chemistry, a student needs to register and pass **at least FIVE prescribed** courses ***excluding the core course CH 103.*** Following are courses for successful minor degree in Chemistry.

3. Minor Program in HSS: A student needs to register and pass **at least FIVE prescribed courses of Humanities and Social Sciences *excluding the core courses*** HS 159 and HS 108 for successful minor degree in Humanities or Social Sciences.

4. **Minor Program in Astronomy (from AY 2016-17):** To get a minor degree in Astronomy, a student needs to register and pass **at least FIVE prescribed** courses*.* Following are courses for successful minor degree in Astronomy.

Course structures of various Minor programs

Semester: Minor course	**Minor Program in BSBE**	**Minor Program in Chemistry**	**Minor Program in Humanities and Social Sciences**	**Minor Program in Astronomy (from AY 2016-17 onwards)**
3rd : Minor1	BSE 201: Biophysics	CH 201: Molecules that Change the World	HS 201: Understanding Philosophy HS 203: Psychology HS 205: Sociology HS 207: French Language-I	AA 201: Introduction to Astronomy
4th : Minor 2	BSE 202: Biomedical Technologies	CH 202: Chemistry of Transition Metals and Lanthanides &	HS 206: Paradigms and Turning Points # HS 208: French Language-II HS 210: Indian Economy HS 211: German Literature and Culture Studies HS 214: History of Indian Culture and Civilization HS 216: Introduction to Hindi Cinema	AA 202N: Astronomical Techniques
5th : Minor 3	BSE 301: Introduction to Molecular Biology	CH 301: Functional Materials	HS 311: Life and Thought of Gandhi HS 313: History of Early Cinema	AA 301: High Energy Astronomy

			HS 315: Sociology of Science and Technology HS 323: International Economics HS 341: Appreciating Indian English Literature	
8th : Two elective courses as Minor 4 and Minor 5	BSE 402: Cancer Diagnosis and Therapy BSE 404/ BSE 604: Biomedical Imaging BSE 405/ BSE 605: Molecular Biophysics BSE 413/ BSE 613: Omics Technologies BSE 417/ BSE 617: Biomolecular Modeling EE 419/ EE 619: Biomedical Optics ME 407/ME 607: Bio-fluid Mechanics	CH 402: Chemistry in Industry CH 404: Chemical Physics CH 406: Nuclear Science	IHS 402: Twentieth Century World History: Critical Perspectives HS 412/ 612: Contemporary Indian Thought HS 418/ 618: Sustainability Studies HS 424/ HS 624: Econometrics-I IHS 422 / HS 622: Development Economics IHS 425: Money and Banking HS 426: Economics of Innovation HS 442/ HS 642: Language and Mind IHS 443/ HS 643: Contemporary Short Fiction IHS 444: Literature of the Twentieth Century IHS 482: Introduction to International Development and Area Studies	AA 404/ AA 604: Spacecraft and Payload Attitude Dynamics, Control and Pointing AA 471N/ AA 671N: Relativity and Cosmology AA 472N/ AA 672N: Galactic and Extragalactic Astronomy AA 474 / AA 674: Basics of Radio Astronomy AA 476/ AA 676: Satellite Based Navigation Systems AA 478/ AA 678: Space Weather

[&] *A student who takes CH 202 will not be allowed to take ME 416/616 in his/her 8th Semester*

Structure of the Minor programs [For AY 2021-22]

A student has to register and pass at least FIVE courses (three core courses and two elective courses) as prescribed for a minor program in order to get a minor degree in that specialization along with the regular BTech degree in his/her engineering Department. A minor program will run only when at least TEN students register for it. Following minor programs are available from AY 2014-15 onwards.

1. Minor program in Biosciences and Biomedical Engineering (BSBE): To get a minor degree in BSBE, a student needs to register and pass **at least FIVE prescribed** courses ***excluding the core course*** BSE 101 Bio-Sciences for successful minor degree in BSBE.

2. MINOR PROGRAM IN CHEMISTRY: To get a minor degree in Chemistry, a student needs to register and pass **at least FIVE prescribed** courses ***excluding the core course CH 103.*** Following are courses for successful minor degree in Chemistry.

3. Minor Program in HSS: A student needs to register and pass **at least FIVE prescribed courses of Humanities and Social Sciences *excluding the core courses*** HS 159 and HS 108 for successful minor degree in Humanities or Social Sciences.

4. **Minor Program in Astronomy (from AY 2016-17):** To get a minor degree in Astronomy, a student needs to register and pass **at least FIVE prescribed** courses*.* Following are courses for successful minor degree in Astronomy.

Course structures of various Minor programs

Semester: Minor course	Minor Program in BSBE	Minor Program in Chemistry	Minor Program in Humanities and Social Sciences	Minor Program in Astronomy (from AY 2016-17 to AY 2021-22)
3rd : Minor1	BSE 201: Biophysics	CH 201: Molecules that Change the World	HS 201: Understanding Philosophy HS 203: Psychology HS 205: Sociology HS 207: French Language-I	AA 201: Introduction to Astronomy
4th : Minor 2	BSE 202: Biomedical Technologies	CH 202: Chemistry of Transition Metals and Lanthanides &	HS 206: Paradigms and Turning Points # HS 208: French Language-II HS 210: Indian Economy HS 211: German Literature and Culture Studies HS 214: History of Indian Culture and Civilization HS 216: Introduction to Hindi Cinema	AA 202N: Astronomical Techniques AA 204: Introduction to Space Exploration
5th : Minor 3	BSE 301: Introduction to	CH 301: Functional	HS 311: Life and Thought of Gandhi	AA 301: High Energy

	Molecular Biology	Materials	HS 313: History of Early Cinema HS 315: Sociology of Science and Technology HS 323: International Economics HS 341: Appreciating Indian English Literature	Astronomy AA 303: IoT for Space Applications
8th : Two elective courses as Minor 4 and Minor 5	BSE 402: Cancer Diagnosis and Therapy BSE 404/ BSE 604: Biomedical Imaging BSE 405/ BSE 605: Molecular Biophysics BSE 413/ BSE 613: Omics Technologies BSE 417/ BSE 617: Biomolecular Modeling BSE 419/ BSE 619: Renewable Energy Technologies EE 419/ EE 619: Biomedical Optics ME 407/ME 607: Bio-fluid Mechanics	CH 402: Chemistry in Industry CH 404: Chemical Physics CH 406: Nuclear Science	IHS 402: Twentieth Century World History: Critical Perspectives HS 412/ 612: Contemporary Indian Thought HS 418/ 618: Sustainability Studies HS 424/ HS 624: Econometrics-I IHS 422 / HS 622: Development Economics IHS 425: Money and Banking HS 426: Economics of Innovation HS 442/ HS 642: Language and Mind IHS 443/ HS 643: Contemporary Short Fiction IHS 444: Literature of the Twentieth Century IHS 482: Introduction to International Development and Area Studies	AA 404/ AA 604: Spacecraft and Payload Attitude Dynamics, Control and Pointing AA 471N/ AA 671N: Relativity and Cosmology AA 472N/ AA 672N: Galactic and Extragalactic Astronomy AA 474 / AA 674: Basics of Radio Astronomy AA 476/ AA 676: Satellite Based Navigation Systems AA 478/ AA 678: Space Weather

& A student who takes CH 202 will not be allowed to take ME 416/616 in his/her 8th Semester

Structure of the Minor programs [from AY 2022-23 onwards]

A student has to register and pass at least FIVE courses (three core courses and two elective courses) as prescribed for a minor program in order to get a minor degree in that specialization along with the regular BTech degree in his/her engineering Department. A minor program will run only when at least TEN students register for it. Following minor programs are available from AY 2014-15 onwards.

1. Minor program in Biosciences and Biomedical Engineering (BSBE): To get a minor degree in BSBE, a student needs to register and pass **at least FIVE prescribed** courses ***excluding the core course*** BSE 101 Bio-Sciences for successful minor degree in BSBE.

2. MINOR PROGRAM IN CHEMISTRY: To get a minor degree in Chemistry, a student needs to register and pass **at least FIVE prescribed** courses ***excluding the core course CH 103.*** Following are courses for successful minor degree in Chemistry.

3. Minor Program in Economics: A student needs to register and pass **at least FIVE prescribed courses of Humanities and Social Sciences** ***excluding the core courses*** HS 159 and HS 108 for successful minor degree in Humanities or Social Sciences.

4. **Minor Program in Liberal Arts**

5. **Minor Program in Astronomy and Space Engineering (from AY 2022-23):** To get a minor degree in Astronomy, a student needs to register and pass **at least FIVE prescribed** courses. Following are courses for successful minor degree in Astronomy.

Course structures of various Minor programs

Semester: Minor course	**Minor Program in BSBE**	**Minor Program in Chemistry**	**Minor Program in Economics (from AY 2022-23 onwards with BTech batch admitted in AY 2021-22)**	**Minor Program in Liberal Arts (from AY 2022-23 onwards with BTech batch admitted in AY 2021-22)**	**Minor Program in Astronomy (from AY 2016-17 to AY 2021-22) Minor Program in Astronomy and Space Engineering (from AY 2022-23 onwards with BTech batch admitted in AY 2021-22)**
3rd : Minor1	BSE 201: Biophysics	CH 201: Molecules that Change the World	HS 209: Intermediate Microeconomics	HS 201: Understanding Philosophy HS 203: Psychology HS 205: Sociology HS 207: French Language-I	AA 201: Introduction to Astronomy

4th : Minor 2	BSE 202: Biomedical Technologies	CH 202: Chemistry of Transition Metals and Lanthanides &	HS 210: Indian Economy	HS 206: Paradigms and Turning Points HS 208: French Language-II HS 211: German Literature and Culture Studies HS 212: History of India after Independence, 1947-2000 HS 213: Cognitive Psychology HS 214: History of Indian Culture and Civilization HS 216: Introduction to Hindi Cinema	AA 202N: Astronomical Techniques AA 204: Introduction to Space Exploration
5th : Minor 3	BSE 301: Introduction to Molecular Biology	CH 301: Functional Materials	HS 323: International Economics HS 325: Industrial Organization	HS 311: Life and Thought of Gandhi HS 313: History of Early Cinema HS 315: Sociology of Science and Technology HS 321: History of Modern Indian Business HS 327: Mind, Action, and Technology HS 341: Appreciating Indian English Literature	AA 301: High Energy Astronomy AA 303: IoT for Space Applications

8th : Two elective courses as Minor 4 and Minor 5	BSE 402: Cancer Diagnosis and Therapy BSE 404/ BSE 604: Biomedical Imaging BSE 405/ BSE 605: Molecular Biophysics BSE 413/ BSE 613: Omics Technologies BSE 417/ BSE 617: Biomolecular Modeling BSE 419/ BSE 619: Renewable Energy Technologies EE 419/ EE 619: Biomedical Optics ME 407/ME 607: Bio-fluid Mechanics	CH 402: Chemistry in Industry CH 404: Chemical Physics CH 406: Nuclear Science	HS 418/ 618: Sustainability Studies IHS 422 / HS 622: Development Economics IHS 425: Money and Banking HS 426: Economics of Innovation HS 424/ HS 624 Econometrics-I HS 431: Innovation and Intellectual Property Rights	IHS 402: Twentieth Century World History: Critical Perspectives HS 412/ 612: Contemporary Indian Thought HS 442/ HS 642: Language and Mind IHS 443/ HS 643: Contemporary Short Fiction IHS 444: Literature of the Twentieth Century IHS 482: Introduction to International Development and Area Studies HS 446: Music and Literary Modernism HS 481/ HS 681: Language, Mind and Society	AA 404/ AA 604: Spacecraft and Payload Attitude Dynamics, Control and Pointing AA 410/ AA 410: Spatial Informatics AA 412/ AA 612: Microwave Remote Sensing AA 471N/ AA 671N: Relativity and Cosmology AA 472N/ AA 672N: Galactic and Extragalactic Astronomy AA 474 / AA 674: Basics of Radio Astronomy AA 476/ AA 676: Satellite Based Navigation Systems AA 478/ AA 678: Space Weather

Structure of the Minor programs for AY 2024-25 onwards (For all UG batches admitted in and after AY 2023-24)

A student has to register and pass at least FIVE courses (three core courses and two elective courses) as prescribed for a minor program in order to get a minor degree in that specialization along with the regular BTech degree in his/her engineering Department. A minor program will run only when at least TEN students register for it. Following minor programs are available from AY 2014-15 onwards.

1. Minor program in Biosciences and Biomedical Engineering (BSBE): To get a minor degree in BSBE, a student needs to register and pass **at least FIVE prescribed** courses ***excluding the core course*** BSE 101 Bio-Sciences for successful minor degree in BSBE.

2. MINOR PROGRAM IN CHEMISTRY: To get a minor degree in Chemistry, a student needs to register and pass **at least FIVE prescribed** courses ***excluding the core course CH 103.*** Following are courses for successful minor degree in Chemistry.

3. Minor Program in Economics: A student needs to register and pass **at least FIVE prescribed courses of Humanities and Social Sciences** ***excluding the core courses*** HS 159 and HS 108 for successful minor degree in Humanities or Social Sciences.

4. **Minor Program in Liberal Arts**

5. **Minor Program in Astronomy and Space Engineering (from AY 2022-23):** To get a minor degree in Astronomy, a student needs to register and pass **at least FIVE prescribed** courses*.* Following are courses for successful minor degree in Astronomy.

Course structures of various Minor programs

Semester: Minor course	**Minor Program in BSBE**	**Minor Program in Chemistry**	**Minor Program in Economics From AY 2024-25 (Batch Admitted in and after AY 2023-24)**	**Minor Program in Liberal Arts From AY 2024-25 (Batch Admitted in and after AY 2023-24)**	**Minor Program in Astronomy From AY 2024-25 (Batch Admitted in and after AY 2023-24)**
3rd : Minor1	BSE 201: Biophysics	CH 201: Molecules that Change the World	HS 209: Intermediate Microeconomics	HS 211: German Literature and Culture Studies HS 212: History of India after Independence, 1947-2000 HS 203: Psychology	AA 201: Introduction to Astronomy

				HS 205: Sociology HS 221 Fundamentals of Linguistics HS 223 Language Variation: Culture and Society	
4th : Minor 2	BSE 202: Biomedical Technologies	CH 202: Chemistry of Transition Metals and Lanthanides &	HS 210: Indian Economy	HS 206: Paradigms and Turning Points HS 214: History of Indian Culture and Civilization HS 213: Cognitive Psychology HS 224 Contemporary Short Fiction HS 226 Sociology of Cinema	AA 202N: Astronomical Techniques AA 204: Introduction to Space Exploration
5th : Minor 3	BSE 301: Introduction to Molecular Biology	CH 301: Functional Materials	HS 323: International Economics HS 321: History of Modern Indian Business	HS 311: Life and Thought of Gandhi HS 327: Mind, Action, and Technology HS 341: Appreciating Indian English Literature	AA 301: High Energy Astronomy AA 303: IoT for Space Applications
6TH : Minor 4			HS 325: Industrial Organization	HS 315: Sociology of Science and Technology HS 328 Philosophy and Film HS 330 Graphic Literature	

7th : (minor project/field study/white paper/domain comprehension (Seminar)/Lab course)	(0-0-4-2) (minor project/field study/white paper/domain comprehension (Seminar)/Lab course)	(0-0-4-2) (minor project/field study/white paper/domain comprehension (Seminar)/Lab course)	(0-0-4-2) (minor project/field study/white paper/domain comprehension (Seminar)/Lab course)	(0-0-4-2) (minor project/field study/white paper/domain comprehension (Seminar)/Lab course)	(0-0-4-2) (minor project/field study/white paper/domain comprehension (Seminar)/Lab course)

Syllabi of Courses

of

Astronomy, Astrophysics and Space Engineering

(from AY 2016-17 onwards)

Course Code	**AA 201**
Title of the Course	**An Introduction to Astronomy**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Department/Centre	Astronomy, Astrophysics and Space Engineering
Prerequisite, if any	None
Scope of the course	To provide an introduction to Astronomy for second-year B.Tech. students. This would become the second course in the Minor in Astronomy, the first being first-year Electrodynamics
Course Syllabus	**Introduction, Distances & Measurement systems** Typical physical scales/conditions in astrophysics; order of magnitude estimation; astronomical observations: electromagnetic, earth vs space based observations, atmospheric transmission; co-ordinate systems; luminosity/magnitude scale, electromagnetic wavebands; distance measurement **Telescopes:** radio, infrared, optical, X-ray, gamma ray; collecting area, diffraction limit, atmospheric seeing; optics, aperture synthesis, spectroscopy (prisms and gratings). **Fundamentals of radiation:** specific intensity, energy density, opacity, black body distribution **Stars & Stellar structure/evolution:** Solar spectrum, luminosity; nuclear fusion; Thomson scattering, hydrostatic equilibrium, gas/radiation pressure; order of magnitude estimates, main sequence; HR diagram **Galactic & Extragalactic Astronomy:** Types of galaxies, Milkyway components:; 21 cm line, rotation curve, dark matter; Jeans instability and star formation, interstellar medium; cosmic rays. Galactic dynamics Active Galaxies; Extragalactic distance scale, classification of clusters, ICM, virial theorem **Cosmology & Relativity:** Olber's paradox; relativity, line element; horizon, orbits, Hawking radiation; FRW metric; redshift, angular and

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Suggested Books	1. Rai Chaudhuri, A., Astrophysics for Physicists, Cambridge University Press, 2010. ISBN 978-0521815536 2. Carroll B. W. & Ostlie, D. A.: An introduction to Modern Astrophysics, Pearson Education-Addison Wesley, 2007. ISBN 978-0805304022 3. Shu, F., The Physical Universe, Universal Science Books, 1982. ISBN 978-0935702057 4. Harwit, M., Astrophysical Concepts, 3rd ed, Springer-verlag, 2006. ISBN 978-0387329437 5. Maoz, D., Astrophysics in a nutshell, Princeton University Press, 2006. ISBN 978-0387329437 6. Padmanabhan, T., Invitation to Astrophyiscs, World Scientific, 2006. ISBN 978-9812566874 7. 7. Acheson, Elementary Fluid Dynamics, Oxford University Press, 1990. ISBN 978-9812566874

Course Code	**AA 202N**
Title of the Course	**Astronomical Techniques**
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Department / Centre	Center of Astronomy
Pre–requisite, if any	None
Scope of the course	To provide a working knowledge of astronomical techniques
Course Syllabus	**1. Introduction:** Radio observations, physical mechanisms generating emission, Multi-waveband observations **2. Receiver and Signal Processing Theory:** Probability Density, Expectation Values, Ergodicity, Auto-correlation and power spectrum, linear systems, Filters, digitization and sampling, square law detectors, and other signal processing, understanding of noise concepts, Noise, statistics, estimation and uncertainties, discussion of flux, surface brightness, Antenna Temperature. Direct Detection and Heterodyne systems; the importance of phase in interferometry, amplifiers, specifically low-noise; mixers and filters. **3. Fourier Transform and Related Topics:** Basics, and physical meaning; properties; coherence (mutual and self; phase-space picture); uncorrelatedness versus incoherence; uses of Fourier transforms; discrete & continuous versions; resolution versus sampling; aliasing (discretization and cyclicity); bandwidth and information content & its rate of change; Nyquist criteria (for real and complex sampling); Fourier synthesis and analysis; symmetries; physical examples (e.g. Fourier pairs relevant to astronomy/physical optics); auto-correlation function & power spectrum; Structure function (and its relation with other functions); convolution versus correlation (including physical meaning); convolution theorem; filtering; impulse-response/point-spread function; sidelobes & window functions; interpolation; digitization and loss of information; Matched filtering and optimum detection/estimation; Fourier versus Laplace transforms. **4. Imaging principles:** resolution, aperture synthesis, methods of cleaning the data, excision of Radio Frequency Interference, switching **5. Observations/data analysis:** Techniques in data reduction and analysis

Suggested Books	1. Bracewell, R.N., ***The Fourier Transform and Its Applications***, McGraw Hill. ASIN, B0006BMAD8 2. Brigham, N.O., ***Fast Fourier Transform and Its Applications***, Pearson, 1988, ISBN: 978-0133075052 3. Roy, A.E. and Clarke, D., Astronomy Principles and Practice, CRC Press, 4th edition, 2003. ISBN 978-0750309172 4. Kitchin, C.R.: Astrophysical Techniques, CRC Press, 6th edition, 2013. ISBN 978-1466513761 5. Knoll, G.F.: Radiation Detection and Measurement, Wiley, 2010. ISBN 978-0470131480 6. Hamaker et al. (A & A Suppl. Ser., 117, 1996): Understanding Radio Polarimetry 6. Jaap Tinbergen: Astronomical Polarimetry, Cambridge University Press, 2005. ISBN 78-0521018586 7. J. D. Krauss: Radio Astronomy, Cygnus-Quasar Books, 2ed, 1986. ISBN 978-1882484003

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Course Code	**AA 203 / PH 203**
Title of the Course	**Classical Mechanics**
Course Category	Core
Credit Structure	L-T-P-Credits (2-1-0-3)
Name of the Department	Physics
Pre–requisite, if any	None
Objectives of the course	This course provides basic knowledge of classical physics
Course Outcomes	Students should be able to • Solve problems using the Lagrange method • Apply Lorentz transformations, understand 4-vector analyses and relativistic kinematics, and use Lagrange and Hamiltonian formulations for relativistic particles. • Develop problem-solving skills in classical and relativistic mechanics.
Course Syllabus	• System of particles, Center of mass, equation of motion of the CM, conservation of linear and angular momentum, conservation of energy, variable mass systems. Elastic and inelastic collisions. • Central Force: uniformly rotating frame, centrifugal and Coriolis forces, Motion under a central force, Kepler's laws, Gravitational Law and field, Conservative and non-conservative forces. • Introduction to Lagrangian mechanics, Mechanics of Rigid Body: Rigid body motion, fixed axis rotations orthogonal transformations and rotations (finite and infinitesimal); Euler's theorem, Euler's angles; moments of Inertia tensor, parallel and perpendicular axes theorem, Principal moments and axes; Euler's equation; Small Oscillations, normal modes, and frequencies. • Special Theory of Relativity: Lorentz transformations; 4-vectors, 4-dimensional velocity, and acceleration; 4-momentum and 4-force; Covariant equations of motion; Relativistic kinematics (decay and elastic scattering); Lagrangian and Hamiltonian of a relativistic particle. • General properties of matter: Introduction to Elasticity, Surface Tension and Viscosity

Suggested Books	Textbooks: 1. Goldstein, Poole, Safko, *Classical Mechanics*, Pearson, (2017), ISBN: 978-0201657029 2. N. Rana and P. Jog, *Classical Mechanics*, Mcgraw Hill, (2017), ISBN: 978-0074603154 Reference Books: 3. Kleppner and Kolenkow, *An Introduction to Mechanics*, Cambridge Univ. Press, (2013), ISBN: 978-0521198110 4. K. C. Gupta, *Classical Mechanics of Particles and Rigid Bodies*, New Age Education, (2018) ISBN: 978-9386649782 5. D. Morin, *Introduction to Classical Mechanics*, Cambridge Univ. Press, (2009), ISBN: 978-0521185028

Course code	**AA 204**
Title of the course	**Introduction to Space Exploration**
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Astronomy, Astrophysics and Space Engineering
Prerequisite, if any	None
Scope of the course	To provide introductory concepts of space science and exploration
Course Syllabus	**Sun and the solar system**: Overview of Sun and Heliosphere; Solar wind plasma and Coronal Mass Ejection. Asteroid belts; **Solar interaction with solar system bodies**: Planetary magnetism; Planetary magnetic fields and observations; Solar interactions with planets and comets, **Earth and Atmosphere**: Remote Sensing from Space; Vertical structure of the Atmosphere and circulations; Chemistry and dynamics of Ionosphere; Ongoing and future missions. **Planetary Science**: Overview of planetary characteristics; Planetary system; Gas planets; Planetary satellites; Planetary atmosphere. **Fundamentals of Satellites**: Basics of rockets and satellite launching; Overview of satellite communications and satellite orbit, orbit principles, basics of space flightorbital mechanics, Spacecraft payloads **Spacecraft-environment interactions**: Spacecraft charging in low Earth orbit and geostationary orbit; Radiation damage effects; Background effects and their minimisation; Penetrating radiation; South Atlantic Anomaly **Space Explorations**: Overview of national and international space agencies; Space policies; Historical overview of space exploration missions; International Space Station; Human Interaction in Space, Astronautics. **Exoplanets and Astrobiology**: Exoplanets; Basic technique to detect exoplanets; Habitable zones; Search for Extraterrestrial Intelligence
Suggested Books	1. B. A. Campbell, S. W. McCandless, Jr.: ***Introduction to Space Sciences and Spacecraft Applications***, Gulf Professional Publishing, 1996, ISBN-978-0-88415-411-2 2. Kivelson M G & Russel C T, ***Introduction to Space Physics***, Cambridge Univ. Press, Cambridge, 1995, ISBN-10, 0521457149 3. Spohn T, Breuer D & Johnson T V, ***Encyclopedia of the Solar System***, 3rd edition, Elsevier, 2014, ISBN: 978-0-12-415845-0 4. 4. G. Joseph and C Jeganathan, ***Fundamentals of Remote Sensing***,

	Third Edition, Universities Press Pvt. Ltd., Hyderabad, India. 2018. ISBN 978-93-86235-46-6. 606

Course code	AA 205 / PH 205
Title of the course	**Electronic Devices and Circuits - I**
Course Category	**Core**
Credit Structure	**L - T - P – Credits (2-1-0-3)**
Name of Dept.	**Astronomy, Astrophysics and Space Engineering**
Prerequisite, if any	None
Objectives of the course	The students will gain foundational knowledge of analogue electronics.
Course Outcome	• Acquire knowledge of basic analog electronics. • Gain skills to design basic electronic circuits.
Course Syllabus	**Module - 1** Basics of semiconductor devices and their characterization: diodes, transistors, BJT, FET, MOSFET, etc. **Module - 2** Small signal analysis in electrical circuits: Estimation of voltage gain, input/output resistance, Miller's theorem, high-frequency transistor model. **Module - 3** Amplifiers and their applications: Single-stage and two-stage amplifier, Differential amplifiers, Operational amplifiers. **Module - 4** Oscillators: Basics of oscillators, phase shifter, multi-vibrators, timers.
Suggested Books	Textbooks: 1. A. Malvino and D. Bates, *Electronics Principles*, McGraw Hill Education, 7th Ed., (2017), ISBN : 978-0070634244 2. A. S. Sedra and K. C. Smith, *Microelectronic Circuits,* Oxford University Press, (2017), ISBN: 978-0199476299 Reference Books: 3. Gray, Hurst, Lewis, and Meyer, *Analysis and Design of Analog Integrated Circuits,* Wiley (2009) ISBN: 978-8126521487 4. R. Gayakwad, *Op-amps and Linear Integrated Circuits*, Pearson, (2021) ISBN: 978-9353949037 5. B. Razavi, *Fundamentals of Microelectronics*, Wiley, (2017), ISBN: 978-8126571352 6. R. L. Boylestad, *Electronic Devices and Circuits Theory*, Pearson (2021) ISBN: 978-9332542600

** This course will be taught by instructors of Department of Astronomy, Astrophysics and Space Engineering

Course code	**AA 206 / PH 206**
Title of the course	**Electronic Devices and Circuits – II**
Course Category	Core
Credit Structure	L - T - P – Credits (2-1-0-3)
Name of the Department	Astronomy, Astrophysics and Space Engineering
Pre-requisite, if any	None
Objectives of the course	The students will develop a basic understanding of digital electronics principles
Course Outcomes	Students will learn about digital electronics and will able to solve related problems in the domain of engineering.
Course Content	**Module -1** **Number System and Codes:** Decimal, Binary, Octal and Hexadecimal number systems and arithmetic, base conversions. Representation of signed and unsigned numbers, addition, subtraction by 2's complement method, and multiplication. **Module -2** **Logic Gates and Boolean algebra:** Truth Tables of OR, AND, NOT, NOR, NAND, XOR, XNOR, Universal Gates, Basic postulates and fundamental theorems of Boolean algebra. **Module -3** **Combinational Logic Analysis, Design and Arithmetic Circuits:** Standard representation of logic functions, Binary Addition. Half and Full Adder. Half and Full Subtractor, 4-bit binary Adder/Subtractor, counters and registers. **Module -4** **Signal Conditioning and D-A and A-D Conversion:** A-D and D-A conversion, sampling and reconstruction of signal, Nyquist sampling, Fourier transform, Fast Fourier Transform.
Suggested Books	Textbooks: 1. D. P. Leech and A. P. Malvino, *Digital Principles and Applications*, Tata McGraw Hill, 8th ed., (2014) ISBN: 978-9339203405. 2. A. S. Sedra, K. C. Smith, *Microelectronic Circuits*, Oxford University Press, (2017), ISBN: 978-0199476299 Reference books: 3. J. G. Proakis and D. G. Manolakis, *Digital Signal Processing: Principle, Algorithms and Applications*, 4th ed., Pearson Education, (2007), ISBN: 978-8131710005. 4. A. V. Oppenheim, A. S. Willsky, and S. H. Nawab, *Signals & systems*,

	Pearson Education, 2nd ed., (2015) ISBN: 9332550239. 5. J. Millman and C. Halkias, *Integrated Electronics: Analog and Digital Circuits and Systems*, McGraw-Hill, 2nd ed., (1972), ISBN: 9780070151420.

Course Code	**AA 207 / PH 207**
Title of the course	Wave Phenomenon and Optics
Course Category	Core
Credit Structure	L-T-P-Credits (2-1-0-3)
Name of Dept.	Astronomy, Astrophysics and Space Engineering
Prerequisite, if any	None
Objectives of the course	The students will be introduced to the basics of waves and oscillations, including optics and lasers.
Course Outcome	• The students will learn to solve for motions in different oscillatory systems • The students will understand the concepts of optics and compare the outcomes in different optical systems
Course Syllabus	**Module 1:** • Oscillations: Harmonic motion (simple, damped, critical). Driven oscillation, resonance. Oscillations of two-particle systems and modes. Oscillations of n particle systems. Oscillation modes. Longitudinal and transverse oscillations. • Waves: Equations of motion, standing waves and travelling waves. Harmonics and their superpositions. Fourier analysis and Fourier coefficients. Doppler effect. **Module 2:** • Geometrical Optics: Fermat's Principle, Refraction, Thick Lens and Lens Combination, Matrix Method, Aberrations, Optical Instruments: Telescopes and Microscopes. • Wave Optics: Electromagnetic Spectrum, Huygen's Principle, Interference: Young's Experiment, Fresnel's Biprism, Newton's Rings, Interferometers: Michelson and Fabry-Perot; Coherence: Temporal and Spatial; Diffraction: Fresnel and Fraunhofer, Single and Double Slit, Circular aperture, Grating, Resolving power. • Polarization, LASER and Holography: Brewster's Law, Birefringence, Dichroism, Babinet's Compensator, Polarimeters, Optical Activity. Coherence, LASER, spontaneous and stimulated emission, Gaussian wave and its diffraction. Holography.

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Suggested Books:	Textbooks: 1. A. P. French, *Vibrations and Wave*, CRC Press; 1st edition, (2017), ISBN: 978-1138414082 2. A. Ghatak, *Optics*, MacGraw Hill, (2020), ISBN: 978-9390113590 [Module 2] Reference Books: 3. F. S. Crawford, *Waves*, MacGraw Hill Education, (2017), ISBN: 978-0070702172 4. N. Bajaj, *The physics of waves and oscillations*, McGraw Hill, (2017), ISBN: 978-0074516102 5. F. Jenkins and H. White, *Fundamentals of Optics*, McGraw Hill Education; 4th edition, (2017), ISBN: 978-1259002298 6. M. Born and E. Wolf, *Principles of Optics*, Cambridge Univ. Press, (2019), ISBN: 978-1108477437

** This course will be taught by instructors of Department of Astronomy, Astrophysics and Space Engineering

Course code	AA 208 / PH 208
Title of the course	**Electrodynamics**
Course Category	Core
Credit Structure	L-T-P–Credits (2-0-0-2)
Name of Dept.	Astronomy, Astrophysics and Space Engineering
Prerequisite, if any	None
Objectives of the course	The students will be introduced to electromagnetism
Course Outcome	Develop understanding of basic electrodynamics and its applications in the domain of engineering.
Course Syllabus	• Review of Electrostatics and Magnetostatics. Time-Varying Fields and Maxwell's Equations: Faraday's law for Electromagnetic induction, Displacement current, Integral and differential forms of Maxwell's equations, and Motional Electromotive forces. Boundary Value Problems, multipole expansion. • Electromagnetic Waves: Derivation of Wave Equation, Coulomb and Lorentz gauges; Plane waves in free space and in a homogenous material. non-conducting and conducting media; reflection and transmission at normal and oblique incidences, Skin effect, Poynting theorem. Polarization. • Lorentz Invariance of Maxwell's Equation, Radiation by moving charges, retarded potentials. Dipole antenna radiation, Introduction to waveguides.
Suggested Books	Textbooks: 1. D. J. Griffiths, *Introduction to Electrodynamics*, Cambridge University Press, (2020), ISBN: 978-1108822909 2. H. C. Verma, *Classical Electromagnetism*, Bharati Bhawan, (2022), ISBN-10:9388704827 Reference Books: 3. M. N. O. Sadiku, *Elements of Electromagnetics*, Oxford University Publication, (2014), ISBN-0199321388 4. W. Hayt, *Engineering Electromagnetics*, McGraw Hill Education, (2012), ISBN-9339203275 5. J. D. Jackson, *Classical Electrodynamics*, 3rd edition, Wiley,

	(2007), ISBN-10: 9788126510948

**This course will be taught by instructors of Department of Astronomy, Astrophysics and Space Engineering

Course code	**AA 209 / PH 209**
Title of the course	**Fundamental Concepts for Solid State Engineering**
Course Category	**Core**
Credit structure	**L-T-P-Credits (2-1-0-3)**
Name of the department	**Physics**
Prerequisites	None
Objectives of the course	This course provides a multidisciplinary introduction to fundamental concepts of solid state physics, encompassing topics ranging from crystals, reciprocal lattices to structural, elastic, thermal, optical and electronic properties of materials. This course will build the foundation for applications of solids in various fields of applied physics and engineering branches.
Course Outcomes	• Develop an understanding of the core concepts of solid-state physics and understand their implications in various applications/branches of engineering. • Application of fundamental concepts in solid state physics to solve relevant conceptual and numerical problems.
Course Syllabus	• Introduction: Periodic array of atoms, Symmetry operations, Point Groups in general, Index system for crystal planes, Lattices in 1–, 2– and 3-D Bravais Lattices. • Reciprocal lattice: Diffraction of waves by crystals, Scattered Wave Amplitude, Brillouin zones, Wigner–Seitz Cells, Fourier analysis of the Basis. • Elastic Properties of Crystals and Crystal Binding. • Crystal Vibrations: mono-atomic lattice, diatomic lattice, quantization of elastic waves, phonon-dispersions. Thermal properties of Crystals: Phonon density of states, Heat capacity, thermal expansion, thermal conductivity. • Electrons in Crystals: Review of Free electron model, Periodic potential, Born–von Karman boundary conditions, Bloch's theorem, Electronic band structure, single electron energy state, degenerate electron levels, Consequences of the nearly free electron model, Fermi surface. • Electronic properties of Materials: Construction of Fermi surfaces, Reduced Zone Scheme, Periodic Zone Scheme, Reflectance and Absorption, Intrinsic and Extrinsic semiconductors, Effective mass and mobility of carriers, Hall Effect, Semiconducting junctions, Metal-semiconductor contacts – Schottky barriers, Ohmic contacts, Brief introduction to semiconductor device fabrication. • Structural Defects: Point defects, Dislocations, Microcracks, Stacking faults, Grain boundaries.

Suggested Books:	Textbooks: 1. C. Kittel, *Introduction to Solid State Physics* (7th Edition), John Wiley & Sons, (2019) ISBN: 9788126578436. 2. A. J. Dekker, *Solid State Physics*, MacMillan India Ltd. (2008) ISBN: 978-0333918333 Reference Books: 3. R. E. Hummel, *Electronic Properties of Materials: An introduction for Engineers*, Springer-Verlag, (1985), ISBN: 978-0387156316 4. M. Ali Omar, *Elementary Solid-State Physics: Principles and Applications* (1st Edition), Pearson Education, (2002) ISBN: 978-8177583779 5. Ashcroft and Mermin, *Solid State Physics*, Thomson Press (India) Ltd. (2021), ISBN:9780030839931

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Course code	**AA 210 / PH 210**
Title of the course	**Fundamentals of Quantum Mechanics**
Course Category	Core
Credit structure	L-T-P-Credits (2-1-0-3)
Name of the department	Physics
Prerequisites	None
Objectives of the course	The students will be introduced to the basics of quantum mechanics
Course Outcomes	Students will be able to • Demonstrate a thorough understanding of the foundational principles of quantum physics • Analyze and solve the Schrödinger equation for various scenarios • Apply quantum mechanical principles to understand and explain several phenomena related to hydrogen atom, atomic nuclei and radioactivity.
Course Syllabus	• Review of Introductory Quantum Physics • Calculation of expectation values, Kets, Bras and operators, Base kets and matrix representations, Measurements, observables and the uncertainty relations, change of basis, position, momentum and translation, wave functions in position and momentum space. • Quantum dynamics: Time evolution and the Schrodinger equation, The Schrodinger versus the Heisenberg picture, Schrödinger equation, and its solution for one, two, and three-dimensional boxes. Solution of Schrödinger equation for the one-dimensional harmonic oscillator. Reflection and transmission at a step potential, Pauli exclusion principle. • WKB approximation, Tunneling through a barrier, Structure of the atomic nucleus, mass, and binding energy. Hydrogen atom, Radioactivity and its applications. Laws of radioactive decay.
Suggested Books	Textbooks: 1. D. J. Griffiths and D. F. Schroeter, *Introduction to Quantum Mechanics*, Cambridge University Press, (2018), ISBN: 978-1107189638 2. R. Shankar, *Principles of Quantum Mechanics*, Springer, (2011), ISBN: 978-0306447907 Reference books: 3. P. M. Mathews and K. Venkatesan, *A Textbook of Quantum Mechanics*, Springer, (2017), ISBN: 978-0070146174 4. J. Townsend, *A Modern Approach to Quantum Mechanics*, University Science Books, (2010) ISBN:978-1891389788. 5. A. Das, *Quantum Mechanics: A Modern Introduction*, CRC Press; 1st edition, (1986) ISBN: 978-2881240539

Course code	**AA 211**
Title of the course	The Blue Planet: Introduction to Earth System Sciences
Course Category	Departmental Elective
Credit Structure	L - T - P - Credits 2-0-2-3
Name of the Concerned Department	Astronomy, Astrophysics and Space Engineering
Pre-requisite, if any	None
Scope of the course (Objectives)	The purpose of this course is to provide with an understanding of how the Earth and its different components works and how it affects the Earth's inhabitants
Course Outcomes	● Students will understand the important processes that occur on Earth ● They will critically analyze human impacts on and interactions with the environment. ● They will conduct scientific experiments and in-situ data collection to validate the observations
Course Content	Theory: ● Introduction to Earth system - review of history of evolution of Earth, plate tectonics, volcanoes and earthquakes. ● Hydrosphere, Atmosphere and Biosphere - Equation of fluid motion for non-rotating and rotating fluid, global ocean and ground water, Earth's dynamic atmosphere, ecosystems and biomes. ● The Changing Earth - land-use land-cover, human induced changes and their impacts on our surroundings, Change detection techniques. Lab: Relevant lab experiments which includes: ● Cloud formation on adiabatic expansion; Measurement of relative humidity with a psychrometer ● Reading and interpretation of weather charts ● Seismograph and its measurements ● Canopy cover mapping with hemispherical photography ● Field survey of different land-use land-cover ● In-situ measurement of different parameters (e.g. temperature,

	humidity, radiance (photometer), soil moisture, etc) ● Pollution measurement from field survey ● Observing Earth and its components from air and space (drone and satellites)
Suggested Books	**Text Book:** 1. Brian J. Skinner and Barbara W. Murck, The Blue Planet: An Introduction to Earth System Science, 3rd Edition: 2011: ISBN: 978-0-471-23643-6 **Reference Books:** 2. Lutgens and Edward J. Tarbuck, Foundations of Earth Science, 9th Edition, 2021, ISBN: 9780135851562 3. A.P. Trujillo and H.V. Thurman, Essentials of Oceanography,12th Edition: 2016 Pearson: ISBN: 978-0134891521

Course Code	**AA 212 / PH 212**
Course Title	**Thermal Physics**
Course Category	Core
Credit Structure	L-T-P-Credits (2 -1-0-3)
Name of the Dept.	Physics
Pre-requisite if any	None
Objectives of the course	This course introduces the basic concepts of heat and thermodynamics
Course Outcomes	Student will be • Able to understand Kinetic theory of gases and apply the theory to gain insights into specific heat and transport phenomena in gases • Grasp and effectively apply the Laws of Thermodynamics to understand the principle of heat engines, phase transitions etc.
Course Syllabus	• **Kinetic Theory of Gases:** Ideal gas, Distribution of velocities, Mean, RMS and Most Probable Speeds, Degrees of Freedom, Law of Equipartition of Energy (statement only), Specific heats of Gases, Mean Free Path. Collision Probability, Transport phenomena (viscosity, thermal conductivity and diffusion), Real Gases, Virial equation, Boyle temperature, Van der Waal's Equation of State, Comparison with Experimental P-V Curves. • **Laws of Thermodynamics:** Zeroth Law of Thermodynamics & Concept of Temperature, Concept of Work & Heat, Internal Energy and First Law of Thermodynamics, Isothermal and Adiabatic Processes, Second Law of Thermodynamics, Reversible and Irreversible process with examples, Carnot's Cycle, Carnot engine & efficiency, Carnot's Theorem, Heat engines, Concept of Entropy, Clausius Theorem and Clausius Inequality, Principle of Increase of Entropy, Third Law of Thermodynamics. • **Thermodynamic potentials:** Internal Energy, Enthalpy, Helmholtz Free Energy, Gibb's Free Energy, their Definitions, Properties and Applications, First and second order Phase Transitions, Clausius-Clapeyron Equation, Maxwell's Thermodynamic Relations, Joule-Kelvin coefficient, Joule-Thomson Effect. • **Non-equilibrium Thermodynamics**: Entropy production, Kinetic coefficients, Proof of Onsager reciprocal relations, Thermoelectricity
Suggested Books	Textbooks: 1. M. W. Zemansky, R. Dittman, *Heat and Thermodynamics*, McGraw-Hill, (1996) ISBN: 978-0070170599 2. D. V. Schroeder, *An Introduction to Thermal Physics,* Oxford University Press, (2021) ISBN: 978-0192895547

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	Reference books: 3. S. J. Blundell and K. M. Blundell, *Concepts in Thermal Physics*, Oxford University Press, (2009), ISBN: 978-0199562107 4. F. Reif, *Fundamentals of Statistical and Thermal Physics,* Waveland Press, (2010) ISBN: 978-1577666127 5. P. K. Nag, *Engineering Thermodynamics,* McGraw Hill Education, (2021) ISBN: 978-9352606429

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Course code	**AA 214**
Title of the course	Stellar and Planetary Science
Course Category	Elective
Credit Structure	L - T - P - Credits 2-1-0-3
Name of Dept.	Astronomy, Astrophysics and Space Engineering
Prerequisite, if any	None
Scope of the course	The course aims to provide a physical picture of how stars and planets form and evolve both within our Solar System and beyond.
Course Outcome	● Demonstrate the role of basic physical processes in the formation of stars and planets. ● Identify the different observational characteristics and detection techniques of stars and planets.
Course Syllabus	**Module 1 - Stellar science**: Star formation - Spherical collapse model, Stellar Structure and HR diagram, concepts of Hydrostatic equilibrium and energy generation and transfer, Stellar evolution - Main sequence/ giants/ supergiants, Our Sun, Binary stars and Mass Transfer Binaries, star clusters, Stellar feedback **Module 2 - Planetary science :** Overview of Solar system, Planetary atmospheres, Planetary surfaces, Planet formation and migration - Minimum mass solar nebula, Core Accretion, Gravitational Instability, Type I and Type II Migration, Exoplanetary detection - Radial Velocity, Transit Method, Microlensing, Habitable zones, planetary satellites and tidal effects.
Suggested Books	**Text Books:** 1. S. W. Stahler and F. Palla, The Formation of Stars, Wiley–VCH, 2004; ISBN:9783527405596 [Module 1] 2. Jack Lissauer and Imke de Pater, Fundamental Planetary Science, Cambridge University Press, 2019, ISBN 9781108411981 [Module 2] 3. **Reference Books:** 4. L. Hartmann; Accretion Processes in Star Formation; Cambridge University Press, 2009; ISBN 978-0511552090 5. Dina Prialnik, An introduction to the theory of stellar structure and evolution, Cambridge University Press; 2010; ISBN : 978-0521866040 6. Scott Tremaine; Dynamics of Planetary Systems; Princeton University Press; 2023; ISBN 978-0691207124 7. Sara Seager; Exoplanets; University of Arizona Press; 2011; ISBN 978-0816529452

Course code	**AA 216**
Title of the course	Flight mechanics and classical control
Course Category	Departmental Elective
Credit Structure	L - T - P - Credits 2-1-0-3
Name of the Concerned Department	Astronomy, Astrophysics and Space Engineering
Pre-requisite, if any	None
Scope of the course (Objectives)	The purpose of this course is to teach performance, static and dynamic stability, and classical feedback control of the spacecraft
Course Outcomes	● Students will be able to understand the mechanism of spacecraft flight ● They will be able to compute rigid body dynamics ● They will understand how the control systems are used in spacecrafts
Course Content	**Module 1:** **Flight mechanics**: Review of Newtonian mechanics; Generalized coordinates, constraints, virtual work; Lagrange's equation; Dynamics of rigid bodies in three dimensions; Euler angles; Euler's equations of motion for rigid bodies, Gyrodynamics, equations of motion for UAVs. **Module 2:** **Classical control**: Linear feedback control systems, frequency and time domain analysis, I/O relationships, transfer function ,stability criteria, Bode diagrams, Root locus method, Analysis of simple problems using software
Suggested Books	**Text Books:** 1. John David Anderson, Introduction to Flight, McGraw-Hill Higher Education, 9th Edition, 2022, ISBN: 9781260226744 [Module I] 2. N.S. Nise, Control Systems Engineering, John Wiley & Sons, India Edition, 2018, ISBN: 978-8126571833 [Module II]

	Reference Book 3. B.C. Kuo, Automatic, Control Systems, Prentice Hall India, 9th edition, 2014, ISBN: 978812655233

Course code	**AA 251 / PH 251**
Title of the course	**Engineering Physics Lab - I**
Credit structure	L-T-P-Credits (0-0-3-1.5)
Course Category	Core
Name of the Dept.	Physics
Pre-requisite if any	None
Objectives of the course	Students will get exposure to several experiments based on various advanced concepts of Physics.
Course Outcomes	• Learn to accurately collect, analyze and interpret data to understand the underlying physical principles/concepts. • Experimental verification of fundamental concepts in Classical Physics, Waves and Optics and Solid State engineering • Evaluate the errors and statistical deviations associated with the experimental results
Course Syllabus	A representative list of experiments will be performed by students: **Classical physics** • Moment of inertia of flywheel • Measurement of Young's modulus • Verification of Bernoulli's theorem • Constant volume and pressure air thermometer • Determination of Planck's constant • Millikan oil drop experiment • Helmholtz coil & measurement of Faraday's number **Waves and Optics** • Michelson interferometer • Verification of Brewster's law • Determination of specific rotation of sugar solution by using Laurent's Half Shade Polarimeter. **Solid State Engineering** • Nature of semiconductor band-gap of a powdered semiconductor using Diffuse Reflectance Spectroscopy. • Demonstration of X-ray diffraction in crystalline solids • Determination of Heat Capacity using Differential Scanning Calorimetry.
Suggested Books	Reference Books: 1. W. F. Smith, *Experimental Physics: Principles and Practice for the laboratory*, CRC Press, (2020), ISBN: 978-1498778473

	2. L. Lyons, *A practical guide to data analysis for physical science students*, Cambridge Univ. Press, (1991), ISBN: 978-0415481519

Course Code	**AA 252 / PH 252**
Title of the Course	**Scientific Computing Lab**
Course Category	**Core**
Credit Structure	**L-T-P-Credits (0-0-2-1)**
Name of the department	**Physics**
Pre–requisite, if any	None
Objectives of the course	To familiarize students with Object-Oriented Programming language, data structures, and their application in Physics-specific problems.
Course outcomes	Student will be able to learn to apply computational techniques for Physics problems using a model programming language in vogue
Course Syllabus	• Introduction to Object-Oriented Programming (OOP), using a model language such as Python. • Object types, numbers, strings, lists, arrays, dictionaries, tuples, files, I/O handling. Statements and syntax, expressions, loops, iterations. • Basic functions, arguments, recursive functions, modules, module packages. Introduction to class and OOP, Error & exceptions handling. • Data structure and data handling. Efficient array handling using standard libraries. Scientific computing and problem solving, Integrating Fortran/C++ code with Python, as a model language. • Application of the model language to solve Physics problems
Suggested Books	Textbook: 1. A. K. Gupta, *Scientific Computing in Python*, Techno World Publishers, (2021) ISBN: 978-81-949567-6-1 Reference Books: 2. M. Lutz, *Learning Python: Powerful Object-Oriented Programming (5th edition)*, Cambridge University Press; (1989), ISBN: 978-1449355739 3. A. K. Gupta, *Python Computing: Fundamentals and Applications,* Techno World, (2023), ISBN: 978-93-92145-55-1

Course code	**AA 255 / PH 255**
Title of the course	**Electronic Devices and Circuits Lab - I**
Course Category	Core
Credit Structure	L-T-P-Credits (0-0-3-1.5)
Name of Dept.	Astronomy, Astrophysics and Space Engineering
Prerequisite, if any	None
Objectives of the course	The students will acquire foundational knowledge and skills in analog electronics experimentation
Course Outcome	• Acquire hands-on experience in the domain of analog electronics. • Learn how to implement electronic circuits.
Course Syllabus	• Diode and its applications; I-V characteristics, Clipping Circuits. • Diode as – Voltage Doublers, Rectified Differentiator, Precision Rectifier, reverse-bias capacitance. • To measure the minority carrier lifetime in a semiconductor photodiode. • Transistor and Op-Amp characteristics - amplification, Op-Amp as summer, Integrator, Differentiator. • Zener Diode - rectification, DC power supply. • Characterization of basic and cascade current mirror circuits (with BJT and MOSFET). • Design of single-stage and differential amplifiers. • 555 Timers - timer and oscillator functions.
Suggested Books	Reference Books: 1. J. Millman, A. Grabel, *Microelectronics*, Tata McGraw-Hill (2017), ISBN: 978-0074637364 2. S. Sedra K. C. Smith: *Microelectronic Circuits,* OUP, (2017), ISBN: 978-0199476299 3. Razavi, *Fundamentals of Microelectronics,* Wiley, (2017) ISBN: 978-8126571352

** This course will be taught by instructors of Department of Astronomy, Astrophysics and Space Engineering

Course code	**AA 256 / PH 256**
Title of the course	**Electronic Devices and Circuits Lab - II**
Course Category	Core
Credit Structure	L - T - P – Credits (0-0-3-1.5)
Name of the Department	Astronomy, Astrophysics and Space Engineering
Pre-requisite, if any	None
Objectives of the course	The students will engage in hands-on digital electronics experiments.
Course Outcomes	● Acquire hand-on experience in digital electronics. ● Implement digital components to solve electronics problems.
Course Content	A representative list of experiments will be performed by students: • Introduction to Logic Circuits: To gain familiarity with digital integrated circuits by setting up simple logic circuits. • Combinational Logic Circuits: Use of TTL adder, multiplexer and decoder. • Sequential building blocks • Digital to Analog and Analog to Digital Conversion • Sampling and Reconstruction of Continuous-Time Signals and Interpolation with Decimation. • Implementation of a (4 X 4) multiplier using registers and a down counter. • MOSFET inverting amplifiers and first-order circuits • Introduction to VHDL and FPGA • Electronics Project
Suggested Books	Reference Books 1. Wakerly, *Digital Design: Principles And Practices*, Pearson India; 4th edition (2008) ISBN: 978-9332508125 2. S. Salivahanan, S. Arivazhagan, *Digital circuits and design*, Oxford University Press; Fifth edition, (2018), ISBN: 978-0199488681 3. S. Franco, *Design with Operational Amplifiers and Analog Integrated Circuits*, McGraw-Hill, 4th edition, (2017), ISBN: 978-9352601943 4. J. Millman, A. *Grabel, Microelectronics*, McGraw Hill Education, 2nd edition, (2017), ISBN: 978-0074637364

** This course will be taught by instructors of Department of Astronomy, Astrophysics and Space Engineering

Course code	**AA 301**
Title of the course	**High Energy Astronomy**
Credit Structure	L - T - P - Credits 2-1-0-3
Name of the Concerned Department	Astronomy
Pre-requisite, if any	NA
Scope of the course	Providing an introduction to astrophysical processes.
Course Syllabus	**Radiative Processes:** Covariant formulation of classical electrodynamics. Radiation from accelerated charges. Cyclotron and synchrotron radiation. Bremsstrahlung. Thomson and Compton scattering. Plasma effects. Atomic and molecular spectra. Transition rates and selection rules. Opacity calculations. Line formation in stellar atmospheres. Fundamentals of radiative transfer, synchrotron radiation, Compton scattering, spectral line transfer, gas heating and cooling and topics in atomic and molecular spectroscopy are discussed within the framework of astrophysical sources and problems. Applications will include the interstellar and intergalactic media, neutron stars, active galactic nuclei, and exoplanetary systems. **Application to Accretion Physics:** Accretion in binary systems, effect on binary evolution_ Accretion physics: The origin of viscosity, time-scales and stability, thin and thick disks,_ Nova and Type Ia SN, ultra compact binaries_ Supermassive Black Holes (BHs): Introduction to Active Galactic Nuclei (AGN), radio sources, quasars, synchrotron radiation, minimum energy, supermassive BHs_ Jets: relativistic effects, radiation. **Photon interaction with matter:** detection of high energy radiation (X-ray and Gamma ray)_ Gamma Ray Bursts: Simple models
Suggested Books	1. H Bradt, ***Astrophysics Porcesses***, Cambridge University Press, : Cambridge, UK : 2008 : 978-1107677241 2. G B Rybicki, A P Lightman, ***Radiative Processes in Astrophysics,*** Wiley, Weinheim, Germany, 1985, 978-0471827597 3. G Ghisellini, ***Radiative Processes in High Energy Astrophysics***, Springer, Heidelberg, Germany, 2013, 978-3319006116 4. Shapiro, S. and Teukolsky, S. ***Black Holes***, White Dwarfs and Neutron Stars, 1983 5. J. Frank, A king & D. Raine: ***Accretion Power in Astrophysics***, 2002 6. Fulvio Melia: ***High Energy Astrophysics***, 2009 7. J. Krolik: Active Galactic Nuclei, 199 8. W.H.G. Lewin, & M. Van del Klis (eds), ***Compact Stellar X-***

	ray Sources, 2006 9. M S Longair, ***High Energy Astrophysics,*** Cambridge University Press, Cambridge, UK, 2011, 978-0521756181

Course code	**AA 301N**
Title of the course	High Energy Astrophysics and Transient Sky
Course Category	Departmental Elective
Credit Structure	L - T - P - Credits 2-1-0-3
Name of Dept.	Astronomy, Astrophysics and Space Engineering
Prerequisite, if any	None
Scope of the course	Concepts related to radiative transfer, high energy astrophysics, compact objects, accretion, and transient phenomena
Course Outcomes	The students will be introduced to the different astrophysical transient sources and their impact on current astrophysics.
Course Syllabus	● **Radiation Mechanisms:** Covariant formulation of classical electrodynamics. Radiation from accelerated charges. Cyclotron and synchrotron radiation. Bremsstrahlung. Thomson and Compton scattering. Plasma effects. Atomic and molecular spectra. Transition rates and selection rules. Opacity calculations. Line formation in stellar atmospheres. Review of radiative transfer, Applications to ISM. ● **Applications of Accretion Physics:** Spherical accretion, Accretion in binary systems, effect on binary evolution, The origin of viscosity, time-scales and stability, thin and thick disks, Roche Lobe Geometry ● **Neutron stars, pulsars, stellar black holes**: Microquasars, X-ray Binaries, Jets, Superluminal motions and beaming, Comparison to radio galaxies and AGN. ● **Transients:** Nova and Supernova, Gamma Ray Bursts, Gravitational Waves, Binary mergers, Fast radio bursts.
Suggested Books	**Textbooks:** 1. F. Melia, High Energy Astrophysics, Princeton University Press, US, 2009, ISBN: 978-0691140292 2. S. Shapiro and S. Teukolsky, Black Holes, White Dwarfs and Neutron Stars, Wiley, Weinheim, Germany, 1983, ISBN: 978-0471873167 **Reference books:** 3. J. Frank, A. King & D. Raine, Accretion Power in Astrophysics,

	Cambridge University Press, UK, 2002, ISBN: 978-0521629577 4. M. S. Longair, High Energy Astrophysics, Cambridge University Press, Cambridge, UK, 2011, ISBN: 978-0521756181 5. G. B. Rybicki and A. P. Lightman, Radiative Processes in Astrophysics, Wiley, Weinheim, Germany, 1985, ISBN: 978-0471827597

Course Code	**AA 303**
Title of the course	**IoT for Space Applications**
Credit Structure	L – T – P – Credits 2 – 1 – 0 – 3
Prerequisite if any	None
Name of Department	Astronomy, Astrophysics and Space Engineering
Scope of the course	Enabling students to implement IoT in Space Applications
Course Syllabus	1. Introduction to IoT in Space: Applications of IoT in space –communications between satellite and ground, sensors and sensor control in space, onboard data storage and analysis on a satellite, onboard signal processing for space applications, IoT framework for Space Applications 2. Space Communications: Protocols, receiving signals from satellites using a Software Defined Radio (SDR), Detecting satellites, Downlink from and Uplink to satellites with a receiver-transmitter 3. Onboard data analysis: Using a low-power device for frontend analysis of data for communications, transmitter-receiver in radio, Using an energy-efficient sensor controller in space 4. Using an array of sensors through IoT for space/atmospheric measurements: Rain Gauge, Humidity, Temperature and Pressure sensing Onboard analysis of sensor data, Simultaneous IoT control of sensors and transmitter-receiver, Sensor array / Transceiver as space communications and sensing solution 5. IoT Framework towards Space Applications Analysis: Analysis of data from Smart Space Sensors - Classification and Regression; Linear, Polynomial Regression; Logistic Regression; Clustering; Optimization techniques; Machine Learning techniques for onboard Space IoT data analysis
Suggested Books	1. Collins, Getz, Pu and Wyglinski; ***Software Defined Radio for Engineers***; Artech House; 2018; ISBN: 978-1-63081-457-1 2. Stewart, Barlee, Atkinson and Crockett; ***Software Defined Radio using MATLAB, Simulink and the RTL-SDR***; Strathclyde Academia Publishers; 2015; ISBN: 978-0992978723 3. S. Monk; ***Programming the Raspberry Pi***, Second Edition: Getting Started with Python; McGraw-Hill Education; 2015; ISBN: 978-1259587405 4. A. Maheshwari; ***Big Data***; McGraw-Hill; 2019; ISBN: 978-9353167950 5. S. Monk; ***Programming Arduino: Getting Started with Sketches***; McGraw-Hill; 2016; ISBN: 978-1259641633 6. J. Grus; ***Data Science From Scratch***: First Principles with Python; O'Reilly; 2019; ISBN: 978-9352138326

Course code	**AA 304**
Title of the course	Radiowave Propagation and Antenna Applications
Course Category	Core
Credit Structure	L - T - P - Credits 2-0-2-3
Name of the Concerned Department	Astronomy, astrophysics and Space Engineering
Pre-requisite, if any	Basics of electromagnetics
Scope of the course (Objectives)	To facilitate students in applying the principles of wave propagation in various mediums, including space, and utilizing fundamental equations to analyze and model the performance of diverse antenna systems relevant to communication and astronomical observations.
Course Outcomes	● Students will learn to use modern tools to design antenna-based applications. ● They will solve problems related to radio wave propagation.
Course Content	**Module 1: Antenna Basics:** Basic Antenna parameters, Polarization, Friis Transmission Equation; Linear wire antennas, Loop antennas, Filled aperture antennas, Planar, Antenna arrays and active antenna receivers; Reflector antennas, Far and Near radiation field zones. Self and Mutual Impedances, Low radio frequency antenna design, Baluns **Module 2: Antenna Applications and Measurements:** Antenna Temperature, Remote Sensing, Radar Cross Section, Radar Range Equation, Antenna Measurements - anechoic chambers, antenna test ranges. Radio astronomy applications - grating lobes and interferometres. Radio antenna designs for space. **Module 3: Radio Wave Propagation:** Different Modes of Wave Propagation, Ground wave propagation: transition between surface and space wave, Space wave propagation: through neutral and ionized medium; Atmospheric absorption, fading, path loss calculations; Ionospheric refraction, reflection, absorption; Multi-Hop propagation, EM wave propagations: VLF, VHF, UHF, EHF and sub-millimetre waves. **Lab Components: Representative experiments** ● Experiment on radio wave propagation - inverse square law ● Study radio wave reflection at different radio frequencies ● Study radio wave transmission at different radio frequencies ● Study radio wave polarization ● Measurement of radiation pattern of antenna at different frequencies

	● Measurement of gain characteristics of antenna at different frequencies ● Study response of different antennas - dipole, helical and reflector type.
Suggested Books	**Text book:** 1. J. D. Kraus, R. J. Marhefka, and A. S. Khan, Antennas and Wave Propagation, McGraw- Hill, USA, 2017, ISBN- 978-9352606184 **Reference Books:** 2. C. A. Balanis, Antenna Theory Analysis and Design, Fourth Edition, 2016, John Wiley & Sons, Inc., Hoboken, New Jersey, ISBN 978-11186420601 3. T. L. Wilson, K. Rohlfs, S. Huttenmeister, Tools of Radio Astronomy, Fifth Edition, 2016, Springer, ISBN: 978-3319908199 4. R. Dean Straw, The ARRL Antenna Book, 21st Edition, The National Association for Amateur Radio, 225 Main Street, Newington, USA, ISBN: 978-0872599876 5. Karl F. Warnick Brigham, R. Maaskant, Ma. V. Ivashina, D. B. Davidson, B. D. Jeffs Brigham, Phased Arrays For Radio Astronomy, Remote Sensing, And Satellite Communications, 2018, Cambridge University Press, ISBN 978-1108423922

Course code	**AA 306**
Title of the course	Signals and Communications in Space
Course Category	Core
Credit Structure	L - T - P - Credits 2-0-2-3
Name of the Department	Astronomy, astrophysics and Space Engineering
Pre-requisite, if any	Basics of Digital and Analog Electronics
Scope of the course (Objectives)	Students will learn to apply Signal Analysis and Communications principles effectively in the context of Space Applications.
Course Outcomes	● The students will learn the basics of space communication. ● They will develop skills required to design space-communication equipment. ● Students will learn using modern tools for designing space based applications.
Course Content	**Module 1: Signals and Estimation:** Continuous and Discrete-time signal and Sequence, Discrete-time Stochastic Processes and Characterization, Autocorrelation, Power Spectral Density and Time Series Models, Optimal linear estimation, Least mean square (LMS) **Module 2: Signal transformation and analysis:** Discrete Fourier Transform: convolution, correlation, leakage, windowing, signal filtering basics of low-pass/high-pass/band-pass. **Module 3: Communications:** Shannon-Hartley Theorem, Modulation techniques (amplitude/frequency/phase), Digital modulation techniques (ASK, PSK, FSK, QPSK), Multiplexing techniques (TDMA, FDMA, CDMA), Frequency Hopping Signal Spreading **Module 4: Satellite Communication Fundamentals**: Transmission theory, Link equation, Propagation effects, Receiver noise, Gain to noise ratio, Link budget, Interference, Satellite tracking, satellite data communication services. **Lab Components:** 1. Amplitude Modulation and Demodulation Experiment 2. Frequency Modulation and Demodulation Experiment 3. Amplitude Shift Keying (ASK) Modulation and Demodulation

	Experiment 4. Frequency Shift Keying (FSK) Modulation and Demodulation Experiment 5. Satellite Communication Trainer Experiments.
Suggested Books	**Textbook** 1. A. Oppenheim, A. Willsky. Signals and Systems. 2nd ed. Prentice Hall, 1996. ISBN: 978-0138147570. 2. B. R. Elbert, Introduction to Satellite Communication, Artech House, 2008, ISBN: 978-1596932104 **Reference book** 3. R. F. Ziemer, W. H. Tranter and D. R. Fannin, Signals and Systems - Continuous and Discrete, 4th Edn. Prentice Hall, 1998. ISBN: 978-0134964560 4. A. V. Oppenheim, Schafer, Discrete Time Signal Processing, Prentice Hall, 1989. ISBN: 978-9332535039

Course Code	**AA 307**
Title of the Course	Space Systems - Orbits and Payloads
Credit Structure	L-T- P-Credits 2-1-0-3
Name of Dept.	AASE
Prerequisite, if any	None.
Scope of the course (Objectives)	Introduction to the essentials of orbital mechanics, the mechanism to inject a satellite into orbits.
Course Outcomes	● Students will learn about orbital dynamics and orbital systems. ● They will develop understanding about the complexities of launching a spacecraft, injecting a satellite in stable orbit, maneuvering and the effect of the orbital motion on the onboard payload.
Course Syllabus	**Module 1: Orbital Mechanics:** Celestial Mechanics, Coordinate Systems and Orbit Geometry, Orbit Determination, Planetary Orbits, Satellite Orbit, Types, Stability and Transfer orbits. **Module 2: Orbit Dynamics:** Physical principles, the two-body problem, moment of momentum, central force field, time and Keplerian orbits, perturbed orbits: non-Keplerian orbits, perturbing forces and their influence, non-homogeneity and oblateness of the earth, perturbations caused by the Sun and the Moon, solar radiation pressure; perturbed geostationary orbit using non-singular orbital elements. Orbital maneuvers: single and multiple impulse orbit adjustments, geostationary orbits, inclination (north-south) and eccentricity (east-west) station-keeping. **Module 3: Orbital systems:** Launch window considerations – launch azimuth, sun-orbit orientation, earth eclipsing of an orbit, sun synchronous orbit; Time of event occurrence. Launch of geostationary satellites. The launch window. Transfer orbits, The apogee maneuver, Drift orbit, Station-keeping. High-e orbits; Frozen orbits **Module 4: Space Systems - Payload:** Introduction to spacecrafts, payloads and missions, Spacecraft environment influence on design; Spacecraft structures - configuration, launch loads, Satellite Subsystems, Thermal Control Systems, Small Satellite - engineering and applications.

Suggested Books	**Text Books:** 1. Sidi, M. J., Spacecraft Dynamics and Control, Cambridge University Press, 2000, ISBN : 0521787807 2. Maini, A. K., and Agrawal, V., Satellite Technology: Principles and Applications, Wiley 2007, ISBN : 1118636473 **Reference Books:** 3. Montenbruck, O., and Gill, E., Satellite Orbits: Models, Methods, Applications, Springer 2000, ISBN: 978-364263547-2 4. Fortescue, Peter W.; Stark, John; Swinerd, Graham, Spacecraft systems engineering, Wiley, Hoboken, N.J., 2011, ISBN: 978-0470750124 5. J. B. Marion and S. T. Thornton, Classical Dynamics of Particles and Systems (4th edition), Holt Rinehart & Winston, 1995, ISBN: 978-0030973023

Course code	**AA 308**
Title of the course	Guidance, Navigation and Control
Course Category	Core Course
Credit Structure	L - T - P - Credits 2-1-0-3
Name of the Concerned Department	Astronomy, Astrophysics and Space Engineering
Pre-requisite, if any	None
Scope of the course (Objectives)	Basic concepts of guidance, navigation and control of a spacecraft
Course Outcomes	● Students will develop basic understanding of spacecraft attitude dynamics and control. ● They will learn about the basics of navigation systems. ● They will understand the principles of orbit determination.
Course Content	**Module 1: Spacecraft Attitude Dynamics and Control:** Attitude parameterization (Quaternions, Euler angles), attitude determination, Euler equation, Attitude sensors, Rigid body Dynamics, Spin stabilization of a Spacecraft, Liquid-Motion Effects, Active Nutation Control, momentum bias satellites; attitude control with reaction wheels, thrusters and magnets; passive and active nutation damping, Three-Axis Stabilization, Disturbance Torques, Three-Axis Reaction Wheel System, single and double gimbal control moment gyros, Effects of Structural Flexibility, Re-entry Flight Mechanics, **Module 2: Navigation Systems: Inertial navigation systems:** Inertial Navigation, Doppler Radar, Star Tracker, Satellite Navigation and Augmentation systems: GNSS: GPS, NavIC and GAGAN, Differential Global Positioning System (DGPS), Biases and Errors in observations and corrections; Precision pointing and tracking controllers for tracking landmarks, and other satellites for crosslink communication. **Module 3: Satellite Orbit Determination and Estimation:** Ground-based satellite observations: Satellite ground tracks, local tangent coordinate system; Preliminary orbit determination from two position vectors and three sets of angles. Time and Reference Systems: Celestial, terrestrial and geodetic reference systems. Linearization: Two-body state transition matrix, Orbit determination and parameter estimation: weighted least

	square, Kalman filtering, satellite-to-satellite tracking techniques,
Suggested Books	**Text book:** 1. Markley, F.,L., Fundamentals of Spacecraft Attitude Determination and Control, Springer – 2014, ISBN: 9781493908011 2. Sidi, M.J., Spacecraft Dynamics and Control, Cambridge University Press, 2000, ISBN: 0521787807 **Reference Book:** 3. Tapley, B. D., Schutz, B.E., and Born, G.H., Statistical Orbit Determination, Elsevier, 2004, ISBN: 0126836302 4. Hughes, P.C., Spacecraft Attitude Dynamics, Dover Publications Inc., 2004, ISBN: 0486439259

Course code	**AA 309**
Title of the course	Space Instrument Design
Course Category	Departmental Core
Credit Structure	L - T - P - Credits 2-1-0-3
Name of Dept.	Astronomy, Astrophysics and Space Engineering
Prerequisite, if any	None
Scope of the course	Basics of detection theory and techniques used in astronomy and space sciences
Course Outcomes	● The students will learn to apply statistics to space detector systems ● They will be introduced to basic detector types and characteristics and will learn to evaluate the fundamental design requirements of detectors for space observations
Course Syllabus	● Fundamentals of detection: photoelectric effect, Compton effect, Pair production, Ionization, nuclear interactions, dipole. ● Basic characteristics of detectors, Amplitude and quadratic detectors, Time/image/aperture domain, frequency domain, noise, sensitivity, resolution, detectors response, background and their sources, efficiency, dead time, anti-coincidence detectors, ● Devices: Semiconductors, ionization detectors, scintillators, gravitational wave detectors, nuclear detectors, antenna. Sensors: Pressure sensors, gyroscope, accelerometer, strain gauges, displacement sensors. ● Design of detectors, challenges for detection in space observations. ● Applications: Imaging, Spectrometer, gratings, photon counting and timing, particle detectors, coincidence detectors, EM wave detection, interferometry, correlators.
Suggested Books	**Textbook:** 1. Astronomy Methods, H. Bradt, Cambridge University Press, 2003, ISBN: 978-0511802188 2. Principles of Space Instrument Design, Bowels, J.A., Patrik TJ, Godall CV, 9th edition, New York Cambridge University Press, 2006, ISBN: 978-0521025942 3. Radiation Detection and Measurement, Glenn E Knoll, John Wiley & Sons, Inc., New York, ISBN: 978-0471073385

	Reference books: 4. Introduction to Engineering Experimentation, Anthony Wheeler and Ahmed Ganji, Pearson, 3rd Edition, 2010, ISBN: 978-0131742765 5. S M Sze Semiconductor based sensors, Wiley-Interscience, ISBN: 978-0471546092 6. Radiation and Detectors, Lucio Cerrito, Springer, 2017, ISBN: 978-3319531816 7. Techniques for Nuclear and Particle Physics Experiments, Leo, Springer; 2nd rev. ed. 1994, ISBN: 978-3540572800

Course code	**AA 310**
Title of the course	Satellite Imaging
Course Category	Departmental Elective
Credit Structure	L - T - P - Credits 2-0-2-3
Name of the Department	Astronomy, Astrophysics and Space Engineering
Prerequisite, if any	None
Scope of the course (Objectives)	It provides an introduction to processing the digital airborne and satellite images in geospatial and astronomical domains
Course Outcome	● Students will learn how to handle, manipulate digital images acquired over different terrains. ● Get hands-on experience in using modern software tools to process digital images ● Analyze digital images and draw inferences useful in everyday applications
Course Content	● **Introduction to Digital Images:** Review of image acquisition systems, Digital numbers in images, conversion to physical quantities-radiance and reflectance, atmospheric correction ● **Geometric Correction**: Internal and External Geometric Errors, corrections, Image-to-Map rectification, geo-referencing ● **Image enhancement**- Filtering, Principal Component Analysis (PCA), indices and their applications. ● **Thematic Information Extraction** - Classification and accuracy assessment, **Practicals:** ● Collection of airborne images using drones ● Python for image data handling, types of raster images and their metadata ● Georeferencing an airborne image ● Image manipulations - filtering, enhancement, segmentation ● Classification with multispectral and hyperspectral images

Suggested Books	**Text books:** 1. J. R. Jensen, "Introductory Digital Image Processing - A Remote Sensing Perspective", Fourth Edition, Pearson, Delhi, India, 2022, ISBN: 978-9352864355 **Reference books:** 2. J.A. Richards. and X. Jia, Remote Sensing Digital Image Analysis, 4th ed., Springer, Berlin, 2006, ISBN:978-3540251286

Course code	**AA 311**
Title of the course	Statistical Physics and Radiative Transfer
Course Category	Core
Credit Structure	L - T - P - Credits 2-1-0-3
Name of the Department	Astronomy, Astrophysics and Space Engineering
Prerequisite, if any	None
Scope of the course (Objectives)	• This course will introduce the concepts of statistical physics and develop fundamentals required to formulate statistical pictures of processes that occur in astrophysical and space environments. • Additionally, this course will provide an overview of interaction of matter with photons and the subsequent transfer of radiation.
Course Outcomes	• Students will develop an understanding of different statistics which govern various physical systems. • Implement the radiative transfer equation in Atmospheric, Astrophysical and Space systems.
Course Content	**Module 1: Statistical Mechanics - Classical** One-dimensional random walk problem, probability distributions: Binomial, Gaussian and Poisson, Phase space, most probable distribution, Maxwell-Boltzmann Statistics with applications, derivation of average velocity, RMS velocity, Microcanonical ensemble, Canonical ensemble, Grand Canonical ensemble, Equipartition and Virial theorems Gibbs paradox; **Module 2 : Quantum Statistics** Bose-Einstein Statistics, application to black body radiation, distribution law of energy, Planck's radiation formula and Stefan's law. Fermi – Dirac statics, Ideal Fermi Gas, paramagnetism, Fermi energy, Applications in Compact objects **Module 3: Radiative Processes** Specific Intensity and Its Moments, Optical Depth and the Fundamental Equation for Radiative Transfer, Einstein Coefficients and Bound-Bound Absorption, Cross-sections, Thermal Radiation and Local Thermodynamic Equilibrium, Spectral Line Formation and Broadening Mechanisms.

Suggested Books	**Text Books:** 1. Huang; Kerson: Introduction to Statistical Physics: CRC Press; 1st edition (20 September 2001): ISBN: 978-0748409426 2. George B. Rybicki, Alan P. Lightman: Radiative Processes in Astrophysics: 2004 WILEY-VCH Verlag GmbH & Co. KGaA: ISBN: 978-3527618170 3. Annamaneni Peraiah: An Introduction to Radiative Transfer Methods and Applications in Astrophysics:Cambridge University Press:June 2012: ISBN:978-1139164474 **Reference Books:** 4. R.K. Pathria, Paul Beale: Statistical Mechanics: Elsevier; 4th edition (1 January 2021): ISBN : 978-9351073970

Course code	**AA 312**
Title of the course	Atmospheric Physics and Remote Sensing
Course Category	Core
Credit Structure	L - T - P - Credits 2-0-2-3
Name of the Concerned Department	Astronomy, Astrophysics and Space Engineering
Pre-requisite, if any	None
Scope of the course (Objectives)	It provides an overview of the atmosphere, background physics and the processes. It also provides an idea about the remote sensing techniques and how the atmosphere can affect the measurements.
Course Outcomes	● Students will critically analyze the problems in atmospheric physics. ● They will apply the techniques of remote sensing for environmental monitoring and sustainability.
Course Content	**Module I: Physics of Atmosphere** ● Atmospheric Evolution: Solar radiation, present atmospheric constituents, evolution of the atmosphere, formation of ozone; ● Lower Atmosphere: Variation of temperature, density, ionization and pressure with altitude, hydrostatic equation, greenhouse effect, lapse rate and stability criteria, cloud formation and precipitation, weather and climate; **Module II: Dynamics of Atmosphere** ● Atmospheric Dynamics: Apparent forces, effective gravity, Coriolis force, pressure gradient force, gradient wind, thermal wind, continuity equation, Atmospheric instabilities; ● Upper Atmosphere: Chapman theory of layer production, formation of ionosphere, photochemistry of the thermosphere, electron, ion and neutral temperatures in the thermosphere, airglow and auroral emissions, Planetary ionospheres. **Module III: Remote Sensing** ● Definition: components of RS, History and development of remote sensing systems, Advantage and disadvantages, EM Spectrum, Blackbody radiation, Active and passive sources. ● Platforms and Sensors: Satellite orbits and sensor characteristics, Concept of resolutions in remote sensing, Types of sensors, Applications of remote sensing **Experiments/Data Analysis:**

	● In-situ atmospheric measurement techniques and interpretation ● Upper and lower atmospheric remote sensing and analysis ● RS data collection using sensors and camera ● RS data sources and types (Bhuvan, ASF DAAC etc) ● RS data visualization and interpretation (ENVI, ERDAS IMAGINE, ArcGIS)
Suggested Books	**Text books** 1. Houghton J T, “The physics of atmosphere”, Cambridge University Press, Cambridge, 2014, ISBN: 978-0521011228. 2. Holton J R, Hakim G J “Introduction to dynamic meteorology”, Elsevier Science, San Diego, 2012, ISBN: 9780123848666 3. Thomas Lillesand, Ralph W. Kiefer, Jonathan Chipman, “Remote Sensing and Image Interpretation”, 7th Edition, Wiley, 2015, ISBN: 978-1118343289 **Reference Book: (restrict to 3 books)** 4. Zdunkowski W and Bott A, “Dynamics of the Atmosphere”, Cambridge University Press, Cambridge, 2003, Online ISBN 978-0511805462. 5. Vallace J and Hobbs P V, “Atmospheric Science'', Academic Press, 2nd ed. 2006, ISBN: 978-0127329512. 6. Rees M H, “Physics & Chemistry of Upper Atmosphere”, Cambridge Univ. Press, Cambridge, 2011, ISBN: 978-0511573118 7. Ratcliffe J A, “An Introduction to the Ionosphere & Magnetosphere”, Cambridge Univ. Press, Cambridge, 1972, ISBN: 978-0521083416. 8. Smithson P, “Fundamentals of Physical Environment”, Routledge, London, 4th ed, 2008, ISBN: 978-0415232944 9. Rogers R R, “ A short course in Cloud Physics”, Butterworth-Heinemann, Oxford UK, 1996, ISBN: 978-0750632157

Course code	**AA 313**
Title of the course	Fluid Dynamics
Course Category	Core
Credit Structure	L - T - P - Credits 2-1-0-3
Name of the Concerned Department	Astronomy, Astrophysics and Space Engineering
Pre-requisite, if any	None
Scope of the course (Objectives)	The primary objective of this course is to introduce the concept of fluid element and its properties both in static and dynamical state.
Course Outcomes	● Define the fluid element concept and its relevance in space engineering systems. ● Explain kinematic properties and differentiate inviscid and viscous flows for varied flow scenarios.
Course Content	**Fluid Basics, Properties, Statics** Basics: Classification of Fluid Flows; Concept of Control Volume; Properties Of Fluids: Viscosity, Capillary Effect, Surface Tension Pressure Fluid Statics: Pressure measurement devices, Hydrostatics, Fluid Rotation, Vorticity, Circulation, Stream Function **Kinematics and Dynamics** Fluid Kinematics: Lagrangian and Eulerian description, Streamlines, Pathlines, Steady Flows, Bernoulli Equations, Dimensional Analysis of Fluids: Reynolds Number, Froude Number, Mach Number. Ideal Conservation Equations; Navier Stokes Equation, Solution Of Navier Stokes Equation: Couette Flow and Poiseuille Flow, Introduction To Compressible Flows and Shocks.
Suggested Books	**Textbook:** 1. J. M. Cimbala, Yunus A. Cengel : Fluid Mechanics: Fundamentals and Applications,: McGraw-Hill; Fourth edition: ISBN : 978-9353166212 2. F. White: Fluid Mechanics: McGraw-Hill Publishing Co.; ISBN : 978-0071168489 **References:** 3. R.W. Fox, A.T. McDonald, John Mitchell: Introduction to Fluid

	Mechanics: John Wiley International: 10th Edition: January 2020: ISBN: 978-1-119-60376-4 4. D. J. Acheson: Elementary Fluid Dynamics: Clarendon Press; ISBN : 978-0198596790

Course Code	**AA 315**
Title of the course	**Data Analytics and Visualization for Space**
Course category	Core Lab
Credit Structure	L - T - P - Credits 0-1-4-3
Name of the Dept	Astronomy, Astrophysics and Space Engineering
Prerequisite, if any	None
Scope of the course (Objectives)	The students will be introduced to some open-source space science-related data analysis packages and databases. Using these packages, they will learn how to perform data analysis, error analysis, cleaning, calibration, and visualization for space science and engineering applications.
Course Outcome	Students will learn to use various astronomy and space science-specific Python packages for data analysis, error analysis, and visualization.
Course Syllabus	**Module 1: Introduction to space science-specific data analysis tools:** A brief revision of the basic Python; Version controlling with open source packages e.g. Git; Introduction to Astropy; Using Astropy for Quantities and Units for astrophysical calculations; File I/O for file types FITS, HDF4, HDF5 etc; Working with Different Coordinate systems (Celestial, Galactic, etc) – specifying, reading, transformation and plotting; **Module 2: Introduction to Space Science Databases:** Introduction to public space science databases e.g. SIMBAD, Aladin Sky Atlas, VizieR, WISE, Gaia, SDSS, PLANCK etc.; Introduction to ADQL; Accessing these databases using ADQL; Utilizing and cross-matching objects from Multi-wavelength Databases etc.; Virtual Observatory – CLEA; Accessing public databases for remote sensing and atmospheric research. **Module 3: Curve Fitting and Error Analysis:** Linear Regression, Curve Fitting, Optimization, chi-square minimization, Maximum Likelihood Analysis, Sources of error in measurements and propagation; Introduction to Time Series Analysis. **Module 4: Introduction to Image Analysis:** Interactive plotting of multi-dimensional data with open source packages e.g. Paraview and VisIt etc; Plotting images with different projections; Image stretching and normalization; mosaicking; hanning and smoothing - convolution; Fourier analysis of images - aliasing;

	Representative Experiments: ● Use Astropy to transform coordinate systems and write an observation proposal for a target object. ● Verification of H-R diagram. ● Spectral classifications of stars. ● Hubble law verification. ● Transits of Venus and Mercury etc. ● Viewing and manipulating FITS images. ● Computing galactic orbits of stars using public databases stars. ● Spectral line fitting. ● Cube Reprojection. ● Cosmological data analysis using different Fourier statistics. ● Power spectrum analysis of pulsar data.
Suggested Books	**Textbooks:** 1. E. D. Feigelson and G. J. Babu; Modern Statistical Methods for Astronomy; Cambridge University Press; 1st edition; ISBN: 978-0-521-76727-9 2. M. Bonamente, Statistics and Analysis of Scientific Data; Springer; 2nd edition; ISBN: 978-1493965700 **Reference Books:** 3. D. J. Pine, Introduction to Python for Science and Engineering; CRC Press; 1st edition; ISBN: 978-1138583900 4. R. Lupton, Statistics in Theory and Practice; Princeton University Press; 1st edition; ISBN: 978-0691074290

Course Code	**AA 317**
Title of the course	Galaxies and Cosmology
Course category	Departmental Elective
Credit Structure	L - T - P - Credits 2-1-0-3
Name of the Dept	Astronomy, Astrophysics and Space Engineering
Prerequisite, if any	None
Scope of the course	The students will be introduced to the basics of galaxy formation, classification, dynamics and distribution. Further, it will introduce them to the basics of cosmology.
Course Outcome	● The students will learn about the galactic dynamics, classification and formation. ● They will be able to use cosmological principles, and models to understand the observations.
Course Syllabus	**Module 1: The galaxies, their formation, dynamics, classification and distribution** ● Galaxies and their constituents: Our galaxy – stars, gas, dust and dark matter. ● The extragalactic distance scales; Galaxy classification. ● Star formation: Population synthesis; Galaxy spectra; The interstellar medium; The cosmic star formation history. ● Galactic dynamics: orbits in axisymmetric potentials, epicyclic limit; Oort's A & B constants, local differential rotation, collisionless Boltzmann equation, Jean's equations. Black holes; AGNs. Galaxy groups; The Local Group; Galaxy clusters. **Module 2: Cosmology** ● Cosmological principle, Expansion of the universe, cosmological redshift, scale factor, Hubble's law, the content of the universe, FRW metric, comoving coordinates, single and multi-component universe. ● Cosmography: age of the universe, horizons, distance ladder. ● CMBR: characteristics, recombination and decoupling, last scattering surface, thermal history, temperature fluctuations and its anisotropies. ● Large scale structures from linear perturbation, spherical collapse, statistical description of structure, matter power spectrum and halo mass function. ● The high-redshift Universe: Cosmic Dawn; The first stars

	and galaxies.
Suggested Books	**Textbooks:** 1. Schneider, P., Extragalactic Astronomy and Cosmology: An Introduction, Springer 2006. ISBN: 978-3540331742. 2. Ryden, B., Introduction to Cosmology, Cambridge University Press, 2nd edition (November 24, 2016), ISBN: 978-1107154834. **Reference books:** 3. S. Dodelson, Modern Cosmology, Academic Press, 2003, ISBN: 978-0122191412. 4. P. J. E. Peebles , Principles of Physical Cosmology, Princeton University Press, 1993, ISBN: 978-0691019339. 5. H. Mo, F. van den Bosch, S. White, Galaxy Formation and Evolution, Cambridge University Press, 2010. ISBN 978-0521857932. 6. J. Binney, S. Tremane, Galactic Dynamics, Princeton University Press; Second edition (January 27, 2008), ISBN: 978-0691130279.

Course code	**AA 318**
Title of the course	Meteorology and Climate Modelling
Course Category	Departmental Elective
Credit Structure	L - T - P - Credits 2-0-2-3
Name of the Department	Astronomy, Astrophysics and Space Engineering
Pre-requisite, if any	None
Scope of the course (Objectives)	The course introduces the concept of satellite and radar meteorology. It also discusses the theory of weather modeling as well as usage of the WRF model for NWP predictions.
Course Outcomes	● Students will gain knowledge about the measurements of atmospheric parameters. ● They will be able to apply the understanding for environment and sustainability
Course Content	**Module I: Satellite and Radar Meteorology** ● History of satellite and radar meteorology, Meteorological satellite orbits and instrumentation, ● Radiative transfer, Gaseous absorption, Scattering, Solar radiation and surface reflection, Exploration of Satellite data for meteorological applications ● Radar basics, Weather radar, Rainfall estimation and uncertainty, Satellite borne Radar for cloud and precipitation ● Doppler radar, Atmospheric temperature and water vapour profiles, ST and MST radars, Exploration of radar data for meteorological applications **Module 2: Climate Modelling and WRF (Weather Research and Forecasting)** ● Fundamental Forces: Pressure Gradient Force, Centrifugal Force, Gravity Force, Coriolis Force ● Description of the Climate System and Its Components: Atmosphere, Ocean, Cryosphere and Land Surface ● Modelling the Climate System: Hierarchy of Models, Components of a Climate Model, Numerical Resolution of the equations, Model evaluation ● Combining Model Results and Observations: Correction of Model Biases, Data Assimilation **Lab: Simulation and analysis of weather events** ● Simulation of Weather Patterns in WRF model

	● Precipitation monitoring using Micro Rain Radar ● Ground validation of satellite measurements of rainfall ● Doppler Weather Radar data analysis
Suggested Books	**Text books:** 1. K. and V. Harr, "Satellite Meteorology: An Introduction", Academic Press, SanDiego California, 1995, ISBN: 978-0124064300 2. R. M. Rauber, Stephen W. Nesbitt, "Radar Meteorology: A First Course", Wiley & Sons, Hoboken New Jersey, 2018, ISBN: 978-1118432624 3. G. H., Barriat P.Y., Lefebvre W., Loutre M.F. and Zunz V., "Introduction to Climate Dynamics and Climate Modeling", Centre de recherche sur la Terre et le climat Georges Lemaître - UCLouvain, Belgium, 2010, ISBN: 978-1107445833. **Reference books:** 4. T. Vasquez, "Weather Analysis and Forecasting Handbook", Weather Graphics Technology, Garland Texas, April 7 2011, ISBN: 9780983253303. 5. R. Kelkar, "Satellite Meteorology", BS Publications, Hyderabad, 2nd ed , 2017, ISBN: 978-8178001371. 6. R. A. Pielke, "Mesoscale Meteorological Modelling", Elsevier, Amsterdam, 2013, ISBN: 978-0123852373. 7. R.H. James, "An Introduction to Dynamic Meteorology", Elsevier Academic Press, Burlington Massachusetts, 2004, ISBN: 978-0123848666

Course code	**AA 319**
Title of the course	Launch Vehicle and Propulsion Systems
Course category	Departmental Elective
Credit Structure	L - T - P - Credits 2-1-0-3
Name of the Dept	Astronomy, Astrophysics and space engineering
Prerequisite, if any	None
Scope of the course	The course will provide an overview of the spacecraft launch systems and the its propulsion
Course Outcome	● Students will understand launch vehicles and their dynamics ● They will analyze the guidance systems and their operating principles ● They will have hands-on experience with simulation and validation setups
Course Syllabus	**Module-1** ● Launch Vehicles and Missiles: Historical review of Launch Vehicles ● Phases in space flight: orbital and interplanetary flight ● Launch Vehicle structures: Loads and Stages. **Module-2** ● Introduction to Launch vehicle dynamics and navigation: Fundamentals of trajectories, essentials of aerodynamics ● Launch vehicle instruments - Communication, Guidance and Navigation. Role of Ground station, Basics of satellite tracking, Related instrumentation **Module-3** ● Basics of space propulsion-solid and liquid propulsion, electric propulsion ● Space Propulsion Devices ● Qualification of space vehicles: Basics of testing and validation such as vibration testing and hardware in loop simulations
Suggested Books	**Textbooks:** 1. Wiesel, W. E., Spacecraft Dynamics, 3rd ed, McGraw-Hill 2010, ISBN : 978-1452879598 2. Kadam, N. V., Practical Design of Flight Control Systems for Launch Vehicles and Missiles, Allied Publishers, 2009, ISBN: 978-9387997813 3. Edberg, D., and Costa, W., Design of Rockets and Space Launch Vehicles, AIAA Education Series, 2020, ISBN: 978-1624105937 **Reference Books:** 4. Noton, M., Spacecraft Navigation and Guidance, Springer 1998, ISBN: 978-1447115854 5. Jahn, Robert G. *Physics of Electric Propulsion*. Dover Publications,

	2006. ISBN: 978-0486450407.

Course code	**AA 320**
Title of the course	Advanced Space Instrument Design
Course Category	Departmental Elective
Credit Structure	L - T - P - Credits 2-0-2-3
Name of the Department	Astronomy, Astrophysics and Space Engineering
Pre-requisite, if any	Space Instrument Design
Scope of the course (Objectives)	Advanced and specialized applications and techniques related to detectors for astronomy and space sciences
Course Outcomes	● The students will learn principles of detection through a quantitative formalism ● The students will be trained to apply them to various practical detectors and sensors ● The students will acquire hands-on experience with prototype setups for space detectors
Course Content	● **Recap of detection principles and discussion of advanced complexities** ● **X-ray/Gamma ray astronomy detectors:** gaseous ionization detector, photomultipliers, Photon tracker detector, calorimeters, Cherenkov detector, Particle detector, Geiger Avalanche Photodetector, Scintillator, Silicon drift detectors, Geiger Avalanche Photodetector, CCD/CMOS, SiPM, silicon drift detetcor, Avalanche Photodiodes (APDs) ● **Optical/UV/IR astronomy detectors**: photovoltaic devices, infrared arrays, CCD, CMOS, spectrometers, Semiconductor radiation detectors, superconductor–insulator–superconductor tunnel junction (SIS) ● **Radio astronomy detectors:** antenna, dipole, phased array, interferrometer, correlator, bolometers, thermal sensors ● **Other detectors for space science:** Thermal imaging detector, Multi-spectral detector, Hyperspectral detector and their types. ● **Applications:** Detection of low and high energy photons, astroparticle detection, photometry, Astrometry, Spectrometry,

	Polarimetry, auxiliary systems, speckle interferometry, adaptive optics, Gravitational wave detection, applications in space science **Practicals:** 1. Characteristics study of a CCD camera 2. Multispectral camera acquisition patterns and its use in object speed tracking 3. Spectroscopy and imaging with Hyperspectral camera 4. Temperature determination of an artificial star/lamp by photometry 5. Michelson interferometer 6. Study of scintillation detector and its applications
Suggested Books	**Textbooks:** 1. P. Léna, D. Rouan, F. Lebrun, F. Mignard, D. Pelat, Observational Astrophysics, Springer-Verlag Berlin Heidelberg, 2012, ISBN: 978-3-662-51733-8 2. W. R. Leo, Techniques for Nuclear and Particle Physics Experiments, Springer; 2nd rev. ed. 1994, ISBN: 978-3540572800 **Reference books:** 1. L. Cerrito, Radiation and Detectors, Springer, 2017, ISBN: 978-3-319-53181-6 2. G. E. Knoll, Radiation Detection and Measurement, John Wiley & Sons, Inc., New York, ISBN: 978-0471073385 3. C.R. Kitchin, Astrophysical Techniques, 6 ed., CRC Press, 2013, ISBN: 978-1-4665-1115-6 4. I. S. McLean, Electronic Imaging in Astronomy, Springer, 2008, ISBN: 978-3540765820

Course code	**AA 322**
Title of the course	Computational Electromagnetics
Course Category	Departmental Elective
Credit Structure	L - T - P - Credits 2-1-0-3
Name of Dept.	Astronomy, Astrophysics and Space Engineering
Prerequisite, if any	None
Scope of the course	The course will provide the basics of finite element methods and integral methods for solving Maxwell equations, electrostatics and electrodynamics. This course will also provide the basics of FDTD simulations for electromagnetics.
Course Outcome	● Students will learn the basics of finite element methods and integral methods to solve Maxwell's equations. ● They will learn the basics of FDTD techniques to solve electromagnetic problems.
Course Syllabus	**Module 1:** Review of EM Theory: vector calculus, electromagnetic fields, and an overview of computational electromagnetics. Analytical Methods: Separation of Variables, Series expansion. **Module 2:** Practical Applications in Transmission Lines, Waveguides, Antennas. **Module 3:** Method of Moments: Differential Equations, Integral Equations, Green's Function, MoM solution of electromagnetic problems, Applications in Radiation Problems and EM absorption in human body. **Module 4:** Finite Element Method: Solution of Laplace's Equation, Solution of the wave equation, High-order elements, Applications of FEM to electromagnetic problems, and Applications in Microstrip Lines. Finite Difference Methods: in PDEs, Finite difference time domain method (FDTD).
Suggested Books	**Text Books:** 1. M. N.O. Sadiku, "Computational Electromagnetics with Matlab", 2019, CRC Press, ISBN: 978-1138558151 2. Peterson, A.F, Ray, S.L. and Mittra, R., "Computational Methods for Electromagnetics",. Wiley-IEEE Press, 1997, ISBN: 978-0780311221 **Reference Books:** 3. Atef Z. Elsherben, Veysel Demir, "The Finite-Difference Time-Domain Method For Electromagnetics with MATLAB Simulations ", SciTech Publishing, 2016, ISBN: 1613531753; ISBN: 978-1613531754

	4. A. Taflove, S. C. Hagness,Computational Electrodynamics: The Finite-Difference Time-Domain Method, Artech House, 3 rd edition (2005), ISBN : 978-1580538320.

Course code	**AA 324**
Title of the course	Space Informatics
Course category	Departmental Elective
Credit Structure	L - T - P - Credits 2-1-0-3
Name of the Dept	Astronomy, Astrophysics and Space Engineering
Prerequisite, if any	None
Scope of the course	The students will be introduced to advanced machine learning algorithms for analysis of BIG astronomical data
Course Outcome	Students will be able to apply advanced statistical and machine learning methods on BIG astronomical DATA and draw quantifiable inferences.
Course Syllabus	**Module 1: Overview of the data science aspect of Astronomy and Space Science**: Virtual Observatory to Space Informatics and beyond; Big Data and Real Time Astronomy. **Module 2: Challenges with Time Domain Data from Space**: Regression - linear & logistic, Use of Neural Networks, Deep Learning algorithms. Case Studies with GRB light curve data, Sunspot data, forecasting with atmospheric datasets. **Module 3: Challenges in analysing 2D or 3D Space Data:** Comparative performances of difference algorithms: Support Vector Machine, Random Forest, Convolutional Neural Network, Deep Learning etc. Case Studies with identification and classification of galaxy clusters, star-forming objects, classification of stars using spectroscopic and photometric data, forecasting of storms, cyclones, etc. **Module 4: Challenges in analysing large volume of 4D Data in Radio and other wavelengths:** Applications of Probabilistic Neural Network, Bayesian Neural Network, Generative Adversarial Network, Gaussian Process Regression etc in detection of ionized and neutral regions in noisy and foreground contaminated radio observations. Case studies for

	Cosmological Inferences. **Module 5: Challenges of Big Data from upcoming telescopes:** Thirty Meter Telescope (TMT), Laser Interferometer Gravitational-Wave Observatory (LIGO) and Square Kilometre Array (SKA): introduction to Science Data Processing.
Suggested Books	**Textbook:** 1. Ž. Ivezić, A. J. Connolly, J. T. VanderPlas, and Alexander Gray, "Statistics, Data Mining and Machine Learning in Astronomy", 2014, Princeton Univ. Press, ISBN: 978-0691151687 2. M. Brescia and S. G. Djorgovski, "Astroinformatics (IAU S325) - Proceedings", Cambridge University Press, 2017, ISBN: 978-110716995X **Reference Books:** 3. David J. C. MacKay Information Theory, Inference and Learning Algorithms. Cambridge University Press. ISBN: 978-0521670517

Course code	**AA 374**
Title of the course	Computational Fluids and Structures
Course Category	Departmental Elective
Credit Structure	L - T - P - Credits 2-1-0-3
Name of Dept.	Astronomy, Astrophysics and Space Engineering
Prerequisite, if any	Basics of Fluid Dynamics
Scope of the course	The course will provide a formal introduction to matrix methods for structural analysis and computational tools for fluid dynamics along with techniques for grid generation and meshing. This course is aimed to train students to adopt computational tools for industrial flows by providing hands-on sessions on open-source platforms and commercial software.
Course Outcome	● Students will be able to evaluate the requirements of grid generation for Computational Fluid Dynamics and Structural applications. ● Apply the meshing tools for grid generation. ● Develop algorithms to evolve steady flows.
Course Syllabus	**Module 1 - Matrix Methods in Structural Analysis:** Planar and space trusses, Stress-strain relationship, Matrix method of analysis for space trusses, Fundamental concepts of Finite element method. **Module 2 - Basics of Grid Generation :** Fundamentals of discretization, Mesh Generation Methods. Hands-on exercises using software. **Module 3 - Computational Fluids:** Introduction to Computational Fluid Dynamics, Classification of partial differential equations, Fundamental Concepts of Finite Volume method, numerical schemes of diffusion problems and convection-diffusion problems, Pressure-Velocity coupling in steady flows, Hands-on exercises using Python and other softwares
Suggested Books	**Text books:** 1. T.H.G.Megson, Aircraft structures for engineering students, Elsevier 2012, Fifth edition; ISBN: 978-0080969053 2. T.J. Chung, Computational Fluid Dynamics; Cambridge University Press; 2010; ISBN : 978-0511606205 3. H. Versteeg, An Introduction to Computational Fluid Dynamics: The Finite Volume Method : Pearson; 2nd edition; ISBN : 978-8131720486 **Reference books:** 4. J. D. Anderson Jr, Computational Fluid Dynamics, McGraw Hill Book Company July 2017; ISBN : 978-1259025969 5. Liesikin; A Computational Differential Geometry Approach to

	Grid Generation; Springer Berlin, Heidelberg; 24 August 2006, ISBN 13 : 978-3540342359

Course Code	**AA 401 / AA 601 (From AY 2025-26)**
Title of the Course	**Astrophysical Fluids and Plasma**
Course Category	Core
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Concerned Department	Department of Astronomy, Astrophysics and Space Engineering
Pre–requisite, if any	None
Course Objective	This course aims to introduce students to the principles of astrophysical fluids with a focus on applying them to astrophysical sources. The course also further extends to introduce the concepts of plasma that are prevalent in astrophysical environments.
Course outcomes	Students will learn about the fundamentals of fluids and plasma typically seen in Astrophysical environments and also will be able to quantify their behaviour using several case studies.
Course Syllabus	**Module 1: Introducing Fluids:** Fluids as continuous medium, Streamlines and Bernoulli's equation with applications; Convective derivative. Equations of fluid dynamics (mass, momentum and entropy) for ideal fluids : Hydrodynamics from kinetic Boltzmann equation; Hydrostatic Equilibrium : Collapse of Molecular clouds, Kelvin's circulation theorem, Vorticity - Free and Forced Vortex. **Module 2: Non-ideal fluids:** Navier-Stokes (NS) equation and vorticity equation; vortex shedding; Boundary layers. Reynolds number: Transition to turbulence. Application in Accretion Disk Dynamics. **Module 3: Waves and Instability**: Linear Perturbation in Hydrodynamics : Sound waves; Supersonic flow: De-laval nozzle, shock properties, Rankine-Hugoniot jump conditions, isothermal shocks. Applications in Solar Wind, Sedov-Taylor blast wave, Supernova shocks. Rayleigh-Taylor & Kelvin-Helmholtz instabilities. Conductive and convective transport of heat equation. Schwarzschild Criteria and plane-parallel atmospheres in stars. **Module 4: Astrophysical Plasmas:** Particle orbit theory and adiabatic invariants. Debye shielding and length in a plasma in thermal equilibrium. Cold plasma oscillations. MHD - Induction equation, magnetic diffusion, flux freezing. Alfven, fast and slow waves. Methods to probe plasmas.

Suggested Books	**Textbooks:** 1. Ray Choudhari, A., The Physics of Fluids and Plasmas: An Introduction for Astrophysicists, Cambridge University Press, 1998, ISBN: 9780521555432 2. Clarke, C. J. and Carswell, R.F., Principles of Astrophysical Fluid Dynamics, Cambridge University Press, 2014, ISBN: 9781107666917 **Reference books:** 3. Landau, L. D. and Lifshitz, E. M, Fluid Mechanics Volume 6 (Course of Theoretical Physics), Butterworth-Heinemann; 2nd edition, 1987, ISBN: 9780750627672 4. Shu, F., The Physics of Astrophysics: Gas Dynamics: 2 (A Series of Books in Astronomy), University Science Books, 1994, ISBN: 9781891389672 5. Hans Goedbloed, J.P. and Poedts, S., Principles of Magnetohydrodynamics: With Applications to Laboratory and Astrophysical Plasmas, Cambridge University Press, 2004, ISBN: 9780521626071

Course code	**AA 403 / AA 603**
Title of the course	**Space Engineering Systems**
Credit Structure	L - T - P - Credits 2-0-2-3
Name of the Department	Astronomy, Astrophysics and Space Engineering
Prerequisite, if any	None
Scope of the course	Students will familiarize with the key features of communication electronics, the space environment and how it affects electronics, how to design for the thermal environment in space, the effects of the radiation environment on electronics and what types of electronics might be used in the future.
Course Syllabus	**Qualifying systems for space:** Total ionizing dose (TID), Single event effects (SEEs), Radiation shielding, Mitigation of SEEs (hardware, software) Electronic, Electrical and Electromechanical - Definition, Screening/testing and reliability, Radiation Hardness Assurance Materials, Thermal modelling of spacecraft, Temperature requirements Thermal cycling and testing, Standards (ECSS), Radiation design margins **Spacecraft-Space Environment Interactions:** Radiation environments, Thermal environment, Launch environment, other environments (space debris, atomic oxygen, low energy plasma, spacecraft charging, arcing), Radiation effects **Payload Design:** Payload requirements, Payload components and their characteristics - antennas, Low Noise Amplifiers (LNAs), microwave filters, channel and power amplifiers, power combiners, FPGAs for space, Onboard processing, Payload Configuration management **Satellite Systems Engineering:** System development methodology, Analog and Digital processor architecture, Transponder / Transceiver gain control, linearity, multipexing, filters, wideband systems Uplink and Downlink power control, beam pointing, modulation and demodulation, individual and block upconverters and downconverters **Space Operations:** Tracking, Telemetry and Command (TT&C), Satellite Network architectures, In-orbit monitors and testing, Earth Stations - Classes and Design, Terrestrial Network Interfaces - Plesiochronous Digital Hierarchy (PDH) and Synchronous Digital Hierarchy (SDH). The future - Use of COTs, Miniaturisation

Suggested Books	1. Cruise, A. M., **Principles of space instrument design**, Cambridge University Press, Cambridge, 2006, ISBN: 052102594x, 0521451647 2. **An Introduction to Space Instrumentation**, Edited by K. Oyama and C. Z. Cheng, Terrapub, 2003, ISBN 978-4-88704-160-8 3. Elbert, B.R., **Introduction to Satellite Communication**, Artech House, 2008, ISBN: 978-1-59693-210-4 4. Fortescue, Peter W.; Stark, John; Swinerd, Graham, **Spacecraft systems engineering,** Wiley, Hoboken, N.J., 2011, ISBN: 047075012X, 9780470750124

Course Code	**AA 404 / AA 604**
Title of the Course	**Spacecraft and Payload Attitude Dynamics, Control and Pointing**
Credit Structure	L-T- P-C 2-1-0-3
Name of the Department / Centre	Astronomy, Astrophysics and Space Engineering
Pre-requisites (if any)	
Course Syllabus	Three-axis Spacecraft Attitude dynamics; quaternions and other representations. Multi-body spacecraft with articulated antennas, sensors, and solar arrays. Design of spacecraft controllers with reaction wheels, magnets, single- and double-gimbaled control moment gyros as actuators. Three-axis large angle manoeuvres. Payload controllers for acquiring, precision pointing, and high-accuracy tracking of landmarks and moving objects of interests for remote sensing and communication. Pointing error budget. Image motion compensation to remove image blur. Solar array controllers for tracking the Sun using micro-stepper motors. Flexible spacecraft dynamics and control. Dynamics and control of spinning spacecraft: stability, precession and nutation. Control of spin-axis attitude during ΔV-firing for changing orbits; active nutation control; dual-spin stabilization; Rhumb-line manoeuvre. Dynamics and precision pointing of bias momentum spacecraft: stability; control using two momentum wheels and a reaction wheel. Reaction jet attitude control and nonlinear controllers: pulse-width-pulse-frequency modulators; minimum-fuel-minimum-time single-axis and three-axis control. Control of spacecraft with liquid propellants: sloshing-control interaction.
Suggested Books	1.Hughes, P.C., Spacecraft Attitude Dynamics, John Wiley,1986, ISBN: 9780486439259 2.Sidi, M.J., Spacecraft Dynamics and Control, Cambridge University Press, 1997, ISBN: 9780521787802 3.Agrawal, B., Design of Geosynchronous Spacecraft, Prentice Hall, 1986, ISBN: 9780132001144 4.Bryson, A.E., Control of Spacecraft and Aircraft, Princeton University Press, 1994, ISBN: 9780691087825 5.Wie, B., Space Vehicle Dynamics and Control, AIAA Education Series, 1998, ISBN: 9781563479533 6.Markley, F.,L., Fundamentals of Spacecraft Attitude Determination and Control, Springer – 2014, ISBN: 9781493908011 7. Smit, G. N., Spacecraft and Payload Pointing, AIAA 2015, ISBN: 9781884989230

Course code	AA 405/ AA 605
Title of the course	**Detectors and sensors for space observations**
Credit Structure	L - T - P – Credits 2-0-2-3
Name of the Concerned Department	Astronomy, Astrophysics and Space Engineering
Prerequisite, if any	None
Scope of the course	Observational techniques and detectors for space telescopes and missions, design, working principle, and operation.
Course Syllabus	**Spacecraft as Observation platforms:** space environment, space effects from Earth's surface, in situ measurements, Noise and Uncertainty. **Attitude and Position sensing, Communication**: sun sensors, earth sensors, star sensors, magnetometers, attitude control, Communication **Detectors for E and B field Measurements in Space:** Spacecraft charging in low Earth orbit and geostationary orbit. Radiation damage effects. Background effects and their minimization. Plasma influx, penetrating radiation, sunlight. Direction of Arrival. **Detectors for Imaging:** Various interaction of radiations with matter for detection purposes, Solid State Detectors, MKIDs (Microwave Kinetic Inductance Detectors), Super Conducting Tunnel Junction Devices (STJs), CCD, SSD (Silicon Strips Detectors), and G-APD, Radiometry, cooling, photoconductors, bolometers, coherent detectors, polarimeters, magnetometers, and electric field sensors, readout, amplifiers, current collectors, future X-ray interferometers **Non-Imaging Detectors:** Laser Interferometer, Incoherent detectors, photodiodes, photoemission detectors, photomultipliers, Channeltrons, microchannel plates, ionization detectors, scintillator detectors, calorimeters **Detectors for Spectroscopy:** Gratings, γ-ray, X-ray, α-particle, neutron, Mossbauer spectrometers. Visible light & dust particle spectroscopic measurement techniques. **In-situ plasma measurements:** Requirements; Energy and mass analysis for charged species from 1eV to 1MeV. Neutral mass spectrometers. **Techniques and Applications of Hyperspectral Sensor:** Elements of Hyperspectral Sensing, Imaging System Design, Hyperspectral Target Detection **Augmented Systems:** Focusing optics, collimators, CAMs **Applications**: Various applications in Astronomy, Atmospheric measurements, Planetary analysis, Radar, Space sciences

Suggested Books	1. K. Oyama and C. Z. Cheng, ***An Introduction to Space Instrumentation***, Terrapub, 2013, ISBN: 978-4-88704-160-8 2. H. Bradt, ***Astronomy Methods***, Cambridge University Press, 2003, ISBN: 9780511802188 3. P. Léna, D. Rouan, F. Lebrun, F. Mignard, D. Pelat, ***Observational Astrophysics***, Springer-Verlag, Berlin, Heidelberg, 2012, ISBN: 978-3-662-51733-8 4. 4. C.R. Kitchin, ***Astrophysical Techniques***, 6 ed., CRC Press, 2013, ISBN: 978-1-4665-1115-6

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Course code	**AA 407/ AA 607**
Title of the course	**Remote sensing for Atmospheric and Space Sciences**
Credit Structure	L - T - P - Credits 2-0-2-3
Name of the Concerned Department	Astronomy, astrophysics and space engineering
Prerequisite, if any	None
Scope of the course	Fundamental concepts of system, sensors and information retrieval techniques for remote sensing system and its application in space and atmospheric science
Course Syllabus	**History and development** of remote sensing technique, Recent trends and state-of-art in optical and microwave remote sensing techniques **Sources of energy in remote sensing**: Active and Passive Radiation, Electromagnetic Radiation -Reflectance, Transmission, Absorption, Thermal Emissions, Wave interaction with atmosphere, Atmospheric windows, Spectral reflectance; **Remote sensing data acquisition platforms**: Characteristics of different types of remote sensing platforms; Sensors for active and passive remote sensing- spatial, spectral and radiometric resolution; **Remote sensing data:** Characteristics, Atmospheric, radiometric and geometric Corrections, Basic principles of visual interpretation of passive remote sensing images, Image processing and feature identification, Case studies with Landsat and Sentinel satellite images for classification of objects. **Microwave Remote Sensing**: Advantages and challenges, Passive microwave remote sensors and operation principle, Basic concepts of radar remote sensing- resolution, range and angular measurements, microwave scattering, imaging radar technique and data interpretation. **Radar remote sensing systems** –Clear air and ST/MST radar for atmospheric studies, Synthetic Aperture Radar for planetary studies, Doppler weather radar, Coherent and incoherent radar for ionospheric studies **Applications and Satellite Missions:** Atmospheric and planetary remote sensing satellites -TRMM/GPM, Cloudsat, NISAR, CALIPSO, MODIS, Megha-tropique, GOES. Applications in Weather monitoring (Temperature, Humidity, Wind, Cloud, Rain, lightning), Ionosphere and change detection, Data exploration using BHUVAN, Google Earth map

	and NASA Earth Explorer.
Suggested Books	1. W.G. Rees : Physical Principles Of Remote Sensing : Cambridge University Press : Cambridge : 2001 : 978-0521181167 2. J.R Jensen : Remote Sensing Of Environment : An Earth Resource Perspective : Pearson Education India : New Delhi : 2013 : 978-9332518940 3. F. T. Ulaby, R. K. Moore, A. K. fung : Microwave Remote Sensing, Active and Passive : Vol I, Fundamentals and Radiometry : Artech House Publishers : _ : 1981 : 978-0890061909 4. F. T. Ulaby, R. K. Moore, A. K. fung : Microwave Remote Sensing, Active and Passive : Vol II, Radar Remote Sensing and Surface Scattering : Artech House Publishers : _ : 1986 : 978-0201107609

Course code	**AA 408N / 608N**
Title of the course	Astrostatistics/Astronomical Data Analysis
Course category	Departmental Elective
Credit Structure	L - T - P - Credits 2-1-0-3
Name of the Dept	Astronomy, Astrophysics and Space Engineering
Prerequisite, if any	None
Scope of the course	The students will be introduced to advanced Bayesian inference methods for analysis of astronomical data.
Course Outcome	Students will be able to draw inferences from BIG astronomical DATA using multi-dimensional models via complex sampling algorithms and Bayesian statistics.
Course Syllabus	**Fundamentals of measurements:** Noise theory, Time Series Analysis. Spectral Fitting. Sources of error. Nyquist Sampling and its applications. Data compression. **Applied Inference & Entropic Information Theory:** Stochastic Processes, Markov Chains, Monte Carlo methods: descriptions and applications to Astronomy, Entropy in Signal Processing and Information Theory. **Parameter Estimation and Model Selection:** Maximum Likelihood and Clustering, Model fitting: Chi Square minimization, Least Squares. Confidence Intervals, Random Inference, Decision Theory. Bayesian Inference and Sampling: The Metropolis-Hastings algorithm, Hamiltonian Monte Carlo, Gibbs Sampling, Nested Sampling etc. Application of above methods to astronomical examples.
Suggested Books	**Textbooks:** 1. J.G. Babu, E.D. Feigelson, Modern Statistical Methods for Astronomy, Chapman & Hall (2012), ISBN: 978-0521767279 **Reference books:** 2. J.M. Hilbe, Astrostatistical Challenges for the New Astronomy, Springer (2012), ISBN: 978-1489993618 3. A. K. Chattopadhyay, T. Chattopadhyay, “Statistics Method for Astronomical Data Analysis”, 2014, Springer, ISBN: 978-1493915064

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	4. D.S. Sivia & J. Skilling, Data Analysis: A Bayesian Tutorial, Oxford University Press. ISBN: 978-0198568322

Course code	**AA 609**
Title of the course	Computational Methods in Astronomy and Space Sciences
Credit Structure	L - T - P -credits 2-1-0 3
Name of the Concerned Discipline	Astronomy, Astrophysics and Space Engineering
Prerequisite, if any	None
Scope of the course	This course is aimed at introducing the various methods that are employed in astrophysical codes. Further, application of these methods in studying processes in the arena of space science will be given as case studies. The versatile nature of techniques taught as part of this course will help students gain insight into modelling tools used in relevant industries.
Course Syllabus	**Fundamentals:** Review of numerical integration, differentiation, root finding, ODE solvers, Hyperbolic, Parabolic and Elliptic Equations and their applications in Astrophysics and Space. Errors in Numerical computations **Grid Based Computations:** Upwind scheme for Advection Equation and Burger Equation, Godunov scheme for Hydrodynamic Equations, Reconstruction schemes and Reimann Solvers; Shock capturing schemes, Adaptive and Multi-grid methods, Divergence Cleaning Methods, Computational Algorithms for Relativistic flows, Time Stepping schemes. **Source Term Modelling:** Radiative Transfer: Ray Tracing Approach, Flux limited diffusion, Operator Splitting (Strang Splitting Method), Turbulent Forcing **Particle Based Methods:** Algorithms for N-body simulations, Smoothed Particle Hydrodynamics, Kernel Smoothing methods, Algorithms for Particle in Cell Method (PIC) **Applications:** Solver for Advection and Burger Equation, Astrophysical Fluid Instabilities, Time evolution of the Trojan satellites of Jupiter using N-body simulations, Setting Cosmological Initial condition, N-body simulation for a pressureless fluid, Modelling 1D spherical collapse under self-gravity, spherically symmetric blast wave for supernova remnants, 1D radiative transfer modelling for Ionization.
Suggested Books	1. G R Liu and M B Liu P. Bodenheimer, G. P. Laughlin, M. Rozyczka, T. Plewa, H. W Yorke, ***Numerical Methods in Astrophysics: An Introduction*** CRC Press; 1st edition (13 December 2006) ISBN-13 : 978-0750308830 2. E. F. Toro, ***Riemann Solvers and Numerical Methods for Fluid Dynamics: A Practical Introduction*** Publisher : Springer; Softcover reprint of hardcover 3rd ed. 2009 edition (14 October 2010) ISBN-13 : 978-3642064388

	3. C.K. Birdsall, A.B Langdon ***Plasma Physics via Computer Simulation*** Publisher : CRC Press; 1st edition (1 October 2004) ISBN-13 : 978-0750310253 4. G. R. Liu and M. B. Liu, ***Smoothed Particle Hydrodynamics: A Meshfree Particle Method*** Publisher, World Scientific Publishing Co Pte Ltd; Illustrated edition (12 February 2003) ISBN-13 : 978-9812384560

Course code	**AA 410/ AA 610**
Title of the course	**Spatial Informatics**
Credit Structure	L - T - P – Credits 2-0-2-3
Name of the Discipline	Astronomy, Astrophysics and Space Engineering
Prerequisite, if any	None
Scope of the course	This course introduces the fundamental concepts of Geographic Information Science (GIS), geospatial data processing and spatial statistics. The course would also lab-based tutorials on spatial data handling and processing using open-source tools/software.
Course Syllabus	GIS, spatial data concepts, map reference systems. Spatial data - sources, models, structures, analysis, and interpolation. Terrain modeling, visualization, data quality, spatial decision support systems, Open GIS standards, GIS applications and advances Spatial Statistics; Basic Concepts of Statistics; Variogram; Semi-Variogram; Fitting Variogram Models, Validation; Applications of Variograms; Interpolation using Spatial Models; Spatial Prediction and Kriging – Ordinary Kriging, Multivariate Kriging, Vornoi diagrams; Analysis of Space-Time Geostatistical Data; Application of Spatial Statistics in Remote Sensing. **Practicals:** Spatial statistics using Python/Matlab, Geospatial data processing and manipulation using open source (*QGIS*) tools and Python libraries (*GDAL, GeoPandas, Shapely)*. Scalable analytics and geospatial data handling using Python libraries (*DASK and XArray*). Introduction to Google Earth Engine and its applications.
Suggested Books	**Text books:** *1.* K. Chang**,** **Introduction to Geographic Information Systems**, Fourth edition (Indian edition), McGraw Hill Education (2017). ISBN-13: 978-0070658981 2. P.A. Burrough and R. A. McDonnell, **Principles of Geographical Information Systems**, Oxford University Press (2006). ISBN-13: 978-0199228621 **Reference books:** 1. O. Schabenberger, & C.A. Gotway, **An introduction to applied geostatistics**. Oxford university press. (2017). ISBN: 9781315275086

	2. N. Cressie, (1993). **Statistics for Spatial Data** (Revised Ed.). John Wiley & Sons, Inc. Chiles, J. P. and Delfiner, P. (1999). ISBN-13: 9780471002550 3. C.P. Lo, and Yeung, Albert K.W., **Concepts and Techniques of Geographic Information Systems**, Prentice Hall (2002). ISBN-13 : 978-0131495029 4. I. H. Sarah, Cornelius and S. Carver, **An Introduction to Geographical Information Systems**. 3rd Edition, Pearson Education. New Delhi (2006). ISBN-13 : 978-027372259

Course code	**AA 411 / AA 611**
Title of the course	**Advanced Optics**
Course Category	Core
Credit Structure	L - T - P - Credits 2-0-2-3
Name of the Concerned Department	Astronomy, Astrophysics and Space Engineering
Pre-requisite, if any	None
Scope of the course (Objectives)	Theoretical and technical concepts behind optical systems
Course Outcomes	This course will help students develop skills in the design/development of solutions and real-life optics related problem analysis. This course will further give students engineering knowledge related to optical and laser systems.
Course Content	1. Geometrical Optics & Ray Tracing : Optical system design, raytracing, spot-size diagram and MTF. Optical aberrations, tolerancing and optical design optimisation. 2. Wave Optics : Concepts of wavefront and phase, complex representation of electromagnetic wave, image formation and spatial resolution, optical path and spatial coherence, monochromaticity and temporal coherence. Interference and diffraction, Fourier Optics. concept of spatial filtering, amplitude and phase filters in spatial frequency domain, image processing. Shack-Hartman wave-front sensor, Zernike decomposition, wavefront correction, deformable optics. 3. Polarization : Stokes parameter, birefringence, Faraday rotation, Jones matrix, Berry phase and Panchratan sphere 4. Laser Interferometry : Two beam (Michelson) and multi-beam (Fabry-Perot), interferometers, Fizeau and white light interferometry, principles of phase shifting techniques and phase un-wrapping. Standard Quantum

	Limits (SQL) of interferometers and sub-SQL measurements. Scanning white light interferometer (SWLI), Doppler velocimetry and Velocity Interferometer System for Any Reflector (VISAR). Stellar interferrometry, Synthetic aperture optical telescope 5. Optical systems : Applications, Waveguides, Holographic systems etc., adaptive optics Typical list of experiments: • Using Michelson's interferometer determine the wavelength of an unknown source. • White light interferometry with Michelson's interferometer. • Using Michelson's interferometer determine the thickness of a thin glass plate or a thin film. • Use a Fabry-Perot interferometer to study Zeeman effect. • Verify Malus law. • Wavefront sensor
Suggested Books	**Textbook:** 1. Ajoy Ghatak, 'Optics', McGraw Hill, India, 2020, 978-9390113590 **Reference books:** 1. Eugene Hecht, 'Optics', Pearson, 2017, 978-0133977226 2. R. S. Longhurst, 'Geometrical and Physical Optics', Orient Blackswan, 1986, 9788125016236 3. Ajoy Ghatak, K Thyagarajan, "Introduction to FiberOptics", Cambridge University Press, 1998, 978-0521571203 4. Born and Wolf, 'Principles of Optics', Cambridge University Press, 1999, 978-0521642224

Course code	**AA 412/ AA 612**
Title of the course	**Microwave Remote Sensing**
Credit Structure	L - T - P – Credits 2-1-0-3
Name of the Discipline	Astronomy, Astrophysics and Space Engineering
Prerequisite, if any	None
Scope of the course	This course introduces the advanced topics in microwave remote sensing for Earth Observation and space sciences. The course is aimed at training students to utilize the microwave and Synthetic Aperture Radar data for various applications including ecosystems, solid earth, disaster mapping, agriculture and planetary remote sensing.
Course Syllabus	Introduction to active and passive microwave remote sensing. Advanced active and passive systems. Doppler Weather radar (Clear air / precipitation), scatterometer, altimeter- Principle and operations Synthetic Aperture Radar (SAR) data processing and image classification, SAR Interferometry - raw data processing, registration, coherence, phase unwrapping, geo-coding Differential SAR interferometry, permanent scatterer interferometry, Polarimetric SAR Interferometry. Radar polarimetry - measurement of the backscattering matrix, polarimetric scattering vectors, covariance matrix, scattering mechanism interpretation Active microwave data for Digital Elevation Model (DEM) generation, change mapping in geo-sciences, passive microwave data for global soil moisture, snow cover mapping, global temperature monitoring, disaster mapping using SAR data, case studies
Suggested Books	**Text Books:** 1. I.H. Woodhouse, (2015). **Introduction to Microwave Remote Sensing** (1st ed.). CRC Press. DOI: 10.1201/9781315272573. ISBN-13: 9780415271233 2. F. T. Ulaby, R. K. Moore, and A. K. Fung, **Microwave Remote Sensing: Active and Passive,** *Vol 1.* Artech House, 1981. ISBN-13: 978-0890061909 Reference books:

	3. J. R. Jensen, **Remote Sensing of the Environment: An earth resource perspective**, Second edition, January 2013, Pearson Education India. ISBN-13: 9789332518940 4. J. C. Curlander and R. N. McDonough, **Synthetic Aperture Radar: Systems and Signal Processing**, April 1992. Wiley. ISBN-13: 9780471857709 5. F.M. Henderson, A.J. Lewis, **Manual of Remote Sensing - Principles and Applications of Imaging Radar**, Volume 2, Third Edition, 1998. ISBN-13: 978-0471294061 6. J.S. Lee, and E. Pottier, **Polarimetric Radar Imaging: From Basics to Applications**, CRC Press; 2nd Edition, 2020. ISBN-13: 978-1466585393

Course Code	**AA 413/AA 613**
Title of the course	**Electrodynamics and Radiative Processes**
Course Category	Core
Credit Structure	L – T – P – Credits 2 – 1 – 0 – 3
Name of the Concerned Department	Department of Astronomy, Astrophysics and Space Engineering
Pre-requisite, if any	None
Course Objective	Students will learn about electrostatics, magnetostatics, electrodynamics and their applications in radiative processes.
Course Outcomes	By the end of this course, students will be able to understand and apply the fundamental principles of classical electrodynamics, including Maxwell's equations, electromagnetic wave propagation, and radiation from moving charges. They will gain insight into key radiative processes such as synchrotron radiation, bremsstrahlung, and Compton scattering, etc., and will be equipped to analyse the physical mechanisms behind astrophysical radiation sources.
Course Syllabus	**Module 1: Brief review of Electromagnetism:** Green's Function, Gauss Law, Laplace's equation, Poisson's equation, electrostatics with conductors, capacitors, dielectrics, Biot-Savart's law, Ampere's law, Lorentz force. Faradays' law, Lenz's law, self and mutual inductance, energy in a magnetic field. **Module 2: Electrodynamics:** Maxwell's equations, displacement current, electromagnetic waves, plane wave solutions of Maxwell's equations. Maxwell's equations in conducting media, Poynting's vector, wave propagation through a boundary, reflection, refraction, absorption and skin-depth. General boundary value problems using special functions. Wave-guides, resonant cavities, cylindrical waveguides and optical fibers, potentials and fields, radiating systems, multipole fields and radiation, scattering and diffraction, relativistic electrodynamics, Lorentz transformations, 4-vectors, 4-momentum, mass-energy equivalence, relativistic covariance of Maxwell's equations, radiation from accelerated charges, communication and radar. **Module 3: Radiative Processes:** Radiative transfer, Thermal Radiation, The Einstein Coefficients, Scattering Effects; Random Walks, optical depth, Free-free emission, Scattering from dust, Scattering of Light: Thomson Scattering, Rayleigh Scattering, Compton Scattering, Synchrotron radiation, Inverse Compton scattering, Cherenkov Radiation

Suggested Books	**Textbooks:** 1. Jackson J. D., Classical Electrodynamics (3rd edition), John - Wiley & Sons, 1998, ISBN: 978-8126510948 2. Griffiths D. J., Introduction to Electrodynamics (3rd edition), Prentice Hall, 1989, ISBN: 978-9332550445 3. Rybicki, G. B., Lightman, A. P., Radiative Processes in Astrophysics, WILEY-VCH Verlag GmbH & Co. KGaA, 2004, ISBN: 978-0471827597 **Reference books:** 4. Feynman, R. P., The Feynman Lectures on Physics, Pearson, 2012, ISBN: 978-9332580954 5. Greiner, W., Classical Electrodynamics, Springer International Edition, 1998, ISBN: 978-0387947990 6. Reitz, J. R., Milford, F. J., and Christy, R. W., Foundations of Electromagnetic Theory (4th edition), Pearson, 2008, ISBN: 978-0321581747

Course Code	**AA 415/AA 615**
Title of the Course	**Quantum Mechanics and Spectroscopy**
Course Category	Core
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Department of Astronomy, Astrophysics and Space Engineering
Pre-requisite, if any	None
Course objective	To introduce fundamental concepts in quantum mechanics required for understanding various astrophysical processes
Course Outcomes	Students will learn the foundational concepts of quantum mechanics and apply them to solve problems in astronomy and astrophysics
Course Syllabus	**Module 1: Review of fundamentals of Quantum Mechanics** Wave-particle duality, Uncertainty relation, Stern-Gerlach experiment, Postulates of QM: Wavefunctions, Position, momentum and translation, Operators as observables, Matrix representation, kets, bras, operators, Schrodinger's wave equation, The Schrodinger vs Heisenberg picture solution in 1D: particle in a box and tunneling, the simple harmonic oscillator, the Hydrogen Atom **Module 2: Perturbation Theory and Applications** Time-independent perturbation theory, Hydrogen-like atom: Fine structure and Zeeman effect, Variational methods - WKB approximation, Time evolution and the Schrodinger Equation, time-dependent potentials, time-dependent perturbation theory and Fermi's golden rule, selection rules.

	Module 3: Angular Momentum in Quantum Mechanics spin ½ systems and finite rotations, Rotation and angular momentum commutation relations, Symmetries, Eigenvalues and Eigenstates of angular momentum, addition of angular momenta, spin-orbit coupling, Clebsch-Gordon Coefficient **Module 4: Application to Atomic and Molecular Spectroscopy** Spontaneous and Stimulated emission, transition rate coefficients, absorption cross-section, line shapes and broadening mechanisms, Interstellar radiation field, equation of radiative transfer, absorption lines and curve of growth; The 21-cm hyperfine transition, absorption and emission issues, the spin temperature, spin and kinetic temperature, column densities, electronic, rotational, vibrational, Electric transition levels of molecular Hydrogen: Lyman and Warner bands, conditions in diffuse molecular clouds.
Suggested Books	**Textbooks:** 1. Sakurai, J.J., and Napolitano, J., Modern Quantum Mechanics, Cambridge University Press, 3rd edition, 2020, ISBN: 978-0805382914 2. Shankar, R., Principles of Quantum Mechanics, Springer, 2014, ISBN: 978-0306447907 3. Draine, B.T., Physics of Interstellar and Intergalactic Medium, Princeton University Press, ISBN-10: 0691122148 **Reference books:** 4. Feynman, R., Quantum Mechanics (Feynman lectures of physics vol. 3), Basic Books, 2011, ISBN:978-0465023820 5. Schiff, L.I., Quantum mechanics, McGraw-Hill, 2024, ISBN:978-0070856431 6. Kleesen, R. S., Glover, S. C. O., Physical Processes in the Interstellar Medium, Star Formation in Galaxy Evolution: Connecting Numerical Models to Reality, Saas-Fee Advanced Course, Volume 43, Springer-Verlag Berlin Heidelberg, 2016, ISBN 978-3-662-47889-9.

Course Code	**AA 617/ AA 417**
Title of the Course	**Electronic Devices and Control**
Course Category	Core
Credit Structure	L-T-P-Credits 2-1-0-3
Name of the Concerned Department	Department of Astronomy, Astrophysics and Space Engineering
Pre-requisite, if any	None
Course Objective	To introduce concepts of devices and electronics used in space engineering and astronomy.
Course outcomes	By the end of this course, students will have a foundational understanding of electronic devices, analog and digital circuit design, and microprocessor systems. They will be able to analyze and design amplifier and oscillator circuits, as well as implement basic digital logic and data conversion techniques.
Course Syllabus	**Module 1: Electronics Basics** Semiconductors, Basics of p-n junction devices, transistor, Field Effect Transistor (FET), and Metal Oxide Semiconductor Field Effect Transistor (MOSFET) devices, their characteristics and applications. **Module 2: Amplifiers and oscillators** Operational Amplifiers (OPAMP), Common-Emitter (CE) amplifiers Common-Source (CS) amplifiers, single-stage, multi-stage, feedback amplifiers, circuit analysis, frequency response, Bode plot, multivibrators, and oscillators. **Module 3: Introduction to digital circuits** Basic logic gates, combinational logic circuits, flip flop, Shift register, counters, Digital to Analog converter (DAC) and Analog to Digital converter (ADC) **Module 4: Microprocessors** Basics of microprocessors and microcontrollers, memory and

	input / output devices
Suggested Books	**Textbooks:** 1. Millman, J., Halkias, C., Integrated electronics, Tata McGraw Hill, 1st edition, 2000, ISBN: 978-0074622452 2. Boylestad, R., Nashelsky, L., Electronic Devices and Circuit Theory, Pearson Education Asia, 8th Edition, 2001, ISBN: 978-0130944443 3. Leach, D., Malvino, A., Digital Principles and Applications, Tata McGraw Hill, 8th edition, 2014, ISBN: 978-9339203405

Course Code	**AA 472N / AA 672N**
Title of the Course	**Galactic and Extragalactic Astronomy**
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Department / Centre	Astronomy, Astrophysics and Space Engineering
Pre–requisite, if any	
Scope of the course	
Course Syllabus	**Types of galaxies:** spirals, ellipticals and irregulars, Hubble pitchfork classification. Milkyway components: gas, stars, magnetic field and cosmic rays; satellites; 21 cm line, rotation curve, dark matter; Jeans instability and star formation, Phases and components of interstellar medium; HII regions; Radiative transfer, optical depth, Free-free emission, Scattering from dust, Optical depth, cosmic rays. **Galactic dynamics:** orbits in axisymmetric potentials, epicyclic limit; Oort's A & B constants, local differential rotation, collisionless Boltzmann equation, Jean's equations, Distribution Functions DFs, isothermal models gas in galaxies. **Evolution of Galaxies:** starbursts, galaxy formation models; color-magnitude diagram for galaxies; initial mass function; **Active Galaxies:** observations of active galaxies and quasars, unified model, radio lobes and jets; relativistic apparent superluminal motion, Doppler boosting, blazars; properties of accretion flows around supermassive black holes; M-σ relation for central black holes; Sgr A*, the Galactic center black hole. **Extragalactic distance scales**: classification of clusters, the local group, superclusters, hot intercluster gas, mass estimates from virial theorem applied to galaxies and hydrostatic equilibrium of hot gas; structure on largest scales.
Suggested Books	1. Mo, H.; van den Bosch, F.; White, S, ***Galaxy Formation and Evolution***, Cambridge University Press, 2010. ISBN 978-0-521-85793-2. 2. Schneider, P., ***Extragalactic Astronomy and Cosmology: An Introduction***, Springer 2006. ISBN 978-3-540-33174-2. 3. Phillipps, S., ***The Structure and Evolution of Galaxies***, John Wiley & Sons, Ltd, 2005; ISBN 978-0-470-85507-X. 4. Longir, Malcolm S., ***Galaxy Formation***, Springer, 2008. ISBN 5. James Binney, Scott Tremane, ***Galactic Dynamics***, Princeton University Press; Second edition (January 27, 2008), ISBN: 978-0691130279 6. Sparke, L.; Gallagher, J., ***Galaxies in the Universe: An Introduction*** (2^{nd} Edition), Cambridge University Press, 2007.

Course Code	**AA 672N / AA 472N**
Title of the Course	**Galactic and Extragalactic Astronomy**
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Discipline / Centre	Astronomy, Astrophysics and Space Engineering
Pre–requisite, if any	
Scope of the course	
Course Syllabus	**Types of galaxies:** spirals, ellipticals and irregulars, Hubble pitchfork classification. Milkyway components: gas, stars, magnetic field and cosmic rays; satellites; 21 cm line, rotation curve, dark matter; Jeans instability and star formation, Phases and components of interstellar medium; HII regions; Radiative transfer, optical depth, Free-free emission, Scattering from dust, Optical depth, cosmic rays. **Galactic dynamics:** orbits in axisymmetric potentials, epicyclic limit; Oort's A & B constants, local differential rotation, collisionless Boltzmann equation, Jean's equations, Distribution Functions DFs, isothermal models gas in galaxies. **Evolution of Galaxies:** starbursts, galaxy formation models; color-magnitude diagram for galaxies; initial mass function; **Active Galaxies:** observations of active galaxies and quasars, unified model, radio lobes and jets; relativistic apparent superluminal motion, Doppler boosting, blazars; properties of accretion flows around supermassive black holes; M-σ relation for central black holes; Sgr A*, the Galactic center black hole. **Extragalactic distance scales**: classification of clusters, the local group, superclusters, hot intercluster gas, mass estimates from virial theorem applied to galaxies and hydrostatic equilibrium of hot gas; structure on largest scales.
8. Suggested Books	1. Mo, H.; van den Bosch, F.; White, S, ***Galaxy Formation and Evolution***, Cambridge University Press, 2010. ISBN 978-0-521-85793-2. 2. Schneider, P., ***Extragalactic Astronomy and Cosmology: An Introduction***, Springer 2006. ISBN 978-3-540-33174-2. 3. Phillipps, S., ***The Structure and Evolution of Galaxies***, John Wiley & Sons, Ltd, 2005; ISBN 978-0-470-85507-X. 4. Longir, Malcolm S., ***Galaxy Formation***, Springer, 2008. ISBN 5. James Binney, Scott Tremane, ***Galactic Dynamics***, Princeton University Press; Second edition (January 27, 2008), ISBN: 978-0691130279 6. Sparke, L.; Gallagher, J., ***Galaxies in the Universe: An Introduction*** (2nd Edition), Cambridge University Press, 2007. ISBN 978-0-521-67186-6. 7. Binney, J.; Merrifield, M., ***Galactic Astronomy***, Princeton University Press, 2008. ISBN 978-0-691-02565-7.

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Course Code	**AA 673/AA 473**
Title of the course	**Classical Mechanics and Relativity**
Course Category	Core
Credit Structure	L – T – P – Credits 2 – 1 – 0 – 3
Pre-requisite, if any	None
Name of the Concerned Department	Department of Astronomy, Astrophysics and Space Engineering
Course Objective	To provide concepts of classical mechanics and relativity and their applications in astronomy.
Course outcomes	The students will be acquainted with the pedagogical concepts of classical mechanics and relativity and their applications in various astrophysical problems. Further, they will develop a better understanding of formulation of equations of motions in the classical as well as general relativistic regime.
Course Syllabus	**Module 1: Classical Mechanics** 2-body problem, Central force orbits, orbital parameters, Keplerian orbits - general equation and analysis (circular, elliptical, parabolic, hyperbolic orbits), Anomalies, Kepler's Time equation Lagrangian and Hamiltonian formulation of mechanics, Rigid body motion, restricted 3-body problem, planetary orbits, perturbation theory, perturbed orbits Variational principle, canonical transformation, Hamilton-Jacobi theory & action-angle principle **Module 2: Relativity** Special Relativity and Relativistic dynamics: Michelson-Morley Experiment, Galilean vs. Lorentz transformations, Lorentz invariance, relativistic dynamics General Relativity: The need for General Relativity, Vectors and Tensors, Geodesics, Equations of Geodesic and Geodesic Deviation, Curvature - definition and expression, heuristic approach to a general equation to relate curvature and matter from weak-field limit / Newtonian approach, Einstein Equations **Module 3: Applications of Relativity** Schwarzschild Metric: as the vacuum, static solution to GR equations, Particle orbits in the Schwarzschild metric, Photon orbits in Schwarzchild geometry, Classical Tests of GR - deviation of light rays near a massive object, anomalous perihelion shift of mercury,

	Gravitational redshift, Bending of light, Lensing, gravitational collapse, examples in observations - GR effects in accretion disc, Compact Objects, Astrophysical black holes
Suggested Books	**Textbooks:** 1. Goldstein, H., Classical Mechanics, Pearson Education, 3rd edition, 2011, ISBN: 978-8131758915 2. Schutz, B., A First Course in General Relativity, Cambridge University Press, 2012, ISBN: 978-0521829519 **Reference books:** 3. Fitzpatrick, R., An Introduction to Celestial Mechanics, Cambridge University Press, 2012, ISBN 978-1-107-02381-9 4. Landau, L. D., and Lifschitz, E. M., Mechanics (Course of Theoretical Physics Vol. 1), CBSPD, 2010, ISBN: 978-8181477866 5. Hobson, M.P., Efstathiou, G.P., Lasenby, A.N., General Relativity: An Introduction for Physicists, Cambridge University Press, 2006, ISBN: 978-0521829519 6. Guidry, M., Modern General Relativity, Cambridge University Press, 2019, ISBN: 978-1107197893

Course Code	**AA 674N/ PH 674N/ AA 474N/ IPH 474**
Title of the Course	**Radio Astronomy**
Credit Structure	L-T- P-Credits 2-1-0-3
Name of the Discipline / Centre	Astronomy, Astrophysics and Space Engineering
Pre–requisite, if any	
Scope of the course	This course is intended to introduce the concepts of radio astronomy.
Course Syllabus	**Review of Electromagnetic theory:** Maxwell's equations and basics of electric and magnetic fields, Basic Electromagnetic Theory and radiation of electromagnetic waves, E & B Field Measurable quantities and Polarization. **Radio Universe and Antenna:** The Radio Universe and the Atmospheric Radio Window Brightness, Flux density and antenna fundamentals- I, Effects of the earth's atmosphere, Basics of Radiative Transfer, Antenna fundamentals – II, Antenna Fundamentals–III. **Radio Interferometry:** Introduction, Uses and Advantages, Essential Ingredients of an interferometer. **Radiometers:** from Voltages to Spectra, Galactic Astrophysics and observations. **Non-thermal Radiative Processes:** Astrophysics with 21 cm emission, Synchrotron emission and Polarisation, Faraday Rotation, Inverse
Suggested Books	1. Thomason, Moran, Swenson, ***Interferometry and Synthesis in Radio Astronomy***, Wiley-VCH, 2nd ed., 2001. ISBN:0471254924 2. Wilson and Rohlfs, ***Tools of Radio Astronomy***, Springer, 6th ed. (2014) ISBN: 978-3642399497 3. Kraus, J. D., ***Radio Astronomy***, Cygnus-Quasar Books, 2nd ed. (1986) ISBN: 978-1882484003 4. J. Tinbergen, ***Astronomical Polarimetry***, Cambridge University Press (August 22, 2005), ISBN: 978-0521018586

Course Code	**AA 476/ AA 676**
Title of the Course	**Satellite Based Navigation Systems**
Credit Structure	L-T-P-Credit 2-1-0-3
Name of the Concerned Department	Center of Astronomy
Pre–requisite	None
Scope of the course	This is a contemporary course on GPS-Aided Geostationary Augmented Navigation (GAGAN) and Navigation with Indian Constellation (NAVIC) satellite-based navigation systems of the country and how they will be used for navigation of land, air and space vehicles.
Course Syllabus	Review of satellite-based navigations: GPS (Global Positioning System), IRNSS (Indian Regional Navigation Satellites System). GPS measurements and error sources; Code phase and carrier phase measurements. Ionospheric and tropospheric delay models; receiver clock error model; User range error; Combining code and carrier phase measurements – carrier-aided smoothing. Differential GPS, local-area DGPS, relative positioning; wide-area DGPS; Indian navigation system GAGAN (Geostationary Augmented GPS Aided navigation). Position, velocity and time estimation with pseudorange and pseudorange rate measurements. Precise positioning with carrier phase, with integer ambiguity resolution using code measurements and dual- and three-frequency measurements; LAMBDA method. Differential GPS-aided INS for flight vehicles: Code and carrier double-differencing, triple-differencing. Integration of differenced observables with inertial navigation (INS); GPS-Aided INS for precise aircraft landing. Tightly coupled GPS/INS integration for missiles and launch vehicle navigation. Absolute and relative navigation with GRAPHIC technique for satellites rendezvous. Unmanned Aerial Vehicle (UAV) and Micro Air Vehicle (MAV) navigation. Spinning sounding rocket navigation. Submarine navigation
Suggested Books	1. Brown and Hwang, **Introduction to Random Signals and Applied Kalman Filtering**, John Wiley, 2012, 4th edition, ISBN : 0470609699 2. Rogers, R.M., **Applied Mathematics in Integrated Navigation Systems**, 3rd Ed., AIAA Education Series, 2007, ISBN : 1563479273 3. Farrell, J.L., **GNSS Aided Navigation and Tracking**, American Literary Press, 2007, ISBN : 1561679798 4. Farrell, J. A., **Aided Navigation: GPS with High Rate Sensors**, McGraw Hill, 2008, ISBN : 0071493298 5. Farrell, J.A. and Barth, M., **The Global Positioning System and**

	Inertial Navigation, McGraw-Hill, 1999, ISBN : 007022045X 6. Misra, P., and Enge, P., **GPS – Signals, Measurements and Performance**, Second Edition, Ganga-Jamuna Press, 2006, ISBN: 0970954425

Course code	**AA 478/ AA 678**
Title of the course	**Space Weather**
Credit Structure	L - T - P - Credits 2-1-0-3
Name of the Concerned Department	Astronomy
Pre-requisite, if any	NA
Scope of the course	This course gives an overview of the space weather systems involving the Sun, Heliosphere, Magnetosphere and Ionosphere.
Course Syllabus	1. Introduction – Definition of Space Weather(Sun, Heliosphere, Magnetosphere, Ionosphere) 2. Solar interior, solar magnetism, structure of solar atmosphere 3. Solar Activity: Flares, Coronal Mass Ejections and Solar Energetic Particles, Solar Wind Formation and Acceleration, Heliospheric Structure 4. Magnetospheric structure, magnetospheric storms and substorms , Geomagnetic Storms– Geomagnetic Variations, Geomagnetic Activity Indices, Geomagnetic Storms 5. Ionosphere – Description of the ionospheric layers, anomalous features of the F-region, ionospheric irregularities, short-term and long-term behavior of the ionospheric layers, sporadic-E, ionospheric models. 6. Space WeatherMeasurement Systems–Ionospheric Sounding Systems, Radar, Transionospheric Propagation Systems, GPS. 7. Space Weather Effects on Telecommunication Systems – outline of ionospheric effects, integrated propagation effects – refraction, phase and group path variation, Doppler shift, Faraday rotation, absorption, differential effects – scintillations, mitigation scheme.
Suggested Books	1. Gerd W. Prolss, ***Physics of the Earth_s Space Environment - An Introduction,*** Springer Publications, Heidelberg, 2004, ISBN-10 : 3540214267 2. MG Kivelson and CT Russel, ***Introduction to Space Physics,*** Cambridge Univ. Press, Cambridge, 1995, ISBN-10, 0521457149 3. M.Kallenrode, ***Space Physics : An Introduction to Plasma and Particles in the Heliosphere and Magnetosphere***, Springer Publications, Heidelberg, 2004, ISBN, 3-540-20617-5 4. M. Moldwin, ***An Introduction to Space Weather,*** Cambridge Univ. Press, Cambridge, 2008, ISBN 9780511801365

Course code	**AA 681/ AA 481**
Title of the course	**Introduction to Climate and Climate Change**
Course Category	Core
Credit Structure	L - T - P - Credits 2-0-0-2
Name of the Concerned Department	AASE
Pre-requisite, if any	Nil
Scope of the course (Objectives)	Introduce the concepts and connections among atmosphere, ocean, and climate. The course also gives an idea about the energy transfer, stability and circulations present in the atmosphere and oceans and the causal relationship to climate change.
Course Outcomes	Students will learn about the physics and mathematics of atmosphere and oceans, and their role in climate in order to analyse and model the climate change implications.
Course Content	Module 1: Climate system and its components, Structure of the atmosphere and physical properties, Energy balance, hydrological and carbon cycles, Stability and waves. Module 2: The general circulation of the atmosphere, Ocean and its circulation, Climate and climate variability.
Suggested Books	**Textbook:** • John Marshall and R. Alan Plumb : Atmosphere, Ocean and Climate Dynamics-An Introductory Text : Academic Press : 2007 : 9780125586917 **Reference Book:** • Roger G. Barry and Richard J Chorley : Atmosphere, Weather and Climate : Routledge (9th edition) : 2017 : 9781138294073

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