Gyanmanjari Innovative University

Course Syllabus
Gyanmanjari Institute of Technology
Semester-4 (B.Tech)

Subject: Space Flight Mechanics - BETAE14310

Type of course: Professional Elective Courses

Prerequisite: Engineering Physics, Engineering Mathematics, Engineering Thermodynamics, Fundamentals of Propulsion

Rationale: This syllabus provides students with a foundation in spacecraft dynamics, orbital mechanics, and rocket propulsion. It combines theory with practical applications like trajectory analysis, mission design, and orbit visualization. Students gain analytical skills and hands-on experience to design, analyse, and optimize space missions effectively.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks					Total Marks
CI	T	P	C	Theory Marks		Practical Marks		CA	
				ESE	MSE	V	P	ALA	
3	0	2	4	60	30	10	20	30	150

Legends: CI-Classroom Instructions; T – Tutorial; P - Practical; C – Credit; ESE - End Semester Examination; MSE- Mid Semester Examination; V – Viva; CA - Continuous Assessment; ALA- Active Learning Activities.

Course Content:

Unit No	Course content	Hrs.	% Weightage
1	**Introduction to Space Flight:** History of Space Flight & spacecraft technologies Difference between space and atmosphere, upper atmosphere, Introduction to basic orbital mechanics, types of Orbits (LEO, MEO, Geosynchronous and Geostationary, Polar orbits), Kepler's Laws of planetary motion.	11	25 %
2	**Fundamentals of Rocket Propulsion and Trajectories:** Rocket propulsion fundamentals, rocket dynamics and ascent flight mechanics, chemical rockets, multi-staging and optimization, Electrical rockets. Fundamentals of orbital mechanics (two body motion, circular and escape velocity, motion in elliptic, hyperbolic and parabolic orbits), basic orbital maneuvers. Near earth missions (satellites to GEO/MEO/Geosynchronous, human flight), deep space missions. Space environment (atmosphere, radiation and magnetic fields). Atmospheric entry flight mechanics, entry heating	11	30 %
3	**Atmospheric Re-entry:** Introduction-Steep ballistic re- Entry-Ballistic orbital re-Entry-Skip reentry- "Double- Dip" re-entry - Aero-braking - Lifting body re-entry. Re-entry heat shields, aerothermodynamics, trajectory analysis, guidance systems, and recovery methods.	10	20 %
4	**Fundamentals of Orbital Mechanics, Orbital Maneuvers:** Kepler's laws and Newton's law of gravitation, Basic orbital dynamics principles. Two-body motion-circular, elliptic, hyperbolic, and parabolic Orbits-Basic Orbital Elements-Ground trace. In-Plane orbit changes-Hohmann Transfer-Bi-elliptical Transfer-Plane changes- Combined Maneuvers Propulsion for maneuvers.	13	25 %

Continuous Assessment:

Sr. No	Active Learning Activities	Marks
1	**Model of Rocket Propulsion System:** Students will design a simple rocket model using cardboard or software (like SolidWorks or Tinker CAD) to understand multi-stage rocket structure and propulsion concepts. They will label major parts (fuel tank, nozzle, fins, payload) and upload a short PDF or image report on the GMIU portal.	10
2	**Orbit Visualization Activity:** Students will draw or simulate different satellite orbits (LEO, MEO, GEO, Polar) using graph paper or digital tools. They will label key parameters like altitude and period and upload a neat diagram or PDF summary to the GMIU portal.	10
3	**Case Study on Re-entry Vehicles:** Students will select one spacecraft (e.g., Space X Dragon, Apollo capsule, or Chandrayaan) and study its re-entry process and heat protection system. Prepare a one-page case report with key data and figures and upload it as a PDF on the GMIU portal.	10
	Total	30

Suggested Specification table with Marks (Theory):60

Distribution of Theory Marks (Revised Bloom's Taxonomy)						
Level	**Remembrance (R)**	**Understanding (U)**	**Application (A)**	**Analyze (N)**	**Evaluate (E)**	**Create (C)**
Weightage	35%	40%	25%	-	-	-

Course Outcome:

After learning the course, the students should be able to:	
CO1	Understand the fundamentals of space flight, orbital mechanics, and various types of satellite orbits.
CO2	Analyze rocket propulsion principles, multi-stage dynamics, and ascent flight performance.
CO3	Evaluate re-entry trajectories, heat shielding methods, and atmospheric entry mechanics.
CO4	Apply orbital maneuvering techniques such as Hohmann and bi-elliptical transfers to space mission design.

List of Practical:

Sr. No	Descriptions	Unit No	Hrs.
1	**Two-Body Orbit Propagation:** To analyse two-body orbital motion and compare analytical and numerical propagation methods.	1	4
2	**Study of Orbital Elements and Ground Track:** To understand the basic orbital parameters and plot the ground track of a satellite using simulation tools such as MATLAB or STK.	1	4
3	**Hohmann Transfer Simulation:** To design and simulate a Hohmann transfer between two circular orbits and calculate the required ΔV and transfer time.	1	2
4	**Plane Change and Combined Maneuvers:** To study the effect of orbital plane changes and combined maneuvers on total ΔV requirements.	2	4
5	**Single-Stage Rocket Ascent Simulation:** To simulate the ascent trajectory of a single-stage rocket and determine variations of altitude, velocity, and acceleration with time.	2	4
6	**Multistage Rocket Performance:** To analyze multistage rocket systems and determine the optimum staging configuration for maximum payload efficiency.	2	2

7	**Ballistic Re-entry Heating Estimation:** To estimate re-entry heating and temperature profiles for a ballistic trajectory using standard heat transfer relations.	3	2
8	**Orbital Decay Due to Atmospheric Drag:** To study the effect of atmospheric drag on satellite orbit decay and estimate its operational lifetime.	3	4
9	**Spacecraft Attitude Control Simulation:** To simulate spacecraft attitude control using reaction control thrusters or reaction wheels and observe stabilization response.	4	2
10	**Space Mission Design Case Study (LEO to GEO):** To design a complete mission profile from Low Earth Orbit (LEO) to Geostationary Orbit (GEO), including propulsion selection, transfer design, and mission timeline.	4	2
		Total	30

Instructional Method:

The course delivery method will depend upon the requirement of content and need of students. The teacher in addition to conventional teaching method by black board, may also use any of tools such as demonstration, role play, Quiz, brainstorming, MOOCs etc.

From the content 10% topics are suggested for flipped mode instruction.

Students will use supplementary resources such as online videos, NPTEL/SWAYAM videos, e-courses, Virtual Laboratory

The internal evaluation will be done on the basis of Active Learning Assignment

Practical/Viva examination will be conducted at the end of semester for evaluation of performance of students in laboratory.

Reference Books:

[1] Space Mission Analysis and Design" by James R. Wertz and Wiley J. Larson.

[2] Introduction to Space Systems: Design and Synthesis" by Miguel R. Aguirre

[3] Fundamentals of Astrodynamics" by Roger R. Bate, Donald D. Mueller, and Jerry E. White

[4] Rocket Propulsion Elements" by George P. Sutton and Oscar Biblarz 5

[5] Introduction to Aerospace Engineering with a Flight Test Perspective" by Stephen Corda.