INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad -500 043

AERONAUTICAL ENGINEERING

COURSE DESCRIPTOR

Course Title	**SPACE MECHANICS**				
Course Code	AAE016				
Programme	B.Tech				
	VII	AE			
Course Type	Core				
Regulation	IARE - R16				
Course Structure	**Theory**			**Practical**	
	Lectures	**Tutorials**	**Credits**	**Laboratory**	**Credits**
	3	1	4	-	-
Chief Coordinator	Dr. P.K. Mohanta, Associate Professor				
Course Faculty	Dr. P.K. Mohanta, Associate Professor Mr. Kasturi Rangan, Asst. Professor				

I. COURSEOVERVIEW:

The course focuses on Space Mechanics topics. It will involve the development of concepts of the two-body problem, the restricted three-body and n-body problem, Hamiltonian dynamics, canonical transformations, and Poincare surface sections. Several basic Newtonian dynamics and spacecraft altitude dynamics will also be analyzed. Several concepts of the launch vehicle will be discussed and its prescribed position will be described. A vehicle’s trajectory will be determined. Additionally, interplanetary spacecraft will also be described and explained. Concepts on satellites and launch vehicles will also be described.

II. COURSEPRE-REQUISITES:

Level	Course Code	Semester	Prerequisites
-	-	-	Nil

III. MARKSDISTRIBUTION:

Subject	SEE Examination	CIA Examination	Total Marks
Space Mechanics	70	30	100

IV. DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✓	White board marker& Talk	✓	Quiz	✓	Assignments	✗	MOOCs
✓	LCD / PPT	✓	Seminars	✗	Mini Project	✓	Videos
✓	Open Ended Experiments						

V. EVALUATION METHODOLOGY:

The course will be evaluated for a total of 100 marks, with 30 marks for Continuous Internal Assessment (CIA) and 70 marks for Semester End Examination (SEE). Out of 30 marks allotted for CIA during the semester, marks are awarded by taking average of two CIA examinations or the marks scored in the make-up examination.

Semester End Examination (SEE): The SEE is conducted for 70 marks of 3 hours duration. The syllabus for the theory courses is divided into FIVE modules and each module carries equal weightage in terms of marks distribution. The question paper pattern is as follows. Two full questions with "either" or "choice" will be drawn from each module. Each question carries 14 marks. There could be a maximum of two sub divisions in a question.

The emphasis on the questions is broadly based on the following criteria:

50 %	To test the objectiveness of the concept.
50 %	To test the analytical skill of the concept OR to test the application skill of the concept.

Continuous Internal Assessment (CIA):

CIA is conducted for a total of 30 marks (Table 1), with 25 marks for Continuous Internal Examination (CIE), 05 marks for Quiz/ Alternative Assessment Tool (AAT).

Table 1: Assessment pattern for CIA

Component	Theory		Total Marks
Type of Assessment	CIE Exam	Quiz / AAT	
CIA Marks	25	05	30

Continuous Internal Examination (CIE):

Two CIE exams shall be conducted at the end of the 8th and 16th week of the semester respectively. The CIE exam is conducted for 25 marks of 2 hours duration consisting of two parts. Part–A shall have five compulsory questions of one mark each. In part–B, four out of five questions have to be answered where, each question carries 5 marks. Marks are awarded by taking average of marks scored in two CIE exams.

Quiz / Alternative Assessment Tool (AAT):

Two Quiz exams shall be online examination consisting of 25 multiple choice questions and are be answered by choosing the correct answer from a given set of choices (commonly four). Marks shall be awarded considering the average of two quizzes for every course. The AAT may include seminars, assignments, term paper, open ended experiments, five minutes video.

VI. HOW PROGRAM OUTCOMES AREASSESSED:

Program Outcomes (POs)		Strength	Proficiency assessed by
PO 1	**Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solutionofcomplex engineering problems.	3	Assignments Lectures
PO 2	**Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences,andengineering sciences	2	AssignmentLectur es
PO 3	**Design/development of solutions**: Design Solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.	1	Assignment LecturesSe minars

3 = High; 2 = Medium; 1 = Low

VII. HOW PROGRAM SPECIFIC OUTCOMES AREASSESSED:

Program Specific Outcomes (PSOs)		Strength	Proficiency assessed by
PSO 1	**Professional skills:** Able to utilize the knowledge of aeronautical/aerospace engineering in innovative, dynamic and challenging environment for design and development of new products	2	Assignment Exam Lectures
PSO 2	**Problem-solving Skills:** Imparted through simulation language skills and general purpose programming to solve practical, design and analysis problems of components to complete the challenge. of orbital mechaics.	3	Assignment Exam
PSO 3	**Practical implementation and testing skills:** Providing different types of in house and training and industry practice to fabricate and test and develop the products with more innovative technologies	1	Assignment

PSO 4	**Successful career and entrepreneurship:** To prepare the students with broad aerospace knowledge to design and develop systems and subsystems of aerospace and allied systems and become technocrats.	-	Seminars

3 = High; 2 = Medium; 1 = Low

VIII. COURSE OBJECTIVES:

The course should enable the students to:	
I	Impart the knowledge in two-body, restricted three-body and n-body problem, Hamiltonian dynamics, canonical transformations, Poincare surface sections.
II	Analyze the basic Newtonian dynamics and spacecraft altitude dynamics
III	Provide necessary knowledge to study the satellite and interplanetary trajectories and formal approaches for handling coordinate transformations
IV	Solve the orbital problem related to Earth satellite orbits using Hamilton's and generate interplanetary orbits in the frame work of restricted three-body problem.

IX. COURSE OUTCOMES(COs):

Cos	Course Outcome	CLOs	Course Learning Outcome
CO 1	Understand and develop basic concepts in Space Mechanics	CLO 1	Describe the solar system, reference frames, and coordinate systems.
		CLO 2	Explain the celestial sphere, the ecliptic, a motion of vernal equinox, sidereal time, solar time, standard time, and the Earth's atmosphere.
		CLO 3	Define and describe the many body problem, and the Lagrange-Jacobi identity.
		CLO 4	Recognize and describe the circular restricted three body problem, libration points, and relative motion in the N-body problem.
CO 2	Obtain a clear understanding of the Two Body Problem.	CLO 5	Derive and describe the Equations of motion. Specifically, the general characteristics of motion for different orbits. Understandthe relations between position and time for different orbits.
		CLO 6	Define and describe the expansions in elliptic motion, and orbital elements.
		CLO 7	Explain the relation between orbital elements and position and velocity. Launch vehicle ascent trajectories, general aspects of satellite injection.
		CLO 8	Discuss the dependence of orbital parameters on in-plane injection parameters, and launch vehicle performances, and orbit deviations due to injection errors.

Cos	Course Outcome	CLOs	Course Learning Outcome
CO 3	Develop a clear understanding of the perturbed satellite orbit, and its various implications.	CLO 9	Explain special and general perturbations, such as the Cowell's method, & Encke's method.
		CLO 10	Understand the method of variations of orbital elements, and the general perturbations approach.
		CLO 11	Define the two-dimensional interplanetary trajectories, fast interplanetary trajectories.
		CLO 12	Understand 3D interplanetary trajectories.
		CLO 13	Discuss about the launch of interplanetary spacecraft, and understand the trajectory of the target planet.
CO 4	Develop a Complete understanding of the BallisticMissile Trajectories	CLO 14	Define and understand the boost phase, the ballistic phase, trajectory geometry and optimal flights.
		CLO 15	Define the time of flight and the re-entry phase.
		CLO 16	Define the position of the impact point and the influence coefficients.
CO 5	Understand the various aspects of low-Thrust trajectories	CLO 17	Understand the equations of motion.
		CLO 18	Understand the constant radial thrust acceleration, constant tangential thrust (Characteristics of the motion), Linearization of the equations of motion, and Performance analysis.

X. COURSE LEARNING OUTCOMES(CLOs):

CLO Code	CLO's	At the end of the course, the student will have the ability to:	PO's Mapped	Strength of Mapping
AAE0016.01	CLO 1	Describe the solar system, reference frames, and coordinate systems.	PO 1	3
AAE0016.02	CLO 2	Explain the celestial sphere, the ecliptic, a motion of vernal equinox, sidereal time, solar time, standard time, and the Earth's atmosphere	PO 1	2
AAE0016.03	CLO 3	Define and describe the many body problem, and the Lagrange-Jacobi identity.	PO 1	3
AAE0016.04	CLO 4	Recognize and describe the circular restricted three body problem, libration points, and relative motion in the N-body problem.	PO 1PO 2	1
AAE0016.05	CLO 5	Derive and describe the Equations of motion. Specifically, the general characteristics of motion for different orbits. Understand the relations between position and time for different orbits.	PO 1PO 2	2
AAE0016.06	CLO 6	Define and describe the expansions in elliptic motion, and orbital elements.	PO 1	3

AAE0016.07	CLO 7	Explain the relation between orbital elements and position and velocity. Launch vehicle ascent trajectories, general aspects of satellite injection.	PO 1PO 2	1
AAE0016.08	CLO 8	Discuss the dependence of orbital parameters on in-plane injection parameters, and launch vehicle performances, and orbit deviations due to injection errors.	PO 1PO 2	2
AAE0016.09	CLO 9	Explain special and general perturbations, such as the Cowell's method, & Encke's method.	PO 1	2
AAE0016.10	CLO 10	Understand the method of variations of orbital elements, and the general perturbations approach	PO1	2
AAE0016.11	CLO 11	Define the two-dimensional interplanetary trajectories, fast interplanetary trajectories.	PO 1	1
AAE0016.12	CLO 12	Understand 3D interplanetary trajectories.	PO 1PO 2	3
AAE0016.13	CLO 13	Discuss about the launch of interplanetary spacecraft, and understand the trajectory of the target planet.	PO 1	2
AAE0016.14	CLO 14	Define and understand the boost phase, the ballistic phase, trajectory geometry and optimal flights.	PO 3	1
AAE0016.15	CLO 15	Define the time of flight and the re-entry phase.	PO 2	2
AAE0016.16	CLO 16	Define the position of the impact point and the influence coefficients.	PO 1PO4	1
AAE0016.17	CLO 17	Understand the equations of motion.	PO 1	3
AAE0016.18	CLO 18	Understand the constant radial thrust acceleration, constant tangential thrust (Characteristics of the motion), Linearization of the equations of motion, and Performance analysis.	PO 1PO2PO 4	2

3= High; 2 = Medium; 1 = Low

XI. MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES

Course Outcomes (COs)	Program Outcomes (POs)				Program Specific Outcomes
	PO 1	PO 2	PO 3	PO 4	PSO 1
CO 1	2	1			2
CO 2	2	1			3
CO 3	2	1			2
CO 4	1	1	1	1	2
CO 5	3	1		1	1

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XII. MAPPING COURSE LEARNING OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFICOUTCOMES:

Course Learning Outcomes (CLOs)	Program Outcomes (POs)												ProgramSpecific Outcomes(PSOs)		
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CLO 1	3												3		
CLO 2	2												1		
CLO 3	3												3		
CLO 4	1	1											2		
CLO 5	2	2											3		
CLO 6	3												3		
CLO 7	1	1											2		
CLO 8	2	2											3		
CLO 9	2												3		
CLO 10	2												1		
CLO 11	1												2		
CLO 12	3	3											1		
CLO 13		3											3		
CLO 14			1										1		
CLO 15		2											3		
CLO 16	1			1									2		
CLO 17	3												1		
CLO 18	2	2		2									1		

3 = High; 2 = Medium; 1 = Low

XIII. ASSESSMENT METHODOLOGIES –DIRECT

CIE Exams	PO1,PO 1, PO 2,PSO1	SEE Exams	PO 1, PO 2, PO 1, PSO 1	Assignments	PO1, PSO1, PO2, PSO2, PO3, PSO3	Seminars	PO 2,PO 1, PO 2,PSO 3
Laboratory Practices	-	Student Viva	-	Mini Project	-	Certification	-
Term Paper	PO 1,PO 2, PO 2,PSO 3						

XIV. ASSESSMENT METHODOLOGIES -INDIRECT

✔	Early Semester Feedback	✔	End Semester OBE Feedback
✘	Assessment of Mini Projects by Experts		

XV. SYLLABUS

Unit-I	**Introduction to Space Mechanics**
Basic concepts: The solar system, Reference frames and coordinate systems, The celestial sphere, The ecliptic, Motion of vernal equinox, Sidereal time, Solar Time, Standard Time, The earth's atmosphere. The many body problem, Lagrange-Jacobi identity. The circular restricted three body problem, Libration points, Relative Motion in the N-body problem.	
Unit-II	**Two Body Problem**
Equations of motion-General characteristics of motion for different orbits-Relations between position and time for different orbits, Expansions in elliptic motion, Orbital Elements. Relation between orbital elements and position and velocity: Launch vehicle ascent trajectories, General aspects of satellite injection. Dependence of orbital parameters on in-plane injection parameters, Launch vehicle performances, Orbit deviations due to injection errors.	
Unit-III	**Perturbed Satellite Orbit**
Special and general perturbations-Cowell's Method, Encke's method. Method of variations of orbital elements,General perturbations approach. Two-dimensional interplanetary trajectories, Fast interplanetary trajectories, Three dimensional interplanetary trajectories. Launch of interplanetary spacecraft. Trajectory about the target planet.	
Unit-IV	**Ballistic Missile Trajectories**
The boost phase, the ballistic phase, Trajectory geometry, optimal flights. Time of flight, Re-entry phase. The position of the impact point, Influence coefficients.	
Unit-V	**Low Thrust Trajectories**
Equations of Motion. Constant radial thrust acceleration, Constant tangential thrust(Characteristics of the motion), Linearization of the equations of motion, Performance analysis.	
Text Books:	
1. J. W. Cornelisse, ―Rocket Propulsion and Spaceflight Dynamics‖, Pitman Publishing, London, 1979 2. William E. Wiesel, ―Spaceflight Dynamics‖, McGraw-Hill, 3rd Edition, New Delhi, 2010.	
Reference Books:	
1. Vladimir A. Chobotov, ―Orbital Mechanics‖, AIAA Education Series, USA, 3rdEdition,2002. 2. Kaplan, Marshall H., ―Modern Spacecraft Dynamics and Control‖, John Wiley & Sons, New York, 1976. 3. Wiesel, William E., ―Spaceflight Dynamics‖, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2ndEdition 2007. 4. David A. Vellado, ―Fundamentals of Astrodynamics and Applications‖, Springer, Germany, 3rdEdition, 2007	

XVI. COURSEPLAN:

The course plan is meant as a guideline. Probably there may be changes.

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
1	Describe the solar system,	CLO 1	T1:2.2.1
2	Reference frames, and coordinate systems.	CLO 1	T1:2.2.1
3	Celestial sphere, the ecliptic, a motion of vernal equinox	CLO 2	T1:2.3.2
4	Sidereal time, solar time, standard time	CLO 2	T1:2.3.2
5	Earth's atmosphere	CLO 2	T1:2.3.2
6	Define and describe the many body problem	CLO 3	T1:2.3.4
7	Lagrange-Jacobi identity	CLO 3	T1:2.3.4
8	Circular restricted three body problem, libration points	CLO 4	T1:2.3.5
9	Libration points	CLO	T1:2.3.5
10	Relative motion in the N-body problem.	CLO	T1:2.3.5
11	Derive and describe the Equations of motion. Specifically, the general characteristics of motion for different orbits.	CLO 5	T1:2.3.6
12	Understand the relations between position and time for different orbits.	CLO 5	T1:2.3.6
13	Define and describe the expansions in elliptic motion,	CLO 6	T1:3.1.1
14	Orbital elements.	CLO 6	T1:3.1.1
15	Explain the relation between orbital elements and position and velocity.	CLO 7	T1:3.1.2 T2:1.2.3
16	Launch vehicle ascent trajectories, general aspects of satellite injection.	CLO 7	T1:3.1.2 T2:1.2.3
17	Discuss the dependence of orbital parameters on in-plane injection parameters,	CLO 8	T1:3.1.2 T2:1.2.3
18	Launch vehicle performances	CLO 8	T1:3.1.2 T2:1.2.3
19	Orbit deviations due to injection errors.	CLO 8	T1:3.1.2 T2:1.2.3
20	Explain special and general perturbations	CLO 9	T1:3.1.2 T2:1.2.3
21	Cowell's method,.	CLO 9	T1:3.1.2 T2:1.2.3

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
22	Encke's method	CLO 9	T2:1.2.3 T2:1.2.3
23	Understand the method of variations of orbital elements	CLO 10	T1:3.1.2 T2:1.2.3
24	General perturbations approach	CLO 10	T1:3.1.2 T2:1.2.3
25	Define the two-dimensional interplanetary trajectories	CLO 11	T1:3.1.2 T2:1.2.3
26	Fast interplanetary trajectories.	CLO 11	T1:3.1.2 T2:1.2.3
27	Understand 3D interplanetary trajectories	CLO 12	T1:3.1.2 T2:2.2.3
28	Launch of interplanetary spacecraft, Understand the trajectory of the target planet.	CLO 13	T1:3.1.2 T2:4.2.3
29-31	Boost phase, the ballistic phase	CLO 14	T1:3.1.2 T2:3.2.3
32	Trajectory geometry and optimal flights.	CLO 14	T1:3.1.2 T2:3.2.3
33-34	Define the time of flight and the re-entry phase	CLO 15	T1:3.1.2 T2:1.2.3
35-36	Define the position of the impact point and the influence coefficients.	CLO 16	T1:3.1.2 T2:1.2.3
37	Understand the equations of motion.	CLO 17	T1:2.1.2 T2:2.2.3
38	Understand the constant radial thrust acceleration,	CLO 18	T1:2.1.2 T2:1.2.3
39-40	Constant tangential thrust (Characteristics of the motion),.	CLO 18	T1:2.1.2
41-42	Linearization of the equations of motion,	CLO 18	T2:1.2.3
43-45	Performance analysis	CLO 18	T1:2.1.2

XVII. GAPS IN THE SYLLABUS-TO MEET INDUSTRY / PROFESSIONREQUIREMENTS:

S NO	DESCRIPTION	PROPOSED ACTIONS	RELEVANCE WITH POs	RELEVANCE WITH PSOs
1	To improve standards and analyze the concepts.	Seminars	PO 1	PSO 1
2	To understand definitions better and be able to derive critical equations.	Seminars / Full time Jobs	PO 3	PSO 1
3	Develop trajectories and equations of motion for the various aspects of space flights	Seminars/internship	PO 2	PSO 1

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