INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)
Dundigal, Hyderabad -500 043

AERONAUTICAL ENGINEERING

COURSE DESCRIPTOR

Course Title	**SPACE PROPULSION**				
Course Code	AAE012				
Programme	B.Tech				
Semester	VI	AE			
Course Type	Core				
Regulation	IARE - R16				
Course Structure	**Theory**			**Practical**	
	Lectures	**Tutorials**	**Credits**	**Laboratory**	**Credits**
	3	1	4	-	-
Chief Coordinator	Dr. Praveen Kumar Balguri, Associate Professor				
Course Faculty	Dr. Praveen Kumar Balguri, Associate Professor Mr. Shiva Prasad U, Assistant Professor				

I. COURSE OVERVIEW:

This course flinches with the basic principles of rocket propulsion and presents an overview of the space missions followed by the system requirements. It includes an overview of different types of propulsion like solid, liquid and hybrid propulsion. Solid propulsion grain design and estimates for the mission will be evaluated by gaining knowledge. In addition to solid, liquid and hybrid propulsion techniques will be detailed in the current course and this also tries to forecast the future development of propulsion technologies, identifying some futuristic propulsion systems, which will need to use new space propulsion technologies. It includes an overview of the relevant propulsion technologies (e.g., cold gas, chemical, electric), propulsion technology selection, system design, and component evaluation.

II. COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites
UG	AAE007	V	Aircraft Propulsion

III. MARKSDISTRIBUTION:

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

IV. DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✘	Chalk & 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 the CIA during the semester, marks are awarded by taking an 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 fiveunits and each unit carries equal weight in terms of marks distribution. The question paper pattern is as follows. Two full questions with "either" or "choice" will be drawn from each unit. Each question carries 14 marks. There could be a maximum of two subdivisions 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 weeks 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 an online examination consisting of 25 multiple choice questions and are being 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 and MOOCs.

VI. HOW PROGRAM OUTCOMES ARE ASSESSED:

Program Outcomes (POs)		Strength	Proficiency assessed by
PO 1	**Engineering knowledge**: Apply the knowledge of mathematics, science, engineeringfundamentals, and an engineering specialization to the solution of complex engineering problems.	3	Assignments
PO 2	**Problem analysis**: Identity, formulate, review research literature, and analyze complexengineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences	2	Seminars
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.	2	Mini Project

3 = High; 2 = Medium; 1 = Low

VII. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

Program Specific Outcomes (PSOs)		Strength	Proficiency assessed by
PSO 1	**Professional skills:**Able to utilize the knowledge of aeronautical/aerospace engineering in an innovative, dynamic and challenging environment for design and development of new products	2	Assignments
PSO2	**Problem-solving Skills:** Imparted through simulation language skills and general-purpose CAE packages to solve practical, design and analysis problems of components to complete the challenge of airworthiness for flight vehicles.	2	Seminars
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	Mini Project
PSO 4	**Successful career and entrepreneurship:** To prepare the students with broad aerospace knowledge to design and develop systems and subsystems of aeronautical/aerospace allied systems to become technocrats.	1	-

3 = High; 2 = Medium; 1 = Low

VIII. COURSE OBJECTIVES :

The course should enable the students to:	
I	Evaluate various space missions, parameters to be considered for designing trajectories and rocket mission profiles.
II	Classify the different chemical rocket propulsion systems, types of igniters and performance considerations of rockets.
III	Discuss the working principle of solid and liquid propellant rockets and gain basic knowledge of hybrid rocket propulsion.
IV	Illustrate electric propulsion techniques, ion, and nuclear rocket and the performances of different advanced propulsion systems.

IX. COURSE OUTCOMES (COs):

COs	Course Outcome	CLOs	Course Learning Outcome
CO 1	Evaluate various space missions, parameters to be considered for designing trajectories and rocket mission profiles.	CLO 1	Demonstrate the basic principles of space propulsion and its applications in different types of orbits.
		CLO 2	Describe the concept of orbital elements and basic orbital equations.
		CLO 3	Adapt the concepts of vertical takeoff and landing for space applications and launch trajectories.
CO 2	Classify the different chemical rocket propulsion systems, types of igniters and performance considerations of rockets.	CLO 4	Explain the operating principle of the rocket engine and demonstrate the rocket equation.
		CLO 5	Discuss the different Newton's laws of motion and the relation of thrust generation to different laws of motion
		CLO 6	Describe the different types of propulsion systems and preliminary concepts in nozzle less propulsion and air augmented rockets.
CO 3	Discuss the working principle of solid propellant rockets, propellant grain designs and combustion.	CLO 7	Demonstrate the salient features of solid propellants rockets and estimate the grain configuration designs suitable for different missions.
		CLO 8	Understand the erosive burning, combustion instability, and burners
		CLO 9	Remember the applications and advantages of solid propellant rockets
CO 4	Demonstrate the working principle of liquid propellant rockets, feed systems and gain basic knowledge of hybrid rocket propulsion.	CLO 10	Recognize the salient features of liquid propellant rockets, various feed systems and injectors.
		CLO 11	Understand the thrust control cooling, heat transfer problems, combustion instability in liquid propellant rockets
		CLO 12	Understand the peculiar problems associated with the operation of cryogenic engines in different missions.
		CLO 13	Recognize the standard and reverse hybrid systems, combustion mechanism, applications, and limitations.
CO 5	Illustrate electric propulsion techniques, ion and nuclear rocket and the performances of different advanced propulsion systems.	CLO 14	Understand the different types of Electric, Ion, and Nuclear propulsion systems.
		CLO 15	Identify the future applications of the electric propulsion system

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
AAE012.01	CLO 1	Demonstrate the basic principles of space propulsion and its applications in different types of orbits.	PO1	3
AAE0012.02	CLO 2	Describe the concept of orbital elements and basic orbital equations.	PO1	3

CLO Code	CLO's	At the end of the course, the student will have the ability to:	PO's Mapped	Strength of Mapping
AAE0012.03	CLO 3	Adapt the concepts of vertical takeoff and landing for space applications and launch trajectories.	PO1	3
AAE0012.04	CLO 4	Explain the operating principle of the rocket engine and demonstrate the rocket equation.	PO2	2
AAE0012.05	CLO 5	Discuss the different Newton's laws of motion and the relation of thrust generation to different laws of motion	PO1	3
AAE0012.06	CLO 6	Describe the different types of propulsion systems and preliminary concepts in nozzle less propulsion and air augmented rockets.	PO2	2
AAE0012.07	CLO 7	Demonstrate the salient features of solid propellants rockets and estimate the grain configuration designs suitable for different missions.	PO2	2
AAE0012.08	CLO 8	Understand the erosive burning, combustion instability, and burners	PO3	2
AAE0012.09	CLO 9	Remember the applications and advantages of solid propellant rockets	PO3	2
AAE0012.10	CLO 10	Recognize the salient features of liquid propellant rockets, various feed systems and injectors.	PO3	2
AAE0012.11	CLO 11	Understand the thrust control cooling, heat transfer problems, combustion instability in liquid propellant rockets	PO3	2
AAE0012.12	CLO 12	Understand the peculiar problems associated with the operation of cryogenic engines in different missions.	PO3	2
AAE0012.13	CLO 13	Recognize the standard and reverse hybrid systems, combustion mechanism, applications, and limitations.	PO3	2
AAE0012.14	CLO 14	Understand the different types of Electric, Ion, and Nuclear propulsion systems.	PO3	2
AAE0012.15	CLO 15	Identify the future applications of the electric propulsion system	PO3	2

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

Course Outcomes (COs)	Program Outcomes (POs)			
	PO 1	PO 2	PO 3	PSO1
CO 1	3	2		2
CO 2	1	2		2
CO 3	2	2		
CO 4	2		1	
CO 5	2	2	2	1

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

Course Learning Outcomes (CLOs)	Program Outcomes (POs)												Program Specific Outcomes (PSOs)			
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
CLO 1	3												2			
CLO 2	3												2			
CLO 3	3															
CLO 4		2												2		
CLO 5	3												2			
CLO 6		2											2			
CLO 7		2												2		
CLO 8			2											2		
CLO 9			2													
CLO 10			3											2		
CLO 11			2										2			
CLO 12			2													
CLO 13			2													1
CLO 14			2											2		
CLO 15			2												1	

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XIII. ASSESSMENT METHODOLOGIES–DIRECT

CIE Exams	PO1,PO2	SEE Exams	PO2,PO3	Assignments	PO1	Seminars	PO2
Laboratory Practices	PO1	Student Viva	-	Mini Project	PO3	Certification	-
Term Paper	-						

XIV. ASSESSMENT METHODOLOGIES-INDIRECT

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

XV. SYLLABUS

Unit-I	PRINCIPLES OF ROCKET PROPULSION
History of rockets, Newton's third law, orbits and space flight, types of orbits, basic orbital equations, elliptical transfer orbits, launch trajectories, the velocity increment needed for launch, the thermal rocket engine, concepts of vertical takeoff and landing, SSTO and TSTO, launch assists.	
Unit-II	**FUNDAMENTALS OF ROCKET PROPULSION**
Operating principle, Rocket equation, Specific impulse of a rocket, internal ballistics, Rocket nozzle classification, Performance characteristics of rockets, air augmented rockets, pulse rocket motors, static testing of rockets and instrumentation, safety considerations.	
Unit-III	**SOLID ROCKET PROPULSION**
Salient features of solid propellant rockets, selection criteria of solid propellants, estimation of solid propellant adiabatic flame temperature, propellant grain design considerations. Types of igniters, Erosive burning in solid propellant rockets, combustion instability, strand burner and T-burner, applications and advantages of solid propellant rockets.	
Unit-IV	**LIQUID AND HYBRID ROCKET PROPULSION**
Salient features of liquid propellant rockets, selection of liquid propellants, various feed systems and injectors for liquid propellant rockets, thrust control cooling in liquid propellant rockets and the associated heat transfer problems, combustion instability in liquid propellant rockets, peculiar problems associated with operation of cryogenic engines, introduction to hybrid rocket propulsion, standard and reverse hybrid systems, combustion mechanism in hybrid propellant rockets, applications and limitations.	
Unit-V	**ADVANCED PROPULSION TECHNIQUES**
Electric rocket propulsion, types of electric propulsion techniques, Ion propulsion, Nuclear rocket, comparison of performance of these propulsion systems with chemical rocket propulsion systems, future applications of electric propulsion systems, Solar sail.	
Text Books:	
1. Turner, M.J.L., Rocket and Spacecraft Propulsion, 2nd Edition, MIT Press, 1922. 2. Sutton, G.P., "Rocket Propulsion Elements" John Wiley & Sons Inc., New York, 5th Edition, 1993 3. PHill, P.G. and Peterson, C.R., Mechanics and Thermodynamics of Propulsion, 2nd Edition, Addison Wesley, 1992.	
Reference Books:	
1. Mathur, M.L., and Sharma, R.P., "Gas Turbine, Jet and Rocket Propulsion", Standard Publishers and Distributors, Delhi, 1988. 2. Tajmar, M., Advanced Space Propulsion Systems, Springer 2003 3. Hieter and Pratt, Hypersonic Air breathing propulsion th Edition, 1993.	

XVI. COURSE PLAN:

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

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
1-2	History of rockets, Newton's third law	CLO 1	T2:1.1-1.1.4
3-5	Orbits and space flight, Types of Orbits, Basic Orbital Equations	CLO 2	T2:1.3-1.4.3
6-7	Elliptical transfer orbits, Launch trajectories, Velocity increment	CLO 2	T2:1.3-

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
	needed for launch, Thermal rocket engine,		1.3.1 ,2.1
8-9	Concepts of vertical takeoff and landing, SSTO and TSTO, launch assists.	CLO 3	T2:8.3
10-11	Operating principle	CLO 5	T2:1.2-1.2.1
12	Rocket equation, Specific impulse of a rocket,	CLO 5	T2:1.2-1.2.1,2.5.1
13	Internal ballistics, Rocket nozzle classification, Rocket performance considerations of rockets	CLO 7	R1 : 3.4
14-15	Types of igniters	CLO 7	R1 : 8.1
16-17	Air augmented rockets, pulse rocket motors,	CLO 7	T2: 6.6
18-19	Static testing of rockets and instrumentation, safety considerations.	CLO 8	T2:7.22
20-21	Salient features of solid propellant rockets,	CLO 8	T2:4.2
22-23	Selection criteria of solid propellants,	CLO 8	R1:12.2
24-27	Estimation of solid propellant adiabatic flame temperature, propellant grain design considerations.	CLO 8	R1:11.3
28	Erosive burning in solid propellant rockets, combustion instability,	CLO 8	R1:11.3
29-31	Strand burner and T-burner, applications and advantages of solid propellant rockets.	CLO 8	R1:11.1
32-33	Salient features of liquid propellant rockets,	CLO 9	R1:6.1
34-36	Selection of liquid propellants, various feed systems and injectors for liquid propellant rockets	CLO 9	R1:7.1
37	Thrust control cooling in liquid propellant rockets and the associated heat transfer problems	CLO 9	R1:8.2
38-40	Combustion instability in liquid propellant rockets, peculiar problems associated with operation of cryogenic engines,	CLO 10	R1:15.4
41-42	Introduction to hybrid rocket propulsion,	CLO 11	R1:15.0
43-46	Standard and reverse hybrid systems	CLO 11	R1:15.2
47	Combustion mechanism in hybrid propellant rockets, applications and limitations.	CLO 15	R1:15.1
48	Electric rocket propulsion,	CLO 12	T2:6.3
49	Types of electric propulsion techniques	CLO 13	T2:6.4
50-51	Ion propulsion, Nuclear rocket, comparison of performance of these propulsion systems with chemical rocket propulsion systems	CLO 14	T2:6.5
52-53	Future applications of electric propulsion systems	CLO 15	T2:6.9
54	Solar sail.	CLO 15	R3:5.1

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

S No	Description	Proposed actions	Relevance with POs	Relevance with PSOs
1	Testing of rocket propulsion systems at various operating conditions	Mini Projects	PO3,PO 4	PSO 3

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