INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad -500 043

MECHANICAL ENGINEERING

COURSE DESCRIPTOR

Course Title	**AEROSPACE PROPULSION AND COMBUSTION**				
Course Code	AAE551				
Programme	B. Tech				
Semester	VI	ME			
Course Type	Open Elective - I				
Regulation	IARE - R16				
Course Structure	**Theory**			**Practical**	
	Lectures	**Tutorials**	**Credits**	**Laboratory**	**Credits**
	3	-	3	-	-
Chief Coordinator	Mr. M Vijay Kumar , Assistant Professor				
Course Faculty	Mr. M Vijay Kumar , Assistant Professor				

I. COURSE OVERVIEW:

The aim of Aerospace propulsion and combustion is to introduce students to the analyze parametric cyclic analysis, performance parameters, efficiency, and specific impulse of air breathing and non air breathing engines and know the design and performance of subsonic and supersonic inlets, types of combustion chambers and factors affecting the combustors. To be able to describe the principal figures of merit for aircraft engine and rocket motor performance and explain how they are related to vehicle performance. To be able to describe the principal design parameters and constraints that set the performance of gas turbine engines and to apply ideal-cycle analysis to a gas turbine engine to relate thrust and fuel burn to component-level performance parameters and flight conditions. It is the branch of rocket science for analyzing the performance of an engine.

II. COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites	Credits
UG	AME003	IV	Thermodynamics	4
UG	AME007	V	Aircraft propulsion	3

III. MARKS DISTRIBUTION

Subject	SEE Examination	CIA Examination	Total Marks
Aerospace propulsion and combustion	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 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 units and each unit 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 unit. 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 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, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.	3	Presentation on real-world problems
PO 2	**Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering 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.	1	Seminars

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 innovative, dynamic and challenging environment for design and development of new products	2	Presentation on current challenges
PSO 2	**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.	-	-
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	-	-
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.		

3 = High; 2 = Medium; 1 = Low

VIII. COURSE OBJECTIVES :

I	Demonstrate with an overview of various aerospace propulsion systems and a sound foundation in the fundamentals of thermodynamics.
II	Distinguish the elementary principles of thermodynamic cycles as applied to propulsion analysis.
III	Prioritize an introduction to combustion& gas kinetic theory.
IV	Discover the knowledge of working knowledge of and the tools to measure various flight propulsion systems such as turbojets, turbofans, ramjets, rockets, air turbo-rockets and nuclear/electric propulsion systems.

IX. COURSE OUTCOMES (COs):

COs	Course Outcome	CLOs	Course Learning Outcome
CO 1	Gain knowledge about power plants and aircraft engines performance	CLO 1	Apply knowledge and understand the essential facts, concepts and principles of thermodynamics.
		CLO 2	Understand the basic function of all aircraft engine components and how they work.
		CLO 3	Analyze classification of aircraft propulsion.
		CLO 4	Demonstrate different type’s aircraft engine operating principle.
CO 2	Assess the importance of various types engine components used in the aircraft	CLO 5	Understand step by step procedure of engine parametric cycle analysis.
		CLO 6	Describe principle of operation of axial and centrifugal compressor.
		CLO 7	Understand different design of compressor and limitations of each method.
		CLO 8	Analyze performance characteristics of axial and centrifugal turbines.
CO 3	Obtain an insight in the concept of propellers, inlets and various nozzles in aircraft	CLO 09	Analyze propeller performance and its types and explain their impact on engine performance.
		CLO 10	Describe operational modes of subsonic inlets and parameters influencing it.
		CLO 11	Describe theory of flow in isentropic nozzle and physics behind nozzle operation.
		CLO 12	Understand different nozzle operating conditions for convergent and divergent nozzle.
CO 4	Assess the significance of combustion inside the engines and its performance	CLO 13	Understand different types of combustion chamber and functions of all the components.
		CLO 14	Describe the effect of operating variables on performance.
		CLO 15	Analyze combustion chamber performance and parameters influencing them.
		CLO 16	Describe the effect of flame tube cooling and its applications.
CO 5	Estimate the flammability limits, premixed flames and their significance in the combustion zone	CLO 17	Understand different types of premixed flames.
		CLO 18	Explain the significance of flammability limits during combustion process.
		CLO 19	Describe theory of droplet combustion and turbulent combustion.
		CLO 20	Analyze the numerical methods of LNS & DNS and explain the parameters influencing them.

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
AAE551.01	CLO 1	Apply knowledge and understand the essential facts, concepts and principles of thermodynamics.	PO 1	3
AAE551.02	CLO 2	Understand the basic function of all aircraft engine components and how they work.	PO 1	3
AAE551.03	CLO 3	Analyze classification of aircraft propulsion.	PO 2	2

CLO Code	CLO's	At the end of the course, the student will have the ability to:	PO's Mapped	Strength of Mapping
AAE551.04	CLO 4	Demonstrate different type's aircraft engine operating principle.	PO 2	2
AAE551.05	CLO 5	Understand step by step procedure of engine parametric cycle analysis.	PO 1	3
AAE551.06	CLO 6	Describe principle of operation of axial and centrifugal compressor.	PO 1	3
AAE551.07	CLO 7	Understand different design of compressor and limitations of each method.	PO 2	2
AAE551.08	CLO 8	Analyze performance characteristics of axial and centrifugal turbines.	PO 2	2
AAE551.09	CLO 9	Analyze propeller performance and its types and explain their impact on engine performance.	PO 1	3
AAE551.10	CLO 10	Describe operational modes of subsonic inlets and parameters influencing it.	PO 1	3
AAE551. 11	CLO 11	Describe theory of flow in isentropic nozzle and physics behind nozzle operation.	PO 2	2
AAE551. 12	CLO 12	Understand different nozzle operating conditions for convergent and divergent nozzle.	PO 2	2
AAE551. 13	CLO 13	Understand different types of combustion chamber and functions of all the components.	PO 1	3
AAE551. 14	CLO 14	Describe the effect of operating variables on performance.	PO 1	3
AAE551. 15	CLO 15	Analyze combustion chamber performance and parameters influencing them.	PO 3	1
AAE551. 16	CLO 16	Describe the effect of flame tube cooling and its applications.	PO 3	1
AAE551. 17	CLO 17	Understand different types of premixed flames.	PO 2	2
AAE551. 18	CLO 18	Explain the significance of flammability limits during combustion process.	PO 2	2
AAE551. 19	CLO 19	Describe theory of droplet combustion and turbulent combustion.	PO 2	2
AAE551. 20	CLO 20	Analyze the numerical methods of LNS & DNS and explain the parameters influencing them.	PO 3	1

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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															
CLO 2	3												2			
CLO 3		2														
CLO 4		2														
CLO 5	3															
CLO 6	3												2			
CLO 7		2														
CLO 8		2														
CLO 9	3															
CLO 10	3															
CLO 11		2														
CLO 12		2														
CLO 13	3															
CLO 14	3															
CLO 15			1													
CLO 16			1													
CLO 17		2														
CLO 18		2											1			
CLO 19		2														
CLO 20			1													

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XIII. ASSESSMENT METHODOLOGIES – DIRECT

CIE Exams	PO 1, PO 2 PO 3	SEE Exams	PO 1, PO 2 PO 3	Assignments	PO 1	Seminars	PO 2
Laboratory Practices	-	Student Viva	-	Mini Project	-	Certification	-
Term Paper	-						

XIV. ASSESSMENT METHODOLOGIES - INDIRECT

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

XV. SYLLABUS

UNIT-I	ELEMENTS OF AIRCRAFT PROPULSION	Classes: 10
Classification of power plants, methods of aircraft propulsion, propulsive efficiency, specific fuel consumption, thrust and power, factors affecting thrust and power, illustration of working of gas turbine engine, characteristics of turboprop, turbofan and turbojet engines and performance.		
UNIT-II	**COMPONENTS OF JET ENGINES**	**Classes: 08**
Ram jet, scram jet engines construction and nomenclature, theory and performance, methods of thrust augmentation, atmospheric properties, introduction to compressors, turbines, combustors and after burners for aircraft engines.		
UNIT-III	**INLETS, NOZZLES AND PROPERLLER THEROY**	**Classes: 10**
Propeller performance parameters, negative thrust, prop fans, ducted propellers, propeller noise, propeller selection, propeller charts. Subsonic and supersonic inlets, relation between minimum area ratio and external deceleration ratio. Starting problem in supersonic inlets, modes of inlet operation, jet nozzle, efficiencies, over expanded, under and optimum expansion in nozzles, thrust reversal.		
UNIT-IV	**THERMODYNAMICS OF REACTING SYSTEMS**	**Classes: 09**
Classification of combustion chambers, combustion chamber performance, flame tube cooling, flame stabilization, effect of operating variables on performance.		
UNIT-V	**PREMIXED FLAMES**	**Classes: 08**
Rankine hugoniot relations, theories of laminar premixed flame propagation, quenching and flammability limits; Diffusion flames: Burke-Schumann theory, laminar jet diffusion flame, droplet combustion, turbulent combustion, closure problem, premixed and non-premixed turbulent combustion, introduction to DNS and LES.		

Text Books:

1. Stephen R. Turns, "An Introduction to Combustion", McGraw-Hill, 3rd Edition, 2012.
2. Thomas A. Ward, "Aerospace Propulsion Systems", John Wiley and Sons, 1st Edition, 2010.

Reference Books:

1. M. H. Sadd, "Elasticity: Theory, Applications, and Numerics", Academic Press, 2nd Edition, 2009.
2. R. G. Budynas "Advanced Strength and Applied Stress Analysis", McGraw-Hill, 2nd Edition, 1999.
3. A.P. Boresi, R.J. Schmidt, "Advanced Mechanics of Materials", John Willey & Sons, 5th Edition, 2003.

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	Introduction to aerospace engineering	CLO 1	T2:5.5 R1:1.12.1
2	Define function of gas generator, Classify gas turbine engines	CLO 1	T2:5.6 R1:1.12.3
3	Operational envelops	CLO 1	T2:5.10 R1:1.15

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
4	Turbojet performance	CLO 1	T2:5.15 R1:1.16
5	Turbo fan performance	CLO 1	T2:5.17 R1:1.13.1
6	Turbo prop performance characteristics	CLO 1	T2:5.18 R1:1.13.2
7	Define engine thrust, takeoff thrust	CLO 2	T2:5.19 R1:1.13.3
8	Thrust equation, installed thrust	CLO 2	T2:5.20 R1:1.17.1
9	Methods of aircraft propulsion	CLO 2	T2:5.24 R1:1.17.3
10	Propulsive efficiency, efficiency of a turbo prop	CLO 3	T2:6.1 R1:2.3
11	Efficiency of a turbo fan and turbo jet	CLO 3	T2:6.3 R1:2.6.1
12	Explanation of performance parameters	CLO 4	T2:6.5 R1:2.6.2
13	Specific fuel consumption, specific impulse	CLO 4	T2:7.3 R1:2.8
14	Components of jet engines	CLO 5	T2:15.13 R1:8.7.2
15	Working principle of ramjet and Scram jet operating principle	CLO 5	T2:15.13 R1:8.7.2
16	Methods of thrust augmentation in aircrafts engines	CLO 5	T2:15.16 R1:8.7.3
17	Atmospheric properties influence on when aircrafts are flying	CLO 6	T1:11.9 R2:12.24
18	Use of after burner in an engine	CLO 6	T1:11.9 R3:12.25
19	Explanation of principle of operation of turbine	CLO 6	T1:3.2 R3:3.2
20	Operation of axial flow turbines	CLO 6	T1:3.3.1 R3:3.2
21	Design of a turbine blade and nomenclature	CLO 7	T2:16.5 R1:8.10
22	Explain principle of operation of compressor	CLO 7	T2:16.9 R1:8.11.1
23	Operation of centrifugal compressor and axial flow compressor	CLO 7	T2:16.9 R1:8.11.2
24	Stage efficiency calculations, cascade testing	CLO 7	T2:16.8 R1:8.12.1
25	Design of velocity triangles of a turbine blade	CLO 5	T2:16.8 R1:8.12.2
26	Define degree of reaction of a compressor	CLO 8	T2:16.11 R1:8.14
27	Internal flow and stall in subsonic inlets	CLO 8	T2:16.11 R1:8.20
28	Relation between minimum area ratio and eternal deceleration ratio	CLO 8	T2:16.12 R1:8.19
29	Working phenomenon of subsonic and supersonic inlets	CLO 8	T2:16.12 R1:8.77
30	Diffuser performance	CLO 9	T2:1.2 R1:7.2
31	Starting problem of subsonic inlets	CLO 9	T2:1.16 R1:7.7

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
32	Shock swallowing by area variation	CLO 9	T2:1.20 R1:7.8
33	Starting problem of supersonic inlets	CLO 9	T2:1.20 R1:7.8
34	Definition of propeller and working principle	CLO 10	T2:2.1 R1:7.9.2
35	Performance of propeller in an engine	CLO 10	T2:16.11 R1:8.14
36	Types of propellers – ducted, prop fans etc	CLO 10	T2:16.8 R1:8.12.1
37	Calculated efficiency of a sub sonic and supersonic inlets of an engine	CLO 10	T2:5.17 R1:1.13.1
38	Definition of nozzle and its importance	CLO 11	T2:5.18 R1:1.13.2
39	Over expanded, under and optimum expansion in nozzles	CLO 11	T2:5.19 R1:1.13.3
40	Concept of thrust reversal in a nozzle	CLO 12	T2:5.20 R1:1.17.1
41	Classification of combustion chambers	CLO 12	T2:5.24 R1:1.17.3
42	Combustion chamber performance	CLO 12	T2:6.1 R1:2.3
43	Effect of operating variables on performance	CLO 12	T2:6.3 R1:2.6.1
44	Flame stabilization	CLO 13	T2:6.5 R1:2.6.2
45	Effect of operating variables on performance and cooling	CLO 13	T2:5.24 R1:1.17.3
46	Combustion chamber types – annular and circular	CLO 13	T2:6.1 R1:2.3
47	Combustion types , combustion inlet temperature and pressure variations	CLO 14	T2:6.3 R1:2.6.1
48	Definition of pre mixed flames	CLO 15	T2:15.13 R1:8.7.2
49	Rankine hugoniot relations for pre mixed flows	CLO 15	T2:15.13 R1:8.7.2
50	Theories of laminar premixed flame propagation	CLO 16	T2:15.16 R1:8.7.3
51	Quenching and flammability limits	CLO 16	T2:15.16 R1:8.7.3
52	Diffusion flames: Burke-Schumann theory	CLO 17	T1:11.9 R3:12.25
53	Laminar jet diffusion flame, droplet combustion	CLO 17	T1:3.2 R3:3.2
54	Turbulent combustion, closure problem	CLO 18	T1:3.3.1 R3:3.2
55	Premixed for turbulent combustion	CLO 18	T2:16.5 R1:8.10
56	Non-premixed turbulent combustion	CLO 19	T2:16.9 R1:8.11.1
57	Introduction to DNS and LES	CLO 19	T2:16.9 R1:8.11.2
58	Discussion of laminar jet diffusion flame Application of numerical techniques in visualizing mixed flows	CLO 20	T2:15.13 R1:8.7.2
59	Application of numerical techniques in visualizing mixed flows	CLO 20	T2:15.16 R1:8.7.3

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

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	Conditional probability, Sampling distribution, correlation, regression analysis and testing of hypothesis	Seminars / NPTEL	PO 2	PSO 1
3	Encourage students to solve real time applications and prepare towards competitive examinations.	Guest lectures	PO 2	PSO 1

Prepared By:
Mr. Vijay Kumar M, Assistant Professor

HOD, AE