INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad -500 043

AEROSPACE ENGINEERING

COURSE DESCRIPTOR

Course Title	**AEROSPACE PROPULSION**			
Course Code	**BAEB02**			
Programme	**M. Tech**			
Semester	**I**			
Course Type	**Core**			
Regulation	**IARE - R18**			
Course Structure	**Theory**		**Practical**	
	Lectures	**Tutorials**	**Practicals**	**Credits**
	3	**-**	**-**	**3**
Course Faculty	**Mr. Shiva Prasad U, Assistant Professor**			

I. COURSE OVERVIEW:

This course presents Aircraft propulsive devices as systems, with functional requirements and engineering and environmental limitations along with requirements and limitations that constrain design choices. Both air-breathing and rocket engines are covered, at a level which enables rational integration of the propulsive system into an overall vehicle design. 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 the knowledge.

II. COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites	Credits
UG	AAEB02	**3**	Thermodynamics	3

III. MARKS DISTRIBUTION

Subject	SEE Examination	CIA Examination	Total Marks
Aerospace Propulsion	70 Marks	30 Marks	100

IV. DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✔	LCD / PPT	✔	Seminars	✔	Videos	✘	MOOCs
✘	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 weight age 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.
30 %	To test the analytical skill of the concept.
20 %	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 Technical Seminar and Term Paper.

Table 1: Assessment pattern for CIA

Component	**Theory**		**Total Marks**
Type of Assessment	**CIE Exam**	**Technical Seminar and Term Paper**	
CIA Marks	25	05	30

Continuous Internal Examination (CIE):

Two CIE exams shall be conducted at the end of the 9^{th} and 17^{th} week of the semester respectively. The CIE exam is conducted for 25 marks of 2 hours duration, consisting of 5 one mark compulsory questions in part-A and 4 questions in part-B. The student has to answer any 4 questions out of five questions, each carrying 5 marks. Marks are awarded by taking average of marks scored in two CIE exams.

Technical Seminar and Term Paper:

Two seminar presentations and the term paper with overview of topic are conducted during II semester. The evaluation of Technical seminar and term paper is for maximum of 5 marks. Marks are awarded by taking average of marks scored in two Seminar Evaluations.

VI. HOW PROGRAM OUTCOMES ARE ASSESSED:

	Program Outcomes (POs)	Strength	Proficiency assessed by
PO 1	Identify, formulate, and solve complex aerospace engineering problems by applying advanced principles of engineering.	3	Presentation on real-world problems
PO 2	Apply aerospace engineering design to produce solutions that meet specified needs with frontier technologies.	2	Seminar
PO 3	Formulate and solve complex engineering problems related to aerospace materials, propulsion, aerodynamics, structures, avionics, stability and control.	1	Term Paper

3 = High; 2 = Medium; 1 = Low

VII. COURSE OBJECTIVES:

The course should enable the students to:

I	Understand the basic working principles of different types of air breathing engines
II	Understand analysis and design principles of IC engines.
III	Analyze and design different components of gas turbine
IV	Analyze and design different components of solid and liquid propellant rockets.

VIII. COURSE OUTCOMES (COs):

COs	Course Outcome	CLOs	Course Learning Outcome
CO 1	Describe the various types, basic function, and performance analysis of air-breathing engine.	CLO 1	Demonstrate different type's aircraft engine operating principle.
		CLO 2	Understand steps involved in performance analysis of all aircraft engine.
		CLO 3	Analyze the engine performance parameters and parameters influencing them.
CO 2	Understand the various inlets and combustion chamber performance parameters affecting it.	CLO 4	Describe operational modes of subsonic inlets and parameters influencing it.
		CLO 5	Understand different types of combustion chamber and functions of all the components.
		CLO 6	Describe supersonic inlets, starting problem in it and their operating modes.
CO 3	Describe principle operations of compressors, with work done and pressure rise explaining the design and performance parameters of turbine, understand configuration associated	CLO 7	Understand different design of compressor and limitations of each method.
		CLO 8	Describe principle of operation of centrifugal and axial flow turbine.
		CLO 9	Analyze performance characteristics of axial and centrifugal compressor.
CO 4	Discuss the working principle of solid and liquid propellant rockets	CLO 10	Appreciate the different propellant feed system options for both chemical and electric propulsion systems, and their similarities/differences.

	and gain basic knowledge of hybrid rocket propulsion.	CLO 11	Demonstrate the salient features of solid propellants rockets and estimate the grain configuration designs suitable for different missions.
		CLO 12	Identify the applications of standard and reverse hybrid systems with an overview of its limitations.
CO 5	Demonstrate the working principle of liquid propellant rockets and gain basic knowledge of rocket propulsion and its feed systems.	CLO 13	Discuss the various feed systems and injectors for liquid propellants rockets and associated heat transfer problems
		CLO 14	Appreciate the different propellant feed system options for both chemical and electric propulsion systems, and their similarities/differences.
		CLO 15	Discuss the various feed systems and injectors for liquid propellants rockets and associated heat transfer problems.

IX. 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
BAEB02.01	CLO 1	Demonstrate different type's aircraft engine operating principle.	PO1	3
BAEB02.02	CLO 2	Understand steps involved in performance analysis of all aircraft engine.	PO2, PO3	3
BAEB02.03	CLO 3	Analyze the engine performance parameters and parameters influencing them.	PO2, PO3	3
BAEB02.04	CLO 4	Describe operational modes of subsonic inlets and parameters influencing it.	PO2	1
BAEB02.05	CLO 5	Understand different types of combustion chamber and functions of all the components.	PO2	1
BAEB02.06	CLO 6	Describe supersonic inlets, starting problem in it and their operating modes.	PO1	1
BAEB02.07	CLO 7	Understand different design of compressor and limitations of each method.	PO2, PO3	2
BAEB02.08	CLO 8	Describe principle of operation of centrifugal and axial flow turbine.	PO2, PO3	2
BAEB02.09	CLO 9	Analyze performance characteristics of axial and centrifugal compressor.	PO2	2
BAEB02.10	CLO 10	Appreciate the different propellant feed system options for both chemical and electric propulsion systems, and their similarities/differences.	PO2	1
BAEB02.11	CLO 11	Demonstrate the salient features of solid propellants rockets and estimate the grain configuration designs suitable for different missions.	PO2, PO3	2
BAEB02.12	CLO 12	Identify the applications of standard and reverse hybrid systems with an overview of its limitations.	PO1, PO3	3
BAEB02.13	CLO 13	Discuss the various feed systems and injectors for liquid propellants rockets and associated heat transfer problems	PO1, PO3	2
BAEB02.14	CLO 14	Appreciate the different propellant feed system options for both chemical and electric propulsion systems, and their similarities/differences.	PO1, PO3	1
BAEB02.15	CLO 15	Discuss the various feed systems and injectors for liquid propellants rockets and associated heat transfer problems.	PO1, PO2	1

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

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

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

Course Learning Outcomes (CLOs)	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
CLO 1	3						
CLO 2		3	3				
CLO 3		3	3				
CLO 4		1					
CLO 5		1					
CLO 6	1						
CLO 7		1	2				
CLO 8		2	1				
CLO 9		2					
CLO 10		1					
CLO 11		2	2				
CLO 12	3		3				
CLO 13	2		1				
CLO 14	1		1				
CLO 15	1	1					

3 = High; 2 = Medium; 1 = Low

XII. ASSESSMENT METHODOLOGIES –DIRECT

CIE Exams	PO1, PO2, PO3	SEE Exams	PO1, PO2, PO3	Seminar and Term Paper	PO1, PO2, PO3
Viva	-	Mini Project	-	Laboratory Practices	-

XIII. ASSESSMENT METHODOLOGIES -INDIRECT

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

XIV. SYLLABUS:

MODULE-I	**AIR-BREATHING ENGINES**
Classification, operational envelopes; Description and function of gas generator, turbojet, turbofan, turboprop, turbo shaft, ramjet, scramjet, turbojet/ramjet combined cycle engine; Engine thrust, takeoff thrust, installed thrust, thrust equation; Engine performance parameters, specific thrust, specific fuel consumption and specific impulse, thermal efficiency, propulsive efficiency, engine overall efficiency and its impact on aircraft range and endurance; Engine cycle analysis and performance analysis for turbojet, turbojet with afterburner, turbofan engine, turboprop engine.	
MODULE -II	**AIRCRAFT ENGINE INLETS, EXHAUST NOZZLES, COMBUSTORS AND AFTERBURNERS**
Subsonic inlets: Function, design variables, operating conditions, inlet performance, performance parameters; Supersonic inlets: Compression process, types, construction, losses, performance characteristics; Exhaust nozzles: primary nozzle, fan nozzle, converging nozzle, converging-diverging nozzle, variable nozzle, and performance maps, thrust reversers and thrust vectoring, Combustors and Afterburners: Geometries, flame stability, ignition and engine starting, adiabatic flame temperature, pressure losses, performance maps, fuel types and properties.	
MODULE-III	**AXIAL FLOW COMPRESSORS AND TURBINES**
Axial flow Compressors: Geometry, definition of flow angles, stage parameters, cascade aerodynamics, aerodynamic forces on compressor blades, rotor and stator frames of reference, compressor performance maps, velocity polygons or triangles, single stage energy analysis, compressor instability, stall and surge. Axial Flow Turbines: Geometry, configuration, comparison with axial flow compressors, velocity polygons or triangles, single stage energy analysis, performance maps, thermal limits of blades and vanes, blade cooling, blade and vane materials, blade and vane manufacture.	
MODULE-IV	**SOLID-PROPELLANT ROCKET MOTORS**
Background description: Classification of rocket propulsion systems; Performance of an ideal rocket, rocket thrust equation, total and specific impulse, effective exhaust velocity, rocket efficiencies, characteristic velocity, thrust coefficient; Description of solid propellant rocket motor, solid propellant grain configurations, homogeneous propellant, heterogeneous or composite propellant, different grain cross sections, propellant burning rate, combustion of solid propellants, physical and chemical processes, ignition process, combustion instability; Hybrid propellant rockets: Hybrid rocket operation and hybrid rocket characteristics.	
MODULE-V	**LIQUID PROPELLANT ROCKET ENGINES: PROPELLANT TYPES**
Bipropellant, monopropellant, cold gas propellant, cryogenic propellant, storable propellants, gelled propellant; Propellant Storage, different propellant tank arrangements, propellant feed system-pressure feed, turbo-pump feed; Thrust chambers, injectors, combustion chamber, nozzle, starting and ignition, variable thrust; Combustion of liquid propellants: Combustion process, combustion instability, thrust vector control.	

Text Books:

1. Ronald D. Flack, "Fundamentals of Jet Propulsion with Applications", Cambridge University Press, 3rd Edition, 2011.
2. George P. Sutton, Oscar Biblarz, "Rocket Propulsion Elements", Wiley India Pvt. Ltd, 7th Edition, 2010.

Reference Books:

1. Jack D. Mattingly, "Elements of Propulsion: Gas Turbines and Rockets", AIAA Education Series, 3rd Edition, 2006.
2. Saeed Farokhi, "Aircraft Propulsion", Wiley, 2nd Edition, 2014.
3. David R. Greatrix, "Powered Flight: The Engineering of Aerospace Propulsion", Springer, 3rd Edition, 2012.

Web References:

1. http://www.aero.iisc.ernet.in/page/propulsion
2. https://afreserve.com/aerospace-propulsion
3. http://ocw.mit.edu/courses/aeronautics-and-astronautics/16-50-introduction-to-propulsion-systems-spring-2012/Syllabus/

E-Text Books:

1. http://as.wiley.com/WileyCDA/WileyTitle/productCd-1118307984.html
2. http://www.freeengineeringbooks.com/AeroSpace/Propulsion-Books.php
3. http://www.springer.com/us/book/9781447124849?token=prtst0416p

XV. COURSE PLAN:

The course plan is meant as a guideline. There may probably be changes.

Lecture No	Topics to be covered	Course Learning Outcomes (CLOs)	Reference
1	Classification, operational envelopes; Description and function of gas generator, turbojet, turbofan, turboprop, turbo shaft, ramjet,	CLO 1	T1- 2.2, 2.6
2-4	scramjet, turbojet/ramjet combined cycle engine; Engine thrust, takeoff thrust, installed thrust, thrust equation	CLO 1	R1-2.6, 2.10
5-6	Engine performance parameters, specific thrust, specific fuel consumption and specific impulse, thermal efficiency, propulsive efficiency	CLO 2	T1-3.2, 3.3,
7-8	Engine overall efficiency and its impact on aircraft range and endurance; Engine cycle analysis.	CLO 2	T-3.5
9-10	Performance analysis for turbojet, turbojet with afterburner, turbofan engine, turboprop engine.	CLO 2	T1-2.13, 2.14and 2.16
11-12	Subsonic inlets: Function, design variables, operating conditions, inlet performance, performance parameters; Supersonic inlets:	CLO 3	T2-2.15
13	Compression process, types, construction, losses, performance characteristics; Exhaust nozzles: primary nozzle, fan nozzle,	CLO 3	T1-3.9, 3.6
14-15	converging nozzle, converging-diverging nozzle, variable nozzle, and performance maps, thrust reversers and thrust vectoring,	CLO 3	T2-6.1, 6.3
16	Combustors and Afterburners: Geometries, flame stability,	CLO 3	T1-6.2, 6.3
17-18	Ignition and engine starting, adiabatic flame temperature, pressure losses, performance maps, fuel types and properties.	CLO 4	T1- 2.2, 2.6
19	Axial flow Compressors: Geometry, definition of flow angles, stage parameters, cascade aerodynamics, aerodynamic forces on compressor blades,	CLO 4	R1-2.6, 2.10
20-22	rotor and stator frames of reference, compressor performance maps, velocity polygons or triangles	CLO 5	T1-3.2, 3.3,
23-24	Single stage energy analysis, compressor instability, stall and surge. Axial Flow Turbines: Geometry, configuration, comparison with axial flow compressors,	CLO 6	T1-3.5
25-26	Velocity polygons or triangles, single stage energy analysis, performance maps, thermal limits of blades and vanes, blade cooling, blade and vane materials, blade and vane manufacture.	CLO 6	T1-3.6, 3.8
27	Background description: Classification of rocket propulsion systems; Performance of an ideal rocket, rocket thrust equation,	CLO 7	T2:7.22
28-30	Total and specific impulse, effective exhaust velocity, rocket efficiencies, characteristic velocity, thrust coefficient;	CLO 8	T2:4.2
31-32	Description of solid propellant rocket motor, solid propellant grain configurations, homogeneous propellant, heterogeneous or composite propellant,	CLO 9	T2:12.2
33-34	Different grain cross sections, propellant burning rate, combustion of solid propellants, physical and chemical processes	CLO 10	T2:11.3
35-36	Ignition process, combustion instability; Hybrid propellant rockets: Hybrid rocket operation and hybrid rocket characteristics.	CLO 11	R2:15.0
37-38	Bipropellant, monopropellant, cold gas propellant, cryogenic propellant, storable propellants, gelled propellant;	CLO 12	T2:7.1
39	Propellant Storage, different propellant tank arrangements, control.	CLO 12	T2:7.1
40-41	Propellant feed system-pressure feed, turbo-pump feed; Thrust chambers, injectors,	CLO 13	T2:33.4 R2:19.4

42-43	Combustion chamber, nozzle, starting and ignition, variable thrust;	CLO 14	T1:15.0
44	Combustion of liquid propellants: Combustion process, combustion instability,	CLO 15	T2:15.0
45	Thrust vector	CLO 15	T2:33.9 R2:19.7

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

S No	Description	Proposed Actions	Relevance with POs
1	Testing of rocket propulsion systems at various operating conditions	Seminars	PO 1
2	Advances in propulsion techniques for Nozzle less propulsion	Seminars / NPTEL	PO 3

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