INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal, Hyderabad - 500 043

COURSE DESCRIPTION

Branch	**AEROSPACE ENGINEERING**				
Course Title	**SPACE PROPULSION**				
Course Code	BAEC01				
Program	M.Tech				
Semester	I	AE			
Course Type	Core				
Regulation	IARE- PG21				
Course Structure	Theory			Practical	
	Lecture	Tutorials	Credits	Laboratory	Credits
	3	-	3	-	-
Course Coordinator	Dr. Maruthupandiyan K, Assistant Professor				

I COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites
B.Tech	AAEB02	III	Engineering Thermodynamics
B.Tech	AAEB08	IV	Aerospace Propulsion

II COURSE OVERVIEW:

An aerospace propulsion system is a device that generates forces to push the aerospace vehicles forward. This course discusses about the various Aerospace propulsive devices in micro level, it includes an overview of different types of propulsive system present in aircrafts and rockets such as turbojet, turboprop, turbofan, IC engine, solid propellant, hybrid propellant and liquid propellant engines. Along with that design and analysis will be discussed on the various parameters and components present in aerospace propulsive system

III MARKS DISTRIBUTION:

Subject	SEE Examination	CIE Examination	Total Marks
Space Propulsion	70 Marks	30 Marks	100

IV DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✓	PPT	✓	Chalk & Talk	✓	Assignments	x	MOOC
x	Seminars	x	Others				

V EVALUATION METHODOLOGY:

Each theory course will be evaluated for a total of 100 marks, out of which 30 marks for Continuous Internal Assessment (CIA) and 70 marks for Semester End Examination (SEE). **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 three 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):
For each theory course the CIA shall be conducted by the faculty / teacher handling the course. CIA is conducted for a total of 30 marks, with 20 marks for Continuous Internal Examination (CIE), 05 marks for Assignment and 05 marks for Alternative Assessment Tool (AAT). Two CIE Tests are Compulsory and sum of the two tests, along with the scores obtained in the assignment / AAT shall be considered for computing the final CIA of a student in a given course.

The CIE Tests/Assignment /AAT shall be conducted by the course faculty with due approval from the HOD. Advance notification for the conduction of Assignment/AAT is mandatory and the responsibility lies with the concerned course faculty. CIA is conducted for a total of 30 marks (Table 1).

Component	Theory			Total Marks
Type of Assessment	CIE Exam	Assignment	AAT	
CIA Marks	20	05	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 five descriptive type questions out of which four 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 COURSE OBJECTIVES:

The students will try to learn:

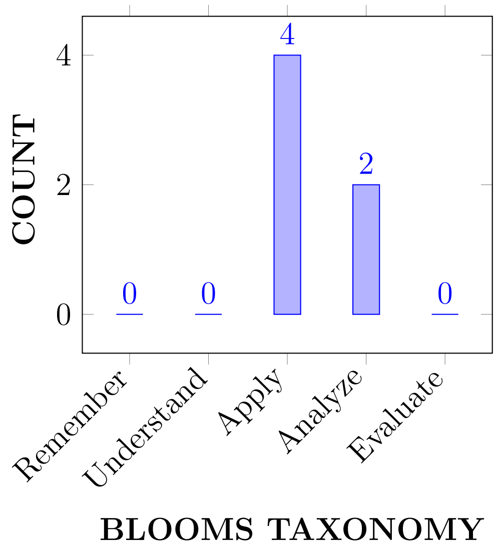
I	The fundamentals of air-breathing propulsion system, their operating principles, and function of an individual component
II	The geometry of inlets, combustion chambers, nozzles and factors affecting their performance
III	The operating principles of various compressors, turbines and performance characteristics under different flight conditions
IV	The application of rocket propulsion technology in design and development of modern and efficient space propulsion system

VII COURSE OUTCOMES:

After successful completion of the course, students should be able to:

CO 1	**Identify** suitable air-breathing engine and operating system for the aircraft based on performance.	Apply
CO 2	**Distinguish** between the functions and performance parameters of inlets, nozzles, combustors and after burners for choosing desired devices to the aero engines.	Analyze
CO 3	**Identify** the performance parameters for estimating the thrust and specific fuel consumption of an aircraft engine.	Apply
CO 4	**Examine** the working procedure of rocket propulsion system and components for selecting them based on mission profile.	Analyze
CO5	**Make use of** the working principles of solid and hybrid rocket motors for increasing the performances level.	Apply
CO6	**Develop** sub-systems and heat transfer systems in liquid propellant rocket for definitive deep space rocket propulsive design.	Apply

COURSE KNOWLEDGE COMPETENCY LEVEL



VIII PROGRAM OUTCOMES:

Program Outcomes	
PO 1	Identify, formulate, analyze and Design complex engineering problems, and design system components or processes by applying appropriate advanced principles of engineering activities and using modern tools
PO 2	Engage in life-long learning and professional development through self-study and continuing education in understanding the engineering solutions in global and management principles to manage projects in multidisciplinary environments.
PO 3	Demonstrate a degree of mastery in emerging areas of Aerospace Engineering such as Aerodynamics, Propulsion, Structure and Flight Dynamics
PO 4	Write and present a substantial technical report/document
PO 5	Independently carry out research/investigation and development work to solve practical problems
PO 6	Function effectively as a member or leader in diverse teams to carry out development work, produce solutions that meet the specified needs with frontier technologies and communicate effectively on complex engineering activities.

IX MAPPING OF EACH CO WITH PO(s):

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	✓	-	✓	-	-	-
CO 2	✓	-	✓	-	-	-
CO 3	✓	-	✓	-	-	-
CO 4	✓	-	✓	-	-	-
CO 5	✓	-	✓	-	-	-
CO 6	✓	-	✓	-	-	-

X COURSE ARTICULATION MATRIX (CO – PO MAPPING):

CO'S and PO'S on the scale of 0 to 3, 0 being no correlation, 1 being the low correlation, 2 being medium correlation and 3 being high correlation.

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	-	1	-	-	-
CO 2	3	-	1	-	-	-
CO 3	3	-	1	-	-	-
CO 4	3	-	3	-	-	-
CO 5	3	-	1	-	-	-
CO 6	3	-	1	-	-	-
TOTAL	18	-	8	-	-	-
AVERAGE	3	-	1.3	-	-	-

XI ASSESSMENT METHODOLOGY DIRECT:

CIE Exams	✓	SEE Exams	✓	Seminar and term paper	-
Laboratory Practices	-	Student Viva	-	Mini Project	-

XII ASSESSMENT METHODOLOGY INDIRECT:

✓	**End Semester OBE Feed Back**

XIII SYLLABUS:

MODULE I	**AIR-BREATHING ENGINES**
	Classification, operational envelopes; Description and function of gas generator, turbojet, turbofan, turboprop, turboshaft, 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 after burner, turbofan engine, turboprop pengine.

MODULE II	**AIRCRAFT ENGINEINLETS, 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 stat or 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: PROPELLANTTYPES**
	Bipropellant,monopropellant,coldgaspropellant,cryogenicpropellant,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 in stability, thrust vector control.

TEXTBOOKS

1. Ronald D. Flack, —Fundamentals of Jet Propulsion with Applications, Cambridge University Press, 3rd Edition, 2011

2. GeorgeP. 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, Edition, 2006
2. Saeed Farokhi, —Aircraft Propulsion‖, Wiley, 2 nd Edition, 2014
3. Anderson 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

COURSE WEB PAGE:

1.

XIV COURSE PLAN:

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

S.No	Topics to be covered	CO's	Reference
OBE DISCUSSION			
1	Course Description on Outcome Based Education (OBE): Course Objectives, Course Outcomes (CO), Program Outcomes (PO) and CO-PO Mapping	-	
CONTENT DELIVERY (THEORY)			
1	Classification, operational envelopes ,	CO 1	T1 : 18
2	Description and function of gas generator	CO 1	T1 : 18.1
3	Turbojet, turbofan, turboprop, turboshaft	CO 1	T1: 18.1.1
4	Ramjet, scramjet	CO 1	T1: 13
5	Turbojet/ramjet combined cycle engine	CO 1	T1:18.2.1
6	Engine thrust, takeoff thrust, installed thrust, thrust equation;	CO 1	T1:18.2.1
7	Engine performance parameters, specific thrust, specific fuel consumption and specific impulse	CO 1	T1:18.2.2
8	Thermal efficiency, propulsive efficiency, engine overall efficiency	CO 1	T1:18.3
9	Impact on aircraft range and endurance	CO 1	T1 :18.3.1, 18.3.2
10	Engine cycle analysis	CO 1	T1 :18.3.1, 18.3.2
11	Performance analysis for turbofan engine, turboprop pengine	CO 2	T2:4.1
12	Performance analysis for turbojet, turbojet with after burner	CO 1	T2:4.1.1

13	Subsonic inlets: Function, design variables,operating conditions, : , ,	CO 2	T2:4.1.5, 4.1.3
14	Inlet performance, performance parameters, ;	CO 2	T2:4.1.5, 4.1.3
15	Supersonic inlets: Compression process, types	CO 2	T2:4.1.4
16	Supersonic intake , , construction, losses	CO 2	T2:4.1.4
17	Supersonic intake performance characteristics	CO 2	T2:4.2.4
18	Exhaust nozzles	CO 2	T2:4.1.6
19	Primary nozzle, fan nozzle	CO 2	T2:4.1.8
20	Converging nozzle, converging-diverging nozzle, variable nozzle	CO 2	T2:4.1.8
21	Thrust reversers and thrust vectoring,	CO 2	T2:4.5.8
22	Combustors and Afterburners: Geometries, flame stability,	CO 2	T2:4.5
23	Ignition and engine starting, adiabatic flame temperature	CO 2	T2:4.5
24	Pressure losses, performance maps, fuel types and properties	CO 3	T2:5.3
25	Axial flow Compressors	CO 3	T2:5.3
26	Geometry, definition of flow angles, stage parameters	CO 3	T2:5.3.2
27	Cascade aerodynamics	CO 3	T2:5.3.2
28	Aerodynamic forces on compressor blades, rotor and stat or frames of reference	CO 3	R2:4.4
29	Compressor performance maps, velocity polygons or triangles	CO 3	R2:4.4
30	Single stage energy analysis, compressor instability, stall and surge.	CO 3	R4:4.4
31	Axial Flow Turbines: Geometry, configuration	CO 3	T2:4.2.8
32	Comparison with axial flow compressors	CO 3	T2:4.2.8
33	Velocity polygons or triangles	CO 3	T2:4.2.8
34	Single stage energy analysis, performance maps.	CO 3	T2:4.2.8
35	Thermal limits of blades and vanes, blade cooling	CO 4	R1:8.1, 8.2
36	Blade and vane materials, blade and vane manufacture.	CO 4	R1:8.1, 8.2
37	Background description: Classification of rocket propulsion systems	CO 4	R1:8.1, 8.2
38	Performance of an ideal rocket	CO 4	R1:8.3 - 8.6
39	Rocket thrust equation	CO 4	R1:8.3 - 8.6
40	Total and specific impulse,effective exhaust velocity	CO 4	R1:8.3 - 8.6
41	Rocket efficiencies,characteristic velocity, thrust coefficient	CO 4	R1:8.3 - 8.6
42	Description of solid propellant rocket motor	CO 4	R1:8.7, 8.8

43	Solid propellant grain configurations, homogeneous propellant, heterogeneous or composite propellant	CO 4	R1:8.7, 8.8
44	Different grain cross sections, propellant burning rate	CO 4	R1:8.9
45	Combustion of solid propellants, physical and chemical processes	CO 5	R2:11.2
46	Ignition process, combustion instability	CO 5	R2:11.3
47	Hybrid propellant rockets	CO 5	R2:11.3
48	Hybrid rocket operation and hybrid rocket characteristics.	CO 5	R2:11.4, 11.5
49	Bipropellant,monopropellant	CO 5	R2:11.7
50	Coldgaspropellant,cryogenicpropellant	CO 5	R2:11.7
51	Storable propellants,gelled propellant	CO 5	R2:11.8
52	Propellant Storage, different propellant tank arrangements	CO 5	R2:11.6
53	Propellant feed system-pressure feed, turbo pump feed	CO 6	T4:9.1, 9.2
54	Thrust chambers, injectors	CO 6	T2:9.3
55	Combustion chamber, nozzle	CO 6	T2:9.4
56	Starting and ignition	CO 6	T2: 9.5
57	Variable thrust	CO 6	T2: 9.6
58	Combustion of liquid propellants	CO 6	T2:9.7
59	Combustion process, combustion in stability	CO 6	T2:9.8
60	Thrust vector control	CO 6	T2:9.9
DISCUSSION OF QUESTION BANK			
61	Module: I- Airbreathing engines	CO 1	T1
62	Module: II- Inlets, combustion chamber and nozzle	CO 2	T2, R1
63	Module: III- Axial compressor and turbines	CO3,4	R1
64	Module: IV- Solid propellant rocket motore	CO 5	R2
65	Module: V-Liquid propellant rocket motor	CO 6	T2

Signature of Course Coordinator **HOD,AE**
Dr.Maruthupandiyan K, Assistant Professor

INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal, Hyderabad - 500 043

COURSE DESCRIPTION

Department	**AERONAUTICAL ENGINEERING**					
Course Title	**UNMANNED AIR VEHICLES**					
Course Code	BAEC07					
Program	M.Tech					
Semester	I	AE				
Course Type	Elective					
Regulation	IARE-PG21					
Course Structure	Theory			Practical		
	Lecture	Tutorials	Credits	Laboratory	Credits	
	3	-	3	-	-	
Course Coordinator	Dr.Praveen Kumar Balguri					

I COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites
B.Tech	AAEB02	III	Engineering Thermodynamics
B.Tech	AAEB03	III	Fluid Dynamics

II COURSE OVERVIEW:

The course focuses on fundamentals related to powered, aerial vehicle systems that does not carry a human operator, including the terminology related to unmanned air vehicles (UAV), subsystems, basic design phases, aerodynamics, and also provides insight into different types of airframes and powerplants. It imparts knowledge about navigation, communications, control, and stability of UAVs.The course is aimed to obtain the knowledge also in commercial, private, public, and educational interest in UAS applications.

III MARKS DISTRIBUTION:

Subject	SEE Examination	CIE Examination	Total Marks
Unmanned Air Vehicles	70 Marks	30 Marks	100

IV DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✓	PPT	✓	Chalk & Talk	✓	Assignments	x	MOOC
x	Seminars	x	Others				

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). CIA is conducted for a total of 30 marks, with 20 marks for Continuous Internal Examination (CIE), and 10 marks for Alternative Assessment Tool (AAT).

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 three 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):
For each theory course the CIA shall be conducted by the faculty / teacher handling the course. CIA is conducted for a total of 30 marks, with 20 marks for Continuous Internal Examination (CIE), 05 marks for Assignment and 05 marks for Alternative Assessment Tool (AAT). Two CIE Tests are Compulsory and sum of the two tests, along with the scores obtained in the assignment / AAT shall be considered for computing the final CIA of a student in a given course.

The CIE Tests/Assignment /AAT shall be conducted by the course faculty with due approval from the HoD. Advance notification for the conduction of Assignment/AAT is mandatory and the responsibility lies with the concerned course faculty. CIA is conducted for a total of 30 marks (Table 1).

Component	Theory			Total Marks
Type of Assessment	CIE Exam	Quiz	AAT	
CIA Marks	20	05	05	30

Continuous Internal Examination (CIE):
Two CIE exams shall be conducted at the end of the 8^{th} and 16^{th} week of the semester respectively. The CIE exam is conducted for 20 marks of 2 hours duration consisting of five descriptive type questions out of which four 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):
This AAT enables faculty to design own assessment patterns during the CIA. The AAT converts the classroom into an effective learning center. The AAT may include tutorial hours/classes, seminars, assignments, term paper, open ended experiments, METE (Modeling and Experimental Tools in Engineering), five minutes video, MOOCs etc.

VI COURSE OBJECTIVES:

The students will try to learn:

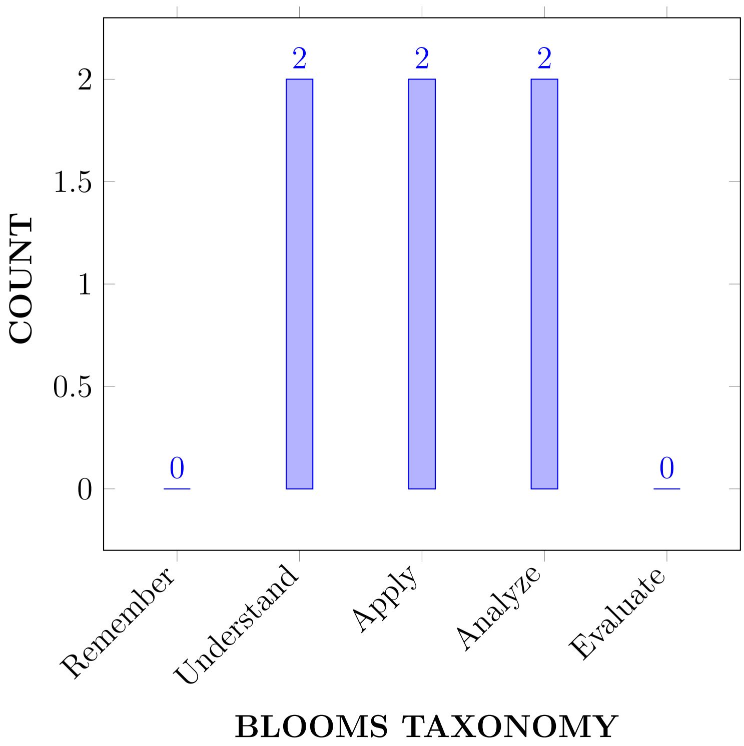
I	The major subsystems and the fundamental design phases of Unmanned Air Vehicle Systems (UAS).
II	The basic drags and airframe configurations of Unmanned Air Vehicles (UAVs).
III	The various communication media and navigation systems of UAVs.
IV	The different techniques used to achieve the control and stability of UAVs.

VII COURSE OUTCOMES:

After successful completion of the course, students should be able to:

CO 1	**Demonstrate** the knowledge of major sub-systems and basic design concepts for the development of unmanned air vehicle systems.	Understand
CO 2	**Illustrate** the different types of airframe configurations available for unmanned air vehicle systems.	Understand
CO 3	**Analyze** the attributes, performance, design issues, and compromises of different types of aircraft for UAV systems to select suitable aircraft.	Analyze
CO 4	**Select** a suitable power-plant based on power generation systems for the given mission requirement.	Apply
CO 5	**Identify** the appropriate communication and navigation systems for the UAVs as per the role requirements.	Apply
CO 6	**Categorize** the different techniques used to achieve the control and stability of UAV systems.	Analyze

COURSE KNOWLEDGE COMPETENCY LEVEL



VIII PROGRAM OUTCOMES:

Program Outcomes	
PO 1	Identify, formulate, analyze and Design complex engineering problems, and design system components or processes by applying appropriate advanced principles of engineering activities and using modern tools
PO 2	Engage in life-long learning and professional development through self-study and continuing education in understanding the engineering solutions in global and management principles to manage projects in multidisciplinary environments.
PO 3	Demonstrate a degree of mastery in emerging areas of Aerospace Engineering such as Aerodynamics, Propulsion, Structure and Flight Dynamics
PO 4	Write and present a substantial technical report/document
PO 5	Independently carry out research/investigation and development work to solve practical problems
PO 6	Function effectively as a member or leader in diverse teams to carry out development work, produce solutions that meet the specified needs with frontier technologies and communicate effectively on complex engineering activities.

IX MAPPING OF EACH CO WITH PO(s):

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	✓	-	✓	-	-	-
CO 2	✓	-	✓	-	-	-
CO 3	✓	-	✓	-	-	-
CO 4	✓	-	✓	-	-	-
CO 5	✓	-	✓	-	-	-
CO 6	✓	-	✓	-	-	-

X COURSE ARTICULATION MATRIX (CO – PO MAPPING):

CO'S and PO'S and on the scale of 0 to 3, 0 being no correlation, 1 being the low correlation, 2 being medium correlation and 3 being high correlation.

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	-	1	-	-	-
CO 2	3	-	1	-	-	-
CO 3	3	-	1	-	-	-
CO 4	3	-	3	-	-	-
CO 5	3	-	1	-	-	-
CO 6	3	-	1	-	-	-
TOTAL	18	-	8	-	-	-
AVERAGE	3	-	1.3	-	-	-

XI ASSESSMENT METHODOLOGY DIRECT:

CIE Exams	✓	SEE Exams	✓	Seminar and term paper	-
Laboratory Practices	-	Student Viva	-	Mini Project	-

XII ASSESSMENT METHODOLOGY INDIRECT:

✓	**End Semester OBE Feed Back**

XIII SYLLABUS:

MODULE I	**INTRODUCTION TO UNMANNED AIRCRAFT SYSTEMS**
	Applications of UAS, categories of UAV systems, roles of unmanned aircraft, composition of UAV system.
MODULE II	**DESIGN OF UAV SYSTEMS-I**
	Introduction to design and selection of the systems-conceptual phase, preliminary design, detailed design; Aerodynamics and airframe configurations-Lift-induced Drag, Parasitic Drag, Rotary-wing Aerodynamics, Response to Air Turbulence, Airframe Configurations; Medium-range, Tactical Aircraft, Characteristics ofAircraftTypes-Long-endurance,Long-rangeRoleAircraft,Medium-range,TacticalAircraft,Close-range/Battle field Aircraft, MUAV Types, MAV and NAV Types, UCAV, Novel Hybrid Aircraft Configurations, Aspects of Airframe Design: Scale Effects, Packaging Density, Aerodynamics, Structures and Mechanisms, Selection of power- plants, Modular Construction, Ancillary Equipment, Design for Stealth: Acoustic Signature,Visual Signature, Thermal Signature, Radio/Radar Signature, Payload Types: Non-dispensable and dispensable payloads.
MODULE III	**DESIGN OF UAV SYSTEMS-II**
	Communications-Communication Media, Radio Communication, Mid-air Collision(MAC) Avoidance, Communications Data Rate and Bandwidth Usage, Antenna Type; Control and Stability: HTOL Aircraft, Convertible Rotor Aircraft, Payload Control, Sensors, Autonomy; Navigation: NAVSTAR Global Positioning System (GPS), TACAN, LORAN C, Inertial Navigation, Radio Tracking, Way-point Navigation; Launch and Recovery. Design for Reliability: Determination of the Required Level of Reliability, Achieving Reliability, Reliability Data Presentation, Multiplexed Systems, Reliability by Design, Design for Ease of Maintenance; Design for Manufacture and Development.
MODULE IV	**THE DEVELOPMENT OF UAV SYSTEMS**
	System Development and Certification-System Development, Certification, Establishing Reliability; System Ground Testing: UAV Component Testing, UAV Sub- assembly and Sub-system Testing, Testing Complete UAV, Control Station Testing, Catapult Launch System Tests, Documentation; System In-flight Testing: Test Sites, Preparation for In-flight Testing, In-flight Testing, System certification.

MODULE V	DEPLOYMENT AND FUTURE OF UAV SYSTEMS
	Operational trials and full certification; UAV System Deployment- Network-centric Operations (NCO),Teaming with Manned and Other Unmanned System; Naval, arm and airforce roles, civilian, paramilitary and commercial roles.

TEXTBOOKS

1. Reg Austin., Unmanned Aircraft Systems, John Wiley and Sons., 2010.

REFERENCE BOOKS:

1. Richard K. Barnhart, Stephen B. Hottman, Douglas M. Marshall, Eric Shappee, (eds.), —Introduction to Unmanned Aircraft Systems‖, CRC Press, 2012.
2. Valavanis, Kimon P., Vachtsevanos, George J. —Handbook of Unmanned Aerial Vehicles‖ AIAA series, 3rd Edition, 2004.

WEB REFERENCES:

https://nptel.ac.in/courses/101104073

COURSE WEB PAGE:

XIV COURSE PLAN:

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

S.No	Topics to be covered	CO's	Reference
OBE DISCUSSION			
1	Course Description on Outcome Based Education (OBE): Course Objectives, Course Outcomes (CO), Program Outcomes (PO) and CO-PO Mapping	-	
CONTENT DELIVERY (THEORY)			
1	Introduction to UAVs.	CO 1	T1-1.1 , 1.3, 1.4,
2	The systemic basis of UAS-system composition	CO 1	T1- 1.2,1.7,
3	The systemic basis of UAS-system composition	CO 1	T1- 1.15, 1.16
4	Conceptual phase; Preliminary design	CO 1	T1- 1.6
5	Selection of the system	CO 1	T1- 2.2, 2.6
6	Some applications of UAS	CO 1	R1-2.6, 2.10
7	Lift-induced Drag; Parasitic Drag	CO 2	T1-3.2, 3.3
8	Rotary-wing aerodynamics	CO 2	T1-3.5
9	Response to air turbulence	CO 2	T1-2.13,and 2.14
10	Airframe configurations	CO 2	R2-2.15
11	Airframe configurations	CO 2	R2-3.9, 3.6
12	Scale effects; Packaging density, Aerodynamics; Structures and mechanisms	CO 2	T1-6.1, 6.3
13	Selection of power-plants	CO 2	T1-6.2, 6.3
14	Modular construction; Ancillary equipment	CO 2	T1-6.5, 6.6

15	Long-endurance, long-range role aircraft	CO 3	R1-6.7, 6.8
16	Long-endurance, long-range role aircraft	CO 3	T1-7.1
17	Medium-range, tactical aircraft	CO 3	T1- 7.2, 7.3 and 7.4
18	Medium-range, tactical aircraft	CO 4	T1- 7.9
19	Close-range /battlefield aircraft	CO 4	T2-7.9, 7.10
20	Close-range /battlefield aircraft	CO 4	T1- 7.11
21	Close-range /battlefield aircraft	CO 4	T1- 10.1, 10.2, 10.3
22	MUAV types	CO 4	T1-10.4, 10.5
23	MAVs and NAVs types	CO 4	R2-2.15
24	MAVs and NAVs types	CO 4	R2-3.9, 3.6
25	MAVs and NAVs types	CO 4	T1-6.1, 6.3
26	UCAV; Novel hybrid aircraft configurations; Research UAV	CO 5	T1-6.2, 6.3
27	Communication media; Radio communication	CO 5	T1-6.5, 6.6
28	Radio communication	CO 5	R1-6.7, 6.8
29	Radio communication , Mid-air collision (MAC) avoidance; communications data rate and bandwidth usage	CO 5	T1-7.1
30	Antenna Types	CO 5	T1- 7.2, 7.3 and 7.4
31	NAVSTAR Global Positioning System (GPS)	CO5	T1- 7.9
32	TACAN - LORAN C - Inertial Navigation	CO 5	T1-7.9, 7.10
33	Radio Tracking - Way-point Navigation	CO 5	T1- 7.11
34	HTOL Aircraft	CO 6	T1- 10.1, 10.2, 10.3
35	HTOL Aircraft	CO 6	T1-10.4, 10.5
36	HTOL Aircraft, Helicopters	CO 6	T1-6.1, 6.3
37	Helicopters	CO 6	T1-6.2, 6.3
38	Helicopters	CO 6	T1-6.5, 6.6
39	Convertible Rotor Aircraft, Payload Control ,Sensors	CO 6	R1-6.7, 6.8
40	Payload Control, Sensors, Autonomy.	CO 6	T1-7.1
41	Explain the different roles where UAVs can perform better than manned aircrafts, discuss them in detail?	CO 1	T1- 7.2, 7.3
42	Explain the different means of navigation (or fall-back options) when GPS system is blocked?	CO1	T1- 7.11
43	Discuss the different design phases of most aircraft based systems.	CO 1	T2-7.9, 7.10
44	Describe the two main causes for an aircraft to have a high response to atmospheric turbulence, discuss by considering wing loading?	CO 2	T1- 7.9
45	Identify the importance of 'Airframe configuration' in design of UAVs?	CO 3	T1-7.1
46	Identify the importance of undercarriage for UAVs and discuss the design parameters.	CO 3	T1- 10.1, 10.2
47	How modular construction concept does helps in the design of UAVs.	CO 3	T1-6.1, 6.3

48	Classify the three main concerns of the Long-endurance, Long-range Role UAV designer, discuss in detail with the necessary diagram?	CO 3	T1-6.5, 6.6
49	Identify the need for close-range UAV systems, discuss few design aspects.	CO 3	T1- 7.11
50	Explain different types of TUAVs and give their applications	CO 3	T1-6.5, 6.6
51	Why the communication is of paramount importance in UAS operations? Discuss the possible reasons for loss of communication during the operations.	CO 4	T1-10.4, 10.5
52	Explain the important points in selection of power-plants for UAVs with the help of power-generation systems.	CO 4	T1- 7.2
53	What are the different ways in which UAV may be vulnerable and discuss how can they be reduced?	CO 5	T1- 1.2,1.8
54	Explain the different sensors used to measure airspeed and height of UAV.	CO 6	T1- 7.10
55	Compare the stability and control of SMR with fixed- wing aircraft.	CO 6	T1-7.9
56	Unmanned aircraft systems, categories, applications	CO 1, CO 2	T1- 10.1, 10.2
57	Aerodynamics and airframe configurations of UAVs	CO 3	T1-6.1, 6.2
58	Characteristics of UAS aircraft types	CO 3	T1-10.4
59	Communications and navigation systems of UAS	CO 5	T1-6.1, 6.4
60	Control and stability of various UAVs	CO 6	T1-6.5, 6.7
DISCUSSION OF QUESTION BANK			
1	MODULE I: UAS-system composition, Design phases	CO 1	T1
2	MODULE II: Airframe configurations	CO 2	T1
3	MODULE III: Characteristics of aircraft types	CO 3	T1
4	MODULE IV: Communications and navigation	CO 5	T1
5	MODULE V: Control and stability	CO 6	T1

Signature of Course Coordinator **HOD,AE**
Dr.Praveen Kumar Balguri, Associate Professor

INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal, Hyderabad - 500 043

COURSE DESCRIPTION

Department	**AEROSPACE ENGINEERING**				
Course Title	**ADVANCED MATHEMATICS IN AEROSPACE ENGINEERING**				
Course Code	BAEC02				
Program	M.Tech				
Semester	I	AE			
Course Type	Core				
Regulation	IARE-PG21				
Course Structure	Theory			Practical	
	Lecture	Tutorials	Credits	Laboratory	Credits
	3	0	3	-	-
Course Coordinator	Mr.Shaik Shafi, Assistant Professor				

I COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites
10+2	-	-	Basic Principles of Algebra and Calculus
B.Tech	AHSC02	I	Linear Algebra and Calculus
B.Tech	AHSC07	II	Mathematical Transform Techniques

II COURSE OVERVIEW:

The course focuses on more advanced Engineering Mathematics topics which provide with the relevant mathematical tools required in the analysis of problems in engineering and scientific professions. The course introduces numerical methods, especially the interpolation, finite difference method for solving unknown values in different types and also includes finding Partial differential equations with applications in Parabolic, Hyperbolic, Elliptic Equations.

III MARKS DISTRIBUTION:

Subject	SEE Examination	CIE Examination	Total Marks
Advanced Mathematics in Aerospace Engineering	70 Marks	30 Marks	100

IV DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✓	PPT	✓	Chalk & Talk	✓	Assignments	x	MOOC
x	Seminars	x	Others				

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 three 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):
For each theory course the CIA shall be conducted by the faculty / teacher handling the course. CIA is conducted for a total of 30 marks, with 20 marks for Continuous Internal Examination (CIE), 05 marks for Assignment and 05 marks for Alternative Assessment Tool (AAT). Two CIE Tests are Compulsory and sum of the two tests, along with the scores obtained in the assignment / AAT shall be considered for computing the final CIA of a student in a given course.
The CIE Tests/Assignment /AAT shall be conducted by the course faculty with due approval from the HOD. Advance notification for the conduction of Assignment/AAT is mandatory and the responsibility lies with the concerned course faculty. CIA is conducted for a total of 30 marks .

Component	Theory			Total Marks
Type of Assessment	CIE Exam	Assignment	AAT	
CIA Marks	20	05	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 20 marks of 2 hours duration consisting of five descriptive type questions out of which four 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 COURSE OBJECTIVES:

The students will try to learn:

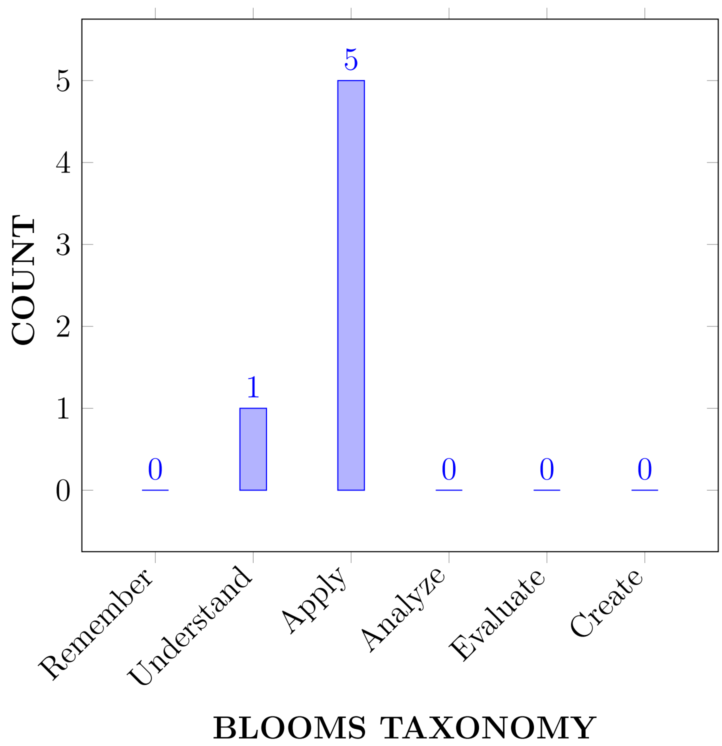
I	The numerical methods of interpolation and approximation of solutions for ordinary differential equations.
II	The mathematical approximation techniques of solutions for partial differential equations.
III	The concept of Parabolic, Hyperbolic and Elliptic equations.

VII COURSE OUTCOMES:

After successful completion of the course, students should be able to:

CO 1	**Calculate** the values of given equal and unequal spaced data by using Numerical method for the Functions.	Apply
CO 2	**make use of** Lagranze's method and method of separation of variables for solving linear and non linear partial differential equations.	Apply
CO 3	**Interpret** the boundary conditions for functions of Parabolic equations by using Finite Difference Method for Heat transfer problems.	Understand
CO 4	**Solve** the Parabolic equations by using Crank-Nicholson implicit method for Heat transfer problems.	Apply
CO 5	**Compute** the numerical solution of the Hyperbolic Equations by using method of characteristics for wave problems.	Apply
CO 6	**Apply** the properties of Elliptic Equations of curved boundary analysis by the five-point approximation for Poisson's equation	Apply

COURSE KNOWLEDGE COMPETENCY LEVEL



VIII PROGRAM OUTCOMES:

Program Outcomes	
PO 1	Identify, formulate, analyze and Design complex engineering problems, and design system components or processes by applying appropriate advanced principles of engineering activities and using modern tools
PO 2	Engage in life-long learning and professional development through self-study and continuing education in understanding the engineering solutions in global and management principles to manage projects in multidisciplinary environments.
PO 3	Demonstrate a degree of mastery in emerging areas of Aerospace Engineering such as Aerodynamics, Propulsion, Structure and Flight Dynamics
PO 4	Write and present a substantial technical report/document
PO 5	Independently carry out research/investigation and development work to solve practical problems
PO 6	Function effectively as a member or leader in diverse teams to carry out development work, produce solutions that meet the specified needs with frontier technologies and communicate effectively on complex engineering activities.

IX MAPPING OF EACH CO WITH PO(s):

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	✓	-	-	-	-	-
CO 2	✓	-	-	-	-	-
CO 3	✓	-	-	-	-	-
CO 4	✓	-	-	-	-	-
CO 5	✓	-	-	-	-	-
CO 6	✓	-	-	-	-	-

X COURSE ARTICULATION MATRIX (CO – PO MAPPING):

CO'S and PO'S on the scale of 0 to 3, 0 being no correlation, 1 being the low correlation, 2 being medium correlation and 3 being high correlation.

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	-	-	-	-	-
CO 2	3	-	-	-	-	-
CO 3	3	-	-	-	-	-
CO 4	3	-	-	-	-	-
CO 5	3	-	-	-	-	-
CO 6	3	-	-	-	-	-
TOTAL	18	-	-	-	-	-
AVERAGE	3	-	-	-	-	-

XI ASSESSMENT METHODOLOGY DIRECT:

CIE Exams	✓	SEE Exams	✓	Seminar and term paper	-
Laboratory Practices	-	Student Viva	-	Mini Project	-

XII ASSESSMENT METHODOLOGY INDIRECT:

✓	**End Semester OBE Feed Back**

XIII SYLLABUS:

MODULE I	**INTERPOLATION**
	Interpolation: Finite differences, forward differences, backward differences and central differences; Symbolic relations; Newton‘s forward interpolation, Newton‘s backward interpolation; Gauss forward central difference formula, Gauss backward central difference formula; Interpolation of unequal intervals: Lagrange‘s interpolation.
MODULE II	**PARTIAL DIFFERENTIAL EQUATIONS**
	Formation of partial differential equations by elimination of arbitrary constants and arbitrary functions, solutions of first order linear equation by Lagrange method; method of separation of variables.
MODULE III	**PARABOLIC EQUATIONS**
	Introduction to finite difference formula; Parabolic equations: Introduction, explicit finite difference approximation to one dimensional equation, Crank-Nicholson implicit method, derivation for boundary conditions.
MODULE IV	**HYPERBOLIC EQUATIONS**
	Analytical solution of first order quasi linear equation. Numerical integration along a characteristic lax wenderoff explicit method. CFI condition Wenderoff's implicit approximation, propagation of discontinues, numerical solution by the method of characteristics.
MODULE V	**ELLIPTIC EQUATIONS**
	Introduction, finite differences in polar co-ordinates, formulas for derivative near a curved boundary analysis of the discretization error of the five-point approximation to Poisson's equation over a rectangle.

TEXT BOOKS

1. G. D. Smith, "Numerical Solution of partial differential equations, finite Differences methods", Brunel University, Clarendon Press Oxford, 3^{rd} Edition, 1985.

2. Joe D. Hoffman, "Numerical Methods for Engineers and scientists", Tata McGraw Hill, 2^{nd} Edition, 2001.

REFERENCE BOOKS:

1. A. R. Mitchel and D. F. Griffiths, “The Finite Difference Methods in Partial Differential equation”, John Wiley, 1^{st} Edition, 1980.
2. Larry J. Segerlind, “Applied Finite Element Analysis”, John Wiley, 2^{nd} Edition, 1984.

WEB REFERENCES:

1. https://www.e-booksdirectory.com/details.php?ebook=2059
2. https://www.e-booksdirectory.com/details.php?ebook=11114
3. https://nptel.ac.in/courses/127/106/127106019/

COURSE WEB PAGE:

1. lms.iare.ac.in

XIV COURSE PLAN:

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

S.No	Topics to be covered	CO's	Reference
OBE DISCUSSION			
1	Course Description on Outcome Based Education (OBE): Course Objectives, Course Outcomes (CO), Program Outcomes (PO) and CO-PO Mapping	-	-
CONTENT DELIVERY (THEORY)			
1	Theory of Interpolation	CO 1	T2:32.1 R1:4.1
2	Types of Interpolation	CO 1	T2:32.1 R1:4.2
3	Symbolic Relations	CO 1	T2:32.1 R1:4.3
4	Introduction - Newton's Interpolation	CO 1	T2:32.1 R1:4.3
5	Newton's Forward Interpolation	CO 1	T2:32.5 R1:4.6
6	Newton's Backward Interpolation	CO 1	T2:32.5 R1:4.6
7	Introduction – Gauss Interpolation	CO 1	T2:32.4 R1:4.5
8	Gauss Forward Central Difference Formula	CO 1	T2:32.7 R1:4.8
9	Gauss Backward Central Difference Formula	CO 1	T2-7.1 R1:7.4
10	Interpolation of Unequal Intervals	CO 1	T2-7.1 R1:7.4

11	Lagrange's Interpolation	CO 1	T2-7.1 R1:7.4
12	Symbolic Relations	CO 1	T2:32.1 R1:4.2
13	Newton's Forward Interpolation	CO 1	T2:32.1 R1:4.3
14	Newton's Backward Interpolation	CO 1	T2:32.1 R1:4.3
15	Gauss Forward Central Difference Formula	CO 1	T2-7.1 R1:7.4
16	Gauss Backward Central Difference Formula	CO 1	T2-7.1 R1:7.4
17	Lagrange's Interpolation	CO 1	T2:7.1 R1:7.4
18	Interpolation: Forward, Backward and Central Differences	CO 1	T3-2.5 R1:2.8
19	Introduction – Partial Differential Equations	CO 2	T2:7.1 R1:7.4
20	Theory of Partial Differential Equations	CO 2	T2:7.1 R1:7.4
21	Formation of Partial Differential Equations by elimination of arbitrary constants	CO 2	T3-2.9 R1:2.1
22	Formation of Partial Differential Equations by elimination arbitrary functions in single function	CO 2	T3-2.5 R1:2.8
23	Formation of Partial Differential Equations by elimination arbitrary functions in two functions	CO 2	T3-2.5 R1:2.8
24	Solutions of First Order Linear Equation	CO 2	T3-2.5 R1:2.8
25	Solutions of First Order Linear Equation - Lagrange method	CO 2	T3-2.5 R1:2.8
26	Theory of Separation of Variables	CO 2	T3-2.5 R1:2.8
27	Method of Separation of Variables	CO 2	T3-2.61 R1:2.10
28	Introduction to Finite Difference Formula	CO 2	T1-7.1 R2:7.5
29	Formation of Partial Differential Equations by elimination of arbitrary constants	CO 2	T2:7.1 R1:7.4
30	Formation of Partial Differential Equations by elimination arbitrary functions	CO 2	T3-2.5 R1:2.8
31	Solutions of First Order Linear Equation	CO 2	T3-2.5 R1:2.8
32	Solutions of First Order Linear Equation - Lagrange method	CO 2	T3-2.5 R1:2.8

33	Theory of Separation of Variables	CO 2	T3-2.5 R1:2.8
34	Formation of Partial Differential Equations by elimination of arbitrary constants	CO 2	T2:7.1 R1:7.4
35	Formation of Partial Differential Equations by elimination arbitrary functions	CO 2	T3-2.5 R1:2.8
36	Partial Differential Equations	CO 2	T3-2.5 R1:2.8
37	Introduction - Parabolic Equations	CO 3	T3-2.61 R1:2.10
38	Theory of Parabolic Equations	CO 3	T1-7.1 R2:7.6
39	Explicit Finite Difference Approximation to One Dimensional Equation	CO 3	T1-7.1 R2:7.7
40	Parabolic Equations	CO 3	T3-2.61 R1:2.10
41	Parabolic Equations	CO 3, 4	T3-2.5 R1:2.8
42	Introduction - Crank-Nicholson	CO 4	T3-2.5 R1:2.8
43	Theory of Crank-Nicholson Implicit Method	CO 4	T3-2.5 R1:2.8
44	Crank-Nicholson Implicit Method	CO 4	T2:7.1 R1:7.4
45	Hyperbolic Equations	CO 5	T3-2.9 R1:2.1
46	Introduction - Hyperbolic Equations	CO 5	T3-2.5 R1:2.8
47	Theory of Hyperbolic Equations	CO 5	T3-2.5 R1:2.8
48	Analytical Solution of First Order Quasi Linear Equation	CO 5	T2-7.1 R1:7.4
49	Numerical integration along a characteristic lax wenderoff explicit method	CO 5	T2:7.1 R1:7.4
50	CFI condition Wenderoff's implicit approximation	CO 5	T2:7.1 R1:7.4
51	Propagation of Discontinues	CO 5	T3-2.9 R1:2.1
52	Numerical Solution by the Method of Characteristics	CO 5	T3-2.5 R1:2.8
53	Introduction - Elliptic Equations	CO 6	T3-2.5 R1:2.8
54	Theory of Elliptic Equations	CO 6	T2:7.1 R1:7.4

55	Introduction - Polar Co-Ordinates	CO 6	T3-2.9 R1:2.1
56	Finite Differences in Polar Co-Ordinates	CO 6	T3-2.5 R1:2.8
57	Formulas for Derivative Near a Curved Boundary Analysis	CO 6	T2:7.1 R1:7.4
58	Discretization Error of the Five-Point Approximation	CO 6	T3-2.9 R1:2.1
59	Polman's Equation Over a Rectangle.	CO 6	T3-2.5 R1:2.8
60	Elliptic Equations	CO 6	T3-2.5 R1:2.8
	DISCUSSION OF QUESTION BANK		
1	Module: I-Interpolation	CO 1	T1
2	Module: II- Partial Differential Equations	CO 2	T1
3	Module: III-Parabolic Equations	CO 3,4	T1
4	Module: IV- Hyperbolic Equations	CO 5	T1
5	Module: V-Elliptic Equations	CO 6	T1

Signature of Course Coordinator **HOD, AE**
Mr.Shaik Shafi, Assistant Professor

INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal, Hyderabad - 500 043
COURSE DESCRIPTION

Branch	**AEROSPACE ENGINEERING**				
Course Title	**ADVANCED COMPUTATIONAL AERODYNAMICS**				
Course Code	BAEC05				
Program	M.Tech				
Semester	I	AE			
Course Type	Elective				
Regulation	IARE- PG-21				
Course Structure	Theory			Practical	
	Lecture	Tutorials	Credits	Laboratory	Credits
	3	-	3	-	-
Course Coordinator	Dr. Bodavula Aslesha, Assistant Professor				

I COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites
B.Tech	AAE004	IV	Low speed Aerodynamics
B.Tech	AHS011	II	Mathematical Transform Techniques
B.Tech	AAE008	V	High Speed Aerodynamics
B.Tech	AAE013	VI	Computational Aerodynamics

II COURSE OVERVIEW:

This course deals with the theory of fluid flow (subsonic and supersonic) and those behind the commercial fluid dynamic software available today. It starts with the mathematical basics such as the spatial resolution methods for numerical solutions of partial differential equations (Boundary Value Problems and Initial Boundary Value Problems) and time dependent methods. Followed by boundary conditions for the formation of boundary layers in different conditions. Later comes the analytical method for solving supersonic flow i.e., Method of Characteristics. Lastly, the quintessential method for solving flow around an airfoil (Panel Methods) is addressed.

III MARKS DISTRIBUTION:

Subject	SEE Examination	CIE Examination	Total Marks
Advanced Computational Aerodynamics	70 Marks	30 Marks	100

IV DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✓	PPT	✓	Chalk & Talk	✓	Assignments	x	MOOC
x	Seminars	x	Others				

V EVALUATION METHODOLOGY:

Each theory course will be evaluated for a total of 100 marks, out of which 30 marks for Continuous Internal Assessment (CIA) and 70 marks for Semester End Examination (SEE). **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 three 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):
For each theory course the CIA shall be conducted by the faculty / teacher handling the course. CIA is conducted for a total of 30 marks, with 20 marks for Continuous Internal Examination (CIE), 05 marks for Assignment and 05 marks for Alternative Assessment Tool (AAT). Two CIE Tests are Compulsory and sum of the two tests, along with the scores obtained in the assignment / AAT shall be considered for computing the final CIA of a student in a given course.

The CIE Tests/Assignment /AAT shall be conducted by the course faculty with due approval from the HOD. Advance notification for the conduction of Assignment/AAT is mandatory and the responsibility lies with the concerned course faculty. CIA is conducted for a total of 30 marks (Table 1).

Component	Theory			Total Marks
Type of Assessment	CIE Exam	Assignment	AAT	
CIA Marks	20	05	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 five descriptive type questions out of which four 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 COURSE OBJECTIVES:

The students will try to learn:

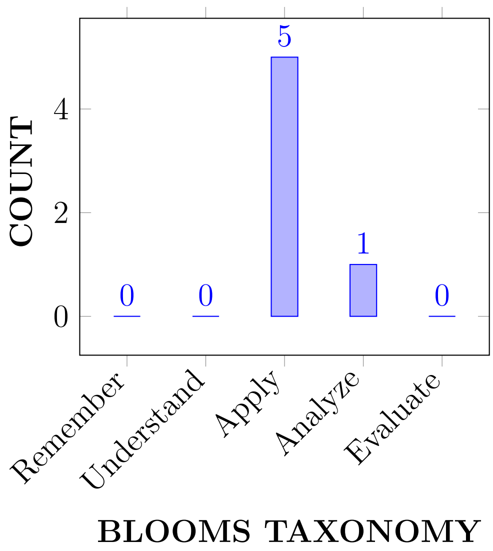
I	The fundamental principles of numerical methods and panel methods for solving the compressible flow problems.
II	The initial methods applied in the process of CFD tools development, their advantages and disadvantages over modern developed methods.
III	The different methods evolved in analyzing the numerical stability of solutions of supersonic nozzle flows.
IV	The techniques in time marching steps to sustain the accurate solution for flow-field problems

VII COURSE OUTCOMES:

After successful completion of the course, students should be able to:

CO 1	**Apply** the flux approach, flux vector splitting, upwind reconstruction-evolution methods for solving the compressible flow problems using Euler's equations.	Apply
CO 2	**Make use of** the explicit, implicit, time split methods and approximate factorization schemes for obtaining the stabilized numerical solution of subsonic and supersonic nozzle flows	Apply
CO 3	**Develop** the boundary layer transformation equations for steady external flows on airfoil, wings and aircraft using finite difference method.	Apply
CO 4	**Analyze** the structured, unstructured grids and dummy cells using physical boundary conditions for attaining the accurate results of fluid flow problems.	Analyze
CO5	**Identify** the characteristic lines and compatibility equations for designing the supersonic nozzle having shock free and isentropic flow	Apply
CO6	**Utlize** the effects of compressibility and viscosity on thin airfoil for establishing the numerical solution in aerodynamic problems	Apply

COURSE KNOWLEDGE COMPETENCY LEVEL



VIII PROGRAM OUTCOMES:

Program Outcomes	
PO 1	Identify, formulate, analyze and Design complex engineering problems, and design system components or processes by applying appropriate advanced principles of engineering activities and using modern tools
PO 2	Engage in life-long learning and professional development through self-study and continuing education in understanding the engineering solutions in global and management principles to manage projects in multidisciplinary environments.
PO 3	Demonstrate a degree of mastery in emerging areas of Aerospace Engineering such as Aerodynamics, Propulsion, Structure and Flight Dynamics
PO 4	Write and present a substantial technical report/document
PO 5	Independently carry out research/investigation and development work to solve practical problems
PO 6	Function effectively as a member or leader in diverse teams to carry out development work, produce solutions that meet the specified needs with frontier technologies and communicate effectively on complex engineering activities.

IX MAPPING OF EACH CO WITH PO(s):

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	✓	-	✓	-	-	-
CO 2	✓	-	✓	-	-	-
CO 3	✓	-	✓	-	-	-
CO 4	✓	-	✓	-	-	-
CO 5	✓	-	✓	-	-	-
CO 6	✓	-	✓	-	-	-

X COURSE ARTICULATION MATRIX (CO – PO MAPPING):

CO'S and PO'S on the scale of 0 to 3, 0 being no correlation, 1 being the low correlation, 2 being medium correlation and 3 being high correlation.

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	-	1	-	-	-
CO 2	3	-	1	-	-	-
CO 3	3	-	1	-	-	-
CO 4	3	-	3	-	-	-
CO 5	3	-	1	-	-	-
CO 6	3	-	1	-	-	-
TOTAL	18	-	8	-	-	-
AVERAGE	3	-	1.3	-	-	-

XI ASSESSMENT METHODOLOGY DIRECT:

CIE Exams	✓	SEE Exams	✓	Seminar and term paper	-
Laboratory Practices	-	Student Viva	-	Mini Project	-

XII ASSESSMENT METHODOLOGY INDIRECT:

✓	**End Semester OBE Feed Back**

XIII SYLLABUS:

MODULE I	**NUMERICAL SOLUTIONS**
	Euler equations: Flux approach, Lax-Wendroff method, basic principles of upwind schemes, flux vector splitting, Steger Warming flux vector splitting, Van Leer flux vector splitting, Upwind reconstruction, evolution, Goduno's first order upwind method, Roe's first order upwind method.
MODULE II	**TIME DEPENDENT METHODS**
	Stability of solution, explicit methods, FTFS, FTCS, FTBS, Leapfrog method, Lax method. Implicit methods: Euler's FTCS, Crank Nicolson method, description of Lax- Wendroff scheme, McCormack two step predictor-corrector method, description of time split methods, approximate factorization schemes.

MODULE III	**BOUNDAY CONDITIONS**
	Boundary Layer Equations: Setting up the boundary layer equations, flat plate boundary layer solution, boundary layer transformations, explicit and implicit discretization, solution of the implicit difference equations, integration of the continuity equation, boundary layer edge and wall shear stress, Keller-box scheme Concept of dummy cells, solid wall inviscid flow, viscous flow, farfield concept of characteristic variables, modifications for lifting bodies inlet outlet boundary, injection boundary, symmetry plane, coordinate cut, periodic boundaries, interface between grid blocks, flow gradients at boundaries of unstructured grids.
MODULE IV	**METHOD OF CHARACTERISTICS**
	Philosophy of method of characteristics, determination of characteristic lines, two dimensional irrotational flow, determination of compatibility equations, unit processes, supersonic nozzle design by the method of characteristics, supersonic wind tunnel nozzle, minimum length nozzles, domain of dependence and range of influence.
MODULE V	**PANEL METHODS**
	Basic formulation, boundary conditions, physical considerations, reduction of a problem to a set of linear algebraic equations, aerodynamic loads, preliminary considerations prior to establishing numerical solution, steps toward constructing a numerical solution, solution of thin airfoil with lumped vortex filament, accounting for effects of compressibility and viscosity.

TEXTBOOKS

1. Culbert B Laney "Computational Gas Dynamics" Cambridge University Press, 1998
2. Tannehill John C, Anderson Dale A, Pletcher Richard H, "Computational Fluid Mechanics and Heat Transfer", Taylor and Francis, 2nd Edition, 1997.
3. Chung T G, "Computational Fluid Dynamics", Cambridge University Press, 2nd Edition, 2010.
4. Katz Joseph and Plotkin Allen, "Low-Speed Aerodynamics", Cambridge University Press, 2nd Edition, 2006.

REFERENCE BOOKS:

1. J. Blazek, "Computational Fluid Dynamics: Principles and Applications" Elseiver, 2001
2. Anderson J D, "Modern Compressible Fluid Flow", McGraw Hill 2nd Edition,1990
3. Anderson J D, "Fundamentals of Aerodynamics", Tata McGraw Hill, 5th Edition, 2010.
4. Anderson J D, "Computational Fluid Dynamics", McGraw Hill, 1995.
5. Rathakrishnan E, "Gas Dynamics", Prentice-Hall India, 2004.

WEB REFERENCES:

1. https://www.afs.enea.it/project/neptunius/docs/fluent/html/ug/main_pre.htm

COURSE WEB PAGE:

1.

XIV COURSE PLAN:

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

S.No	Topics to be covered	CO's	Reference
OBE DISCUSSION			
1	Course Description on Outcome Based Education (OBE): Course Objectives, Course Outcomes (CO), Program Outcomes (PO) and CO-PO Mapping	-	
CONTENT DELIVERY (THEORY)			
1	Introduction to discretization methods	CO 1	T1 : 18
2	Euler equations: Flux approach	CO 1	T1 : 18.1
3	Lax-Wendroff method	CO 1	T1: 18.1.1
4	Basic principles of upwind schemes	CO 1	T1: 13
5	Flux vector splitting	CO 1	T1:18.2.1
6	Steger Warming flux vector splitting	CO 1	T1:18.2.1
7	Van Leer flux vector splitting	CO 1	T1:18.2.2
8	Upwind reconstruction, evolution	CO 1	T1:18.3
9	Godunov's first order upwind method	CO 1	T1 :18.3.1, 18.3.2
10	Roe's first order upwind method	CO 1	T1 :18.3.1, 18.3.2
11	Stability solution, Explicit methods	CO 2	T2:4.1
12	FTFS, FTCS, FTBS	CO 2	T2:4.1.1
13	Leapfrog methods	CO 2	T2:4.1.5, 4.1.3
14	Lax method	CO 2	T2:4.1.5, 4.1.3
15	Implicit method	CO 2	T2:4.1.4
16	Euler's FTCS	CO 2	T2:4.1.4
17	Crank Nicolson method	CO 2	T2:4.2.4
18	Description of Lax- Wendroff scheme,	CO 2	T2:4.1.6
19	McCormack two step predictor corrector method	CO 2	T2:4.1.8
20	McCormack two step predictor corrector method	CO 2	T2:4.1.8
21	Description of time split methods,	CO 2	T2:4.5.8
22	Approximate factorization schemes	CO 2	T2:4.5
23	Approximate factorization schemes	CO 2	T2:4.5
24	Boundary Layer Equations	CO 3	T2:5.3
25	Setting up the boundary layer equations	CO 3	T2:5.3
26	flat plate boundary layer solution	CO 3	T2:5.3.2
27	Boundary layer transformations	CO 3	T2:5.3.2
28	Explicit discretization	CO 3	R4:4.4
29	Implicit discretization	CO 3	R4:4.4

30	Solution of the implicit difference equations	CO 3	R4:4.4
31	integration of the continuity equation	CO 3	T2:4.2.8
32	boundary layer edge and wall shear stress	CO 3	T2:4.2.8
33	Keller-box scheme	CO 3	T2:4.2.8
34	Concept of dummy cells.	CO 3	T2:4.2.8
35	solid wall inviscid flow, viscous flow	CO 4	R1:8.1, 8.2
36	farfield variables	CO 4	R1:8.1, 8.2
37	concept of characteristic variables	CO 4	R1:8.1, 8.2
38	Modifications for lifting bodies	CO 4	R1:8.3 - 8.6
39	inlet outlet boundary,	CO 4	R1:8.3 - 8.6
40	injection boundary	CO 4	R1:8.3 - 8.6
41	symmetry plane, coordinate cut	CO 4	R1:8.3 - 8.6
42	Periodic boundaries	CO 4	R1:8.7, 8.8
43	Interface between grid blocks	CO 4	R1:8.7, 8.8
44	Flow gradients at boundaries of unstructured grids	CO 4	R1:8.9
45	Philosophy of method of characteristics	CO 5	R2:11.2
46	Determination of characteristic lines, two dimensional irrotational flow	CO 5	R2:11.3
47	two dimensional irrotational flow	CO 5	R2:11.3
48	Determination of compatibility equations, Unit processes	CO 5	R2:11.4, 11.5
49	supersonic nozzle design by the method of characteristics	CO 5	R2:11.7
50	Supersonic wind tunnel nozzle	CO 5	R2:11.7
51	Minimum length nozzles	CO 5	R2:11.8
52	Domain of dependence and range of influence	CO 5	R2:11.6
53	Basic formulation, boundary conditions	CO 6	T4:9.1, 9.2
54	Physical considerations	CO 6	T4:9.3
55	Reduction of a problem to a set of linear algebraic equations	CO 6	T4:9.4
56	Aerodynamic Loads	CO 6	T4: 9.5
57	Preliminary considerations prior to establishing numerical solution	CO 6	T4: 9.6
58	Steps toward constructing a numerical solution	CO 6	T3:9.7
59	Solution of thin airfoil with lumped vortex filament	CO 6	T3:9.8
60	Accounting for effects of compressibility and viscosity	CO 6	T3:9.9
DISCUSSION OF QUESTION BANK			
61	Module: I- Numerical Solutions	CO 1	T1
62	Module: II- Time Dependent Methods	CO 2	T2, R1

63	Module: III- Boundary Conditions	CO3,4	R1
64	Module: IV- Method of Characteristics	CO 5	R2
65	Module: V- Panel Methods	CO 6	T4

Signature of Course Coordinator **HOD,AE**
Dr.Bodavula Aslesha, Assistant Professor

INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal, Hyderabad - 500 043

AERONAUTICAL ENGINEERING
COURSE DESCRIPTION

Course Title	Advanced Computational Aerodynamics Laboratory				
Course Code	BAEC11				
Program	M.Tech				
Semester	I	AE			
Course Type	Laboratory				
Regulation	IARE-PG21				
Course Structure	Theory			Practical	
	Lecture	Tutorials	Credits	Laboratory	Credits
	-	-	-	4	2
Course Coordinator	Dr. Bodavula Aslesha, Assistant Professor				

I COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites
B.Tech	AAE004	IV	Low speed Aerodynamics
B.Tech	AAE008	V	High Speed Aerodynamics
B.Tech	AAE013	VI	Computational Aerodynamics

II COURSE OVERVIEW:

Computational Fluid Dynamics (CFD) is a modern tool based numerical solution for equations of fundamental laws of fluid flows and heat transfer process. This lab course Advanced computational aerodynamics laboratory, focus on the students to get acquaint with the procedure for computational fluid dynamics simulation using a computational fluid dynamics solver. Learners have the experience in computing the aerodynamic problems and understand the flow phenomenon. Learners able to produce structured and unstructured grids on simple and complex geometries. The students will have hands on experience on setting up the aerodynamic problems like low Reynolds number flows using computational fluid dynamic solver. This course provides the information that enables the skills to analyze computational fluid dynamic solutions through post processing of the results. In addition, it will be a first step into the large and escalating research in the area of computational aerodynamics.

III MARKS DISTRIBUTION:

Subject	SEE Examination	CIE Examination	Total Marks
Advanced Computational Aerodynamics laboratory	70 Marks	30 Marks	100

IV DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✓	Demo Video	✓	Lab Worksheets	✓	Viva Questions	✓	Probing further Questions

V EVALUATION METHODOLOGY:

Each lab will be evaluated for a total of 100 marks consisting of 30 marks for internal assessment and 70 marks for semester end lab examination. Out of 30 marks of internal assessment, continuous lab assessment will be done for 20 marks for the day to day performance and 10 marks for the final internal lab assessment. The semester end lab examination for 70 marks shall be conducted by two examiners, one of them being a internal examiner and another is external examiner, both nominated by the Principal from the panel of experts recommended by Chairman, BOS.
All the drawing related courses are evaluated in line with lab courses. The distribution shall be 30 marks for internal evaluation (20 marks for day–to–day work, and 10 marks for internal tests) and 70 marks for semester end lab examination. There shall be ONE internal test for 10 marks each in a semester.
The emphasis on the experiments is broadly based on the following criteria given in Table: 1

	Experiment Based	Programming based
20 %	Objective	Purpose
20 %	Analysis	Algorithm
20 %	Design	Programme
20 %	Conclusion	Conclusion
20 %	Viva	Viva

Continuous Internal Assessment (CIA):

CIA is conducted for a total of 30 marks (Table 1), with 20 marks for continuous lab assessment during day to day performance, 10 marks for final internal lab assessment.

Component	**Laboratory**		**Total Marks**
Type of Assessment	**Day to day performance**	**Final internal lab assessment**	
CIA Marks	20	10	30

Continuous Internal Examination (CIE):

One CIE exams shall be conducted at the end of the 16th week of the semester. The CIE exam is conducted for 10 marks of 3 hours duration.

1. **Experiment Based**

Objective	Analysis	Design	Conclusion	Viva	Total
-	-	-	-	-	-

2. **Programming Based**

Objective	Analysis	Design	Conclusion	Viva	Total
2	2	2	2	2	10

VI COURSE OBJECTIVES:

The students will try to learn:

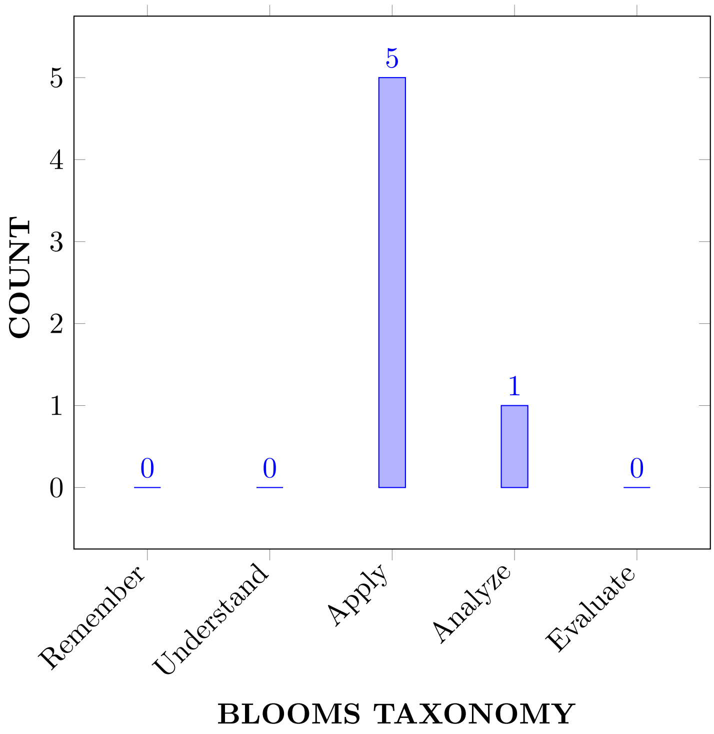
I	The formulation of the problem, discretization and suitable boundary conditions by using numerical methods.
II	The basic computational coding techniques that provides the data and contours in the predicting the performance of fluid systems.
III	The environment and usage of commercial Computational Fluid Dynamics packages for analyzing fluid flows.

VII COURSE OUTCOMES:

After successful completion of the course, students should be able to:

CO 1	**Apply** the philosophy behind the computational fluid dynamics for recognizing flow properties in solving fluids and heat transfer problems.	Apply
CO 2	**Select** the structured, unstructured mesh and multi-blocking strategy in basic, complex geometries and flow domains for computing aerodynamic characteristics.	Apply
CO 3	**Identify** the appropriate physical boundary conditions for attaining the precise results of fluid flow over a body.	Apply
CO 4	**Choose** the suitable numerical modelling and schemes for computational simulations of aerodynamics and thermo-fluid problems using ANSYS.	Apply
CO 5	**Analyze** the numerical solution of fluid flow problems using flow visualization Software's for recognizing the flow physics in and around the supersonic intake and free jet.	Anlayze
CO 6	**Develop** the numerical code for one dimensional heat and wave equation using explicit finite difference method.	Apply

COURSE KNOWLEDGE COMPETENCY LEVEL



VIII PROGRAM OUTCOMES:

Program Outcomes	
PO 1	Identify, formulate, analyze and Design complex engineering problems, and design system components or processes by applying appropriate advanced principles of engineering activities and using modern tools
PO 2	Engage in life-long learning and professional development through self-study and continuing education in understanding the engineering solutions in global and management principles to manage projects in multidisciplinary environments.
PO 3	Demonstrate a degree of mastery in emerging areas of Aerospace Engineering such as Aerodynamics, Propulsion, Structure and Flight Dynamics
PO 4	Write and present a substantial technical report/document
PO 5	Independently carry out research/investigation and development work to solve practical problems
PO 6	Function effectively as a member or leader in diverse teams to carry out development work, produce solutions that meet the specified needs with frontier technologies and communicate effectively on complex engineering activities.

IX HOW PROGRAM OUTCOMES ARE ASSESSED:

Program		Strength	Proficiency Assessed by
PO1	Identify, formulate, analyze and Design complex engineering problems, and design system components or processes by applying appropriate advanced principles of engineering activities and using modern tools	2	CIE, SEE
PO3	Demonstrate a degree of mastery in emerging areas of Aerospace Engineering such as Aerodynamics, Propulsion, Structure and Flight Dynamics	2	CIE, SEE
PO4	Write and present a substantial technical report/document	1	CIE, SEE
PO 5	Independently carry out research/investigation and development work to solve practical problems	2	CIE, SEE

3 = High; 2 = Medium; 1 = Low

X MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	2	-	2	1	2	-
CO 2	2	-	2	1	2	-
CO 3	2	-	2	1	2	-
CO 4	2	-	2	1	2	-
CO 5	2	-	2	1	2	-
CO 6	2	-	2	1	2	-

XI ASSESSMENT METHODOLOGY DIRECT:

CIE Exams	✓	SEE Exams	✓	Seminars	-
Laboratory Practices	✓	Student Viva	✓	Certification	-

XII ASSESSMENT METHODOLOGY INDIRECT:

✓	Early Semester Feedback	✓	End Semester OBE Feedback
X	Assessment of Mini Projects by Experts		

XIII SYLLABUS:

WEEK I	**INTRODUCTION**
	Introduction to computational aerodynamics, the major theories, approaches and methodologies used in computational aerodynamics. Applications of computational aerodynamics for classical aerodynamics problems.
WEEK II	**INTRODUCTION TO ANSYS CFX**
	Introduction to gambit, geometry creation, suitable meshing types and boundary conditions.
WEEK III	**INTRODUCTION TO ANSYS FLUENT**
	Introduction to fluent, boundary conditions, solve conditions and post processing results.
WEEK IV	**FLOW THROUGH NOZZLE**
	Flow Through Nozzle.
WEEK V	**FLOW THROUGH SUPER SONIC INTAKE**
	Flow Through Supersonic Intake.
WEEK VI	**SUPERSONIC FREEJET**
	Flow over a Supersonic FreeJet.
WEEK VII	**SHOCK BOUNDARY LAYER INTERACTION**
	Shock Boundary Layer Interaction
WEEK VIII	**FLOW OVER A RE-ENTRY VEHICLES**
	Flow overare-entry vehicle .
WEEK IX	**SUPER SONIC FLOW OVER A CONE**
	Flow over wedge body at supersonic Mach number; observe the shock wave phenomena and change of properties across the shockwave.
WEEK X	**THERMAL TESTING TURBINE BLADE**
	Flow over a Missile body.
WEEK XI	**CASCADE TESTING COMPRESSOR BLADE**
	Solution for the following equations using finite difference method 2. One dimensional wave equation using explicit method of lax. 3. One dimensional heat conduction equation using explicit method.
WEEK XII	**EXAMINATION**
	Examination .

TEXTBOOKS

1. ANSYS Fluent Theory and Tutorial Guide.
2. ICEM CFD Lab Manual
3. Anderson, J.D., Jr., Computational Fluid Dynamics The Basics with Applications, McGraw-Hill Inc, 1st Edition 1998.
4. Hoffmann, K. A. and Chiang, S. T., —Computational Fluid Dynamics for Engineers, 4th Edition, Engineering Education Systems (2000).

REFERENCE BOOKS:

1. Hirsch, C., —Numerical Computation of Internal and External Flows: The Fundamentals of Computational Fluid Dynamics, Vol. I, 2nd Edition., Butterworth-Heinemann (2007).
2. JAF. Thompson, Bharat K. Soni, Nigel P. Weatherill —Grid generation, 1st Edition 2000.

XIV COURSE PLAN:

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

S.No	Topics to be covered	CO's	Reference
1	Introduction.	CO 1	R1: 2.3
2	Introduction to gambit, geometry creation, suitable meshing types and boundary conditions.	CO 2	R2: 2.6
3	Introduction to fluent, boundary conditions, solve conditions and post processing results.	CO 3, CO 4	R1: 2.6
4	Flow Through Nozzle.	CO 2, CO 3,CO 4,CO 5	R1: 2.7
5	Flow Through Supersonic Intake.	CO 2, CO 3, CO 4,CO 5	R1: 2.22
6	Flow over a Supersonic FreeJet.	CO 2, CO 3, CO 4, CO 5	R1: 2.25
7	Shock Boundary Layer Interaction	CO 2, CO 3, CO 4,CO 5	R1: 2.55
8	Flow overare-entry vehicle.	CO 2, CO 3, CO 4,CO 5	R1: 2.3
9	Flow over wedge body at supersonic Mach number; observe the shock wave phenomena and change of properties across the shockwave.	CO 4,CO 5	R1: 2.6
10	Flow over a Missile body.	CO 3,CO 4, CO 5	R1: 2.8
11	Solution for the following equations using finite difference method 2. One dimensional wave equation using explicit method of lax. 3. One dimensional heat conduction equation using explicit method.	CO 1, CO 3,CO 4, CO 5	R1:2.18
12	Examination .	CO 1, CO 6	R5:2.22

XV EXPERIMENTS FOR ENHANCED LEARNING (EEL):

S.No	Design Oriented Experiments
1	Aerodynamic analysis on wing.
2	Flow Through supersonic channel.
3	Subsonic flow in a convergent divergent nozzle.
4	Analysis of heat pipe using volume of fluid method.
5	Flow through spike at high mach number

Signature of Course Coordinator **HOD,AE**
Dr. Bodavula Aslesha, Assistant Professor

INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal, Hyderabad - 500 043

AERONAUTICAL ENGINEERING
COURSE DESCRIPTION

<table>
<tr><td>Course Title</td><td colspan="5">COMPUTATIONAL AEROSPACE ENGINEERING LABORATORY</td></tr>
<tr><td>Course Code</td><td colspan="5">BAEC12</td></tr>
<tr><td>Program</td><td colspan="5">M.Tech</td></tr>
<tr><td>Semester</td><td>I</td><td colspan="4">AE</td></tr>
<tr><td>Course Type</td><td colspan="5">Laboratory</td></tr>
<tr><td>Regulation</td><td colspan="5">IARE-PG21</td></tr>
<tr><td rowspan="3">Course Structure</td><td colspan="3">Theory</td><td colspan="2">Practical</td></tr>
<tr><td>Lecture</td><td>Tutorials</td><td>Credits</td><td>Laboratory</td><td>Credits</td></tr>
<tr><td>-</td><td>-</td><td>-</td><td>4</td><td>2</td></tr>
<tr><td>Course Coordinator</td><td colspan="5">Mr. A Rathan Babu, Assistant Professor</td></tr>
</table>

I COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites
B.Tech	AAEC06	IV	Aerospace Structures

II COURSE OVERVIEW:

This course aims to enhance the skills through a detailed introduction to the state-of-the-art computational methods and their applications for digital age aerospace engineering applications. It provides a unique opportunity for cross-disciplinary education and knowledge transfer in the computational engineering of fluid and solid mechanics for aerospace industrial applications. Focusing on fully integrated digital design for aerospace applications, you will be able to understand and implement numerical methods on various computing platforms for aerospace applications.

III MARKS DISTRIBUTION:

Subject	SEE Examination	CIE Examination	Total Marks
Computational Aerospace Engineering Laboratory	70 Marks	30 Marks	100

IV DELIVERY / INSTRUCTIONAL METHODOLOGIES:

X	Demo Video	✓	Lab Worksheets	✓	Viva Questions	✓	Probing further Questions

V EVALUATION METHODOLOGY:

Each laboratory will be evaluated for a total of 100 marks consisting of 30 marks for internal assessment and 70 marks for semester end lab examination. Out of 30 marks of internal assessment, continuous lab assessment will be done for 20 marks for the day today performance and 10 marks for the final internal lab assessment.

Semester End Examination (SEE): The semester end lab examination for 70 marks shall be conducted by two examiners, one of them being Internal Examiner and the other being External Examiner, both nominated by the Principal from the panel of experts recommended by Chairman, BOS. The emphasis on the experiments is broadly based on the following criteria given in Table: 1

	Experiment Based	Programming based
20 %	Objective	Purpose
20 %	Analysis	Algorithm
20 %	Design	Programme
20 %	Conclusion	Conclusion
20 %	Viva	Viva

Continuous Internal Assessment (CIA):

CIA is conducted for a total of 30 marks (Table 1), with 20 marks for continuous lab assessment during day to day performance, 10 marks for final internal lab assessment.

Component	**Laboratory**		**Total Marks**
Type of Assessment	**Day to day performance**	**Final internal lab assessment**	
CIA Marks	20	10	30

Continuous Internal Examination (CIE):

One CIE exams shall be conducted at the end of the 16th week of the semester. The CIE exam is conducted for 10 marks of 3 hours duration.

1. **Experiment Based**

Objective	Analysis	Design	Conclusion	Viva	Total
2	2	2	2	2	10

2. **Programming Based**

Objective	Analysis	Design	Conclusion	Viva	Total
-	-	-	-	-	-

VI COURSE OBJECTIVES:

The students will try to learn:

I	The basic MATLAB software and use them to solve structural aero dynamic and flight control system problems.

II	Basics of plotting in MATLAB both in two dimensional and three dimensional.
III	Coding for solving structural response problems, aerodynamic simulation problems and flight control system analysis and design

VII COURSE OUTCOMES:

After successful completion of the course, students should be able to:

CO 1	**Make use of** Matlab and Simu-link tools for solving aerospace engineering problems in designing.	Apply
CO 2	**Examine** the thin walled beams and shells using finite element method for analyzing the bending stiffness of aircraft structure.	Analyze
CO 3	**Solve**the Burger's equation using explicit Mccomack method for analyzing fluid flows	Apply
CO 4	**Develop** the numerical code for solving laminar flow over a flat plate.	Analyze
CO 5	**Make use of** Matlab and Simu-link for simulating the motion of aircraft and re-entry vehicles.	Apply
CO 6	**Build**the mathematical model by using different techniques for simulating satellite attitude dynamics.	Analyze

VIII PROGRAM OUTCOMES:

Program Outcomes	
PO 1	Identify, formulate, analyze and Design complex engineering problems, and design system components or processes by applying appropriate advanced principles of engineering activities and using modern tools
PO 2	Engage in life-long learning and professional development through self-study and continuing education in understanding the engineering solutions in global and management principles to manage projects in multidisciplinary environments.
PO 3	Demonstrate a degree of mastery in emerging areas of Aerospace Engineering such as Aerodynamics, Propulsion, Structure and Flight Dynamics
PO 4	Write and present a substantial technical report/document
PO 5	Independently carry out research/investigation and development work to solve practical problems
PO 6	Function effectively as a member or leader in diverse teams to carry out development work, produce solutions that meet the specified needs with frontier technologies and communicate effectively on complex engineering activities.

IX HOW PROGRAM OUTCOMES ARE ASSESSED:

Program		Strength	Proficiency Assessed by
PO1	Identify, formulate, analyze and Design complex engineering problems, and design system components or processes by applying appropriate advanced principles of engineering activities and using modern tools	2	CIE, SEE
PO3	Demonstrate a degree of mastery in emerging areas of Aerospace Engineering such as Aerodynamics, Propulsion, Structure and Flight Dynamics	2	CIE, SEE
PO4	Write and present a substantial technical report/document	1	CIE, SEE
PO 5	Independently carry out research/investigation and development work to solve practical problems	2	CIE, SEE

3 = High; 2 = Medium; 1 = Low

X MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	2	-	2	1	2	-
CO 2	2	-	2	1	2	-
CO 3	2	-	2	1	2	-
CO 4	2	-	2	1	2	-
CO 5	2	-	2	1	2	-
CO 6	2	-	2	1	2	-

XI ASSESSMENT METHODOLOGY DIRECT:

CIE Exams	✓	SEE Exams	✓	Seminars	-
Laboratory Practices	✓	Student Viva	✓	Certification	-

XII ASSESSMENT METHODOLOGY INDIRECT:

X	Early Semester Feedback	✓	End Semester OBE Feedback
X	Assessment of Mini Projects by Experts		

XIII SYLLABUS:

WEEK I	**MATLAB/SIMULINK FUNDAMENTALS FOR AERO SPACE APPLICATIONS**
	MATLAB introduction, Plotting and graphics: Plot, log and semi-log plots, polar plots; Sub-plots,axis,mesh,contour diagrams,flow diagrams,movies,MATLAB tool boxes:continuous transfer functions,root locus, Nichols chart, Nyquist chart, linear quadratic regulator, state space design, digital design,aerospace toolbox; M cells, structures and M-files, MEX files; Standard simulink libraries, simulink aerospace blockset, Building simulink linear models: transfer function modelling in simulink, zero polemodel, state- space model; simulink LTI viewer and usage of it, equivalent simulink LTI models, single input single output design tool, building Multi-input, multi output models, building simulink S-functions; State flow introduction: Opening, executing, and saving state flow models, constructing a simple state flow model, using a state flow truth table.
WEEK II	**THIN WALLED BEAMS**
	Software development for thin walled beams using finite element method.
WEEK III	**PLATE BENDING**
	Software development for Plate bending using finite element method.
WEEK IV	**BEAMS ANALYSIS**
	Software development for Beams analysis using finite element method.
WEEK V	**TRUSSES ANALYSIS**
	Software development for Trusses analysis using finite element method
WEEK VI	**THIN SHELLS ANALYSIS**
	Software development for Thin shells analysis using finite element method.
WEEK VII	**GENERATION OF STRUCTURED AND UNSTRUCTURED**
	Software development for simulation in generation of structures and unstructured grids in two and three dimensions of fluid flows.
WEEK VIII	**SOLUTION OF BURGERS EQUATION**
	Software development for simulation in solution of burgers equation using explicit McCormack method of fluid flows.
WEEK IX	**BLASIUS SOLUTION FOR LAMINAR BOUNDARY LAYER OVER A FLAT PLATE**
	Software development for simulation in Blasius solution for laminar boundary layer over a flat plate of fluid flows.
WEEK X	**RIEMANN SOLVER FOR SHOCK TUBE PROBLEM**
	Software development for simulation in Riemann solver for shock tube problem of fluid flows.
WEEK XI	**SIMULATION OF AIRCRAFT MOTION**
	Simulation experiment in dynamics and control using MATLAB and simulink to Simulate aircraft motion such as longitudinal dynamics, lateral dynamics.
WEEK XII	**SIMULATION OF AIRCRAFT MOTION WITH ILLUSTRATION OFF-16 MODEL**

	Six-degrees-of-freedom simulation of aircraft motion with illustration of F-16 model using MATLAB and simulink.
WEEK XIII	**SIMULATION OF RE-ENTRY VEHICLE DYNAMICS**
	Simulation of re-entry vehicle dynamics for ballistic re-entry and maneuvering re-entry.
WEEK XIV	**SIMULATION OF NON-LINEAR CONTROL SYSTEM**
	Simulation of non-linear control system for controlling roll dynamics of a fighter aircraft.
WEEK XV	**SIMULATION OF SATELLITE ATTITUDE DYNAMICS**
	Simulation of the following relating to satellite attitude dynamics: a. Torque free rotation of axi symmetric and asymmetric space craft. b. Attitude maneuvers of spin-stabilized spacecraft.

TEXTBOOKS

1. Richard Colgren, ―Basic MATLAB, Simulink, and State Flow‖, AIAA Education Series, 1st Edition, 2007.
2. StevenT.Karris, ―Introduction to Simulink with Engineering Application‖, Orchard Publication, 3rd Edition, 2006.

REFERENCE BOOKS:

1. AshishTewari, ―Atmospheric and Space Flight Dynamics‖, Birkha user Publication, 1st Edition, 2007.
2. A.Tewari, ―Modern Control Design with MATLAB and Simulink‖, Wiley, 1st Edition, 2002.

XIV COURSE PLAN:

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

S.No	Topics to be covered	CO's	Reference
1	Introduction to MATLAB.	CO 1	R1: 1.2
2	Introduction to SIMULINK.	CO 1	R2: 3.5
3	Development of MATLAB for Thin-Walled Beams by FEM.	CO 1	R1: 3.4
4	Development of MATLAB for Plate Bending by FEM.	CO 2	R1: 2.2
5	Development of MATLAB for Truss Analysis by FEM .	CO 2	R1: 2.4
6	Development of MATLAB for Thin Shell Analysis by FEM.	CO 3	R3: 4.5
7	Development of Structured and Unstructured Grids in MATLAB.	CO 3	R3: 4.6
8	Determine the Solution of BURGERS Equation.	CO 4	R2: 5.1
9	Development of RIEMANN Solver for Shock Tube Problem.	CO 5	R2: 5.2
10	Develop a Simulation of Aircraft Motion.	CO 5	R1: 7.1
11	Develop a Simulation of Re-Entry Vehicle Dynamics.	CO 6	R1:7.2
12	Develop a Simulation of Satellite Attitude Dynamics.	CO 6	R1:7.3

XV EXPERIMENTS FOR ENHANCED LEARNING (EEL):

S.No	Design Oriented Experiments
1	Development of Structured and Unstructured Grids in MATLAB.
2	Development of RIEMANN Solver for Shock Tube Problem.
3	Develop a Simulation of Aircraft Motion.
4	Develop a Simulation of Re-Entry Vehicle Dynamics.
5	Develop a Simulation of Satellite Attitude Dynamics.

Signature of Course Coordinator **HOD,AE**
Mr. A Rathan Babu, Assistant Professor

INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal, Hyderabad - 500 043
COURSE DESCRIPTION

Branch	**AEROSPACE ENGINEERING**				
Course Title	**FLIGHT DYNAMICS AND CONTROL**				
Course Code	BAEC13				
Program	M.Tech				
Semester	II	AE			
Course Type	Core				
Regulation	IARE- PG21				
Course Structure	Theory			Practical	
	Lecture	Tutorials	Credits	Laboratory	Credits
	3	-	3	-	-
Course Coordinator	Dr. Yagya Dutta Dwivedi, Associate Professor				

I COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites
B.Tech	AAEB10	IV	Aerodynamics
B.Tech	AHSB11	II	Mathematical Transform Techniques
B.Tech	AAEB15	V	High Speed Aerodynamics

II COURSE OVERVIEW:

Flight dynamics and control is the study of the performance, stability, and control of vehicles flying through the air or in outer space. It is concern with how the forces/moments are acting on the vehicle to determine its velocity and attitude with respect to time. This course is going to develop as an engineering science throughout succeeding generations of aircraft engineer to support increasing demands of aircraft stability and control and it now has a major role to play in the design of modern aircraft to ensure efficient, comfortable and safe flight. Modern aircraft control is ensured through automatic control systems known as autopilot. Their role is to increase safety, facilitate the pilot's task and improve flight qualities. The course will introduce modern aircraft stability and control and discuss some of its objectives and applications.

III MARKS DISTRIBUTION:

Subject	SEE Examination	CIE Examination	Total Marks
Flight Dynamics and Control	70 Marks	30 Marks	100

IV DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✓	PPT	✓	Chalk & Talk	✓	Assignments	x	MOOC
x	Seminars	x	Others				

V EVALUATION METHODOLOGY:

Each theory course will be evaluated for a total of 100 marks, out of which 30 marks for Continuous Internal Assessment (CIA) and 70 marks for Semester End Examination (SEE). **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 three 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):
For each theory course the CIA shall be conducted by the faculty / teacher handling the course. CIA is conducted for a total of 30 marks, with 20 marks for Continuous Internal Examination (CIE), 05 marks for Assignment and 05 marks for Alternative Assessment Tool (AAT). Two CIE Tests are Compulsory and sum of the two tests, along with the scores obtained in the assignment / AAT shall be considered for computing the final CIA of a student in a given course.

The CIE Tests/Assignment /AAT shall be conducted by the course faculty with due approval from the HOD. Advance notification for the conduction of Assignment/AAT is mandatory and the responsibility lies with the concerned course faculty. CIA is conducted for a total of 30 marks (Table 1).

Component	Theory			Total Marks
Type of Assessment	CIE Exam	Assignment	AAT	
CIA Marks	20	05	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 five descriptive type questions out of which four 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 COURSE OBJECTIVES:

The students will try to learn:

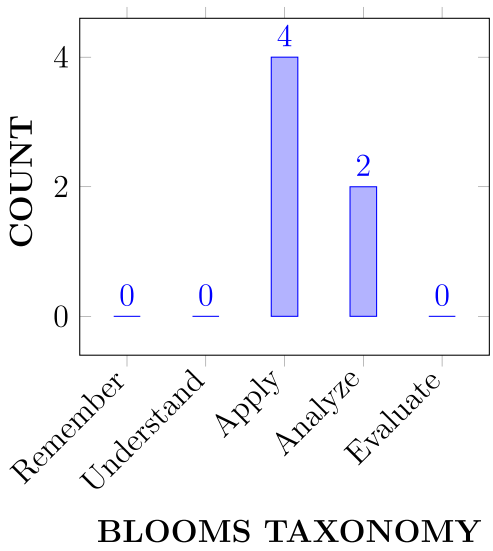
I	The fundamental principles of flight, controls, aerodynamic flows, forces and moments related to airfoils and aircraft.
II	The mathematical formulations of aerodynamic performance, stability and the equations of motion related to flight dynamics of a rigid body in linear and non-linear motion.
III	The essential knowledge on coupled and decoupled equations of motion and the derivatives related to longitudinal and lateral dynamic stability of the air vehicles.
IV	The advance concept of automated control and numerical simulations of aircraft stability for the development of modern future aircraft and flight vehicles.

VII COURSE OUTCOMES:

After successful completion of the course, students should be able to:

CO 1	**Make use of** the principles of flight and governing aerodynamics laws for the control of aircraft motions for getting the desired aircraft attitude characteristics.	Apply
CO 2	**Model** the range, endurance and stability of equilibrium under different types of motions for calculating the aerodynamic performance of an airplane.	Apply
CO 3	**Analyse** the concept of aircraft dynamics, equations of motion in linear and nonlinear motion for optimal flight conditions.	Analyse
CO 4	**Determine** the linear equations off motion and derivatives for the coupled and decoupled motion in terms of stability axis system by using small perturbation theory for obtaining the state of dynamic stability.	Analyze
CO5	**Develop** the mathematical model for the dynamic and static stability and its derivatives by using computational numerical simulation for the different types of aircraft.	Apply
CO6	**Examine** the flight control system by using control theories and modern computational tools system for the conventional and automatic flight of the aircraft.	Analyse

COURSE KNOWLEDGE COMPETENCY LEVEL



VIII PROGRAM OUTCOMES:

Program Outcomes	
PO 1	Identify, formulate, analyze and Design complex engineering problems, and design system components or processes by applying appropriate advanced principles of engineering activities and using modern tools
PO 2	Engage in life-long learning and professional development through self-study and continuing education in understanding the engineering solutions in global and management principles to manage projects in multidisciplinary environments.
PO 3	Demonstrate a degree of mastery in emerging areas of Aerospace Engineering such as Aerodynamics, Propulsion, Structure and Flight Dynamics
PO 4	Write and present a substantial technical report/document
PO 5	Independently carry out research/investigation and development work to solve practical problems
PO 6	Function effectively as a member or leader in diverse teams to carry out development work, produce solutions that meet the specified needs with frontier technologies and communicate effectively on complex engineering activities.

IX MAPPING OF EACH CO WITH PO(s):

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	✓	-	✓	-	-	-
CO 2	✓	-	✓	-	-	-
CO 3	✓	-	✓	-	-	-
CO 4	✓	-	✓	-	-	-
CO 5	✓	-	✓	-	-	-
CO 6	✓	-	✓	-	-	-

X COURSE ARTICULATION MATRIX (PO – PSO MAPPING):

CO'S and PO'S on the scale of 0 to 3, 0 being no correlation, 1 being the low correlation, 2 being medium correlation and 3 being high correlation.

COURSE OUTCOMES	**PROGRAM OUTCOMES**					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	-	2	-	-	-
CO 2	3	-	2	-	-	-
CO 3	3	-	2	-	-	-
CO 4	3	-	3	-	-	-
CO 5	3	-	2	-	-	-
CO 6	3	-	2	-	-	-
TOTAL	18	-	13	-	-	-
AVERAGE	3	-	2.2	-	-	-

XI ASSESSMENT METHODOLOGY DIRECT:

CIE Exams	✓	SEE Exams	✓	Seminar and term paper	-
Laboratory Practices	-	Student Viva	-	Mini Project	-

XII ASSESSMENT METHODOLOGY INDIRECT:

✓	**End Semester OBE Feed Back**

XIII SYLLABUS:

MODULE I	**INTRODUCTION**
	Basic principles of flight, Flying control surfaces, Elevator, ailerons and rudder, Pilots controls, The throttle, the control column, modes of flight Basic principles governing aerodynamic flows: Introduction, continuity principle, Bernoullis principle, laminar flows and boundary layers, turbulent flows, aerodynamics of airfoils and wings, slender body aerodynamics, wing-body interference, empennage aerodynamics, aerodynamics of complete aircraft, aerodynamic forces and moments.

MODULE II	**MECHANICS OF EQUILIBRIUM FLIGHT**
	Introduction, speeds of equilibrium flight, basic aircraft performance, conditions for minimum drag, range and endurance estimation, trim, stability of equilibrium flight, longitudinal static stability, maneuverability, lateral stability and stability criteria, experimental determination of aircraft stability margins; Aircraft non linear dynamics, Equations of motion, introduction, aircraft dynamics, aircraft motion in a two dimensional plane, moments of inertia, Eulers equations and the dynamics of rigid bodies, aircraft equations of motion, motion induced aerodynamic forces and moments, non-linear dynamics of aircraft motion, trimmed equations of motion.
MODULE III	**SMALL PERTURBATIONS AND THE LINEARISED, DECOUPLED EQUATIONSOF MOTION**
	Small perturbations and linearization; Linearizing the aerodynamic forces and moments: Stability derivative concept, direct formulation in the stability axis, decoupled equations of motion, decoupled equations of motion in terms of the stability axis aerodynamic derivatives, decoupled equations of motion in terms of the stability axis aerodynamic derivatives. Non-dimensional longitudinal and lateral dynamics; Simplified state-space equations of longitudinal and lateral dynamics, simplified concise equations of longitudinal and lateral dynamics.
MODULE IV	**LONGITUDINAL AND LATERAL LINEAR STABILITY AND CONTROL**
	Dynamic and static stability, modal description of aircraft dynamics and the stability, aircraft lift and drag estimation, estimating the longitudinal aerodynamic derivatives, estimating the lateral aerodynamic derivatives, aircraft dynamic response, numerical simulation and non-linear phenomenon longitudinal and lateral modal equations, methods of computing aircraft dynamic response, system block diagram representation, atmospheric disturbance, deterministic disturbances, principles of random atmospheric disturbance modeling, application to atmospheric turbulence modeling, aircraft non-linear dynamic response phenomenon.
MODULE V	**AIRCRAFT FLIGHT CONTROL**
	Automatic flight control systems: An introduction, functions of a flight control system, integrated flight control system, flight control system design.

TEXTBOOKS

1. Vepa, R., "Flight Dynamics, Simulation and Control: For Rigid and Flexible Aircraft", CRC Press, Taylor and Francis Group, 2015.

REFERENCE BOOKS:

1. Wayne Durham, "Aircraft Flight Dynamics and Control", CRC Press, 2nd Edition 2013.
2. Robert F. Stengel "Flight Dynamics". CRC Press, 2nd Edition 2013

WEB REFERENCES:

1. http://www.engin.umich.edu/aero/research/areas/controls

2. http://nptel.ac.in/courses/101106043/

COURSE WEB PAGE:

1. http://nptel.ac.in/courses/101106043/

XIV COURSE PLAN:

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

S.No	Topics to be covered	CO's	Reference
OBE DISCUSSION			
1	Course Description on Outcome Based Education (OBE): Course Objectives, Course Outcomes (CO), Program Outcomes (PO) and CO-PO Mapping	-	
CONTENT DELIVERY (THEORY)			
1	Introduction to Flight dynamics	CO 1	T1 : 18
2	Basic principles of flight and different forces acting during flight.	CO 1	T1 : 18.1
3	Flight control surfaces	CO 1	T1: 18.1.1
4	Basic principles control surfaces elevator, aileron and rudder	CO 1	T1: 13
5	Throttle and control column	CO 1	T1:18.2.1
6	Modes of flight	CO 1	T1:18.2.1
7	Basic principles and governing aerodynamic flow	CO 1	T1:18.2.2
8	Continuity principle and Benoullis principle	CO 1	T1:18.3
9	Laminar and turbulent flow	CO 1	T1 :18.3.1, 18.3.2
10	Aerodynamics of airfoil and wings	CO 1	T1 :18.3.1, 18.3.2
11	Slender body aerodynamics	CO 1	T1:4.1
12	Wing body interference and empennage aerodynamics	CO 1	T1:4.1.1
13	Aerodynamics of complete aircraft, forces and moments	CO 1	T1:4.1.5, 4.1.3
14	Speed of equilibrium flight	CO 2	T1:4.1.5, 4.1.3
15	Basic aircraft performance and condition of minimum drag	CO 2	T1:4.1.4
16	Range and endurance estimation	CO 2	T1:4.1.4
17	Trim and stability of equilibrium flight	CO 2	T1:4.2.4
18	Longitudinal static stability and maneuverability	CO 2	T1:4.1.6
19	Lateral stability and stability criteria, experimental determination of aircraft stability margins	CO 2	T1:4.1.8
20	Aircraft non- linear dynamics	CO 2	T1:4.1.8

21	Equations of motion, introduction, aircraft dynamics	CO 2	T1:4.5.8
22	Aircraft motion in a two dimensional plane, moments of inertia	CO 2	T1:4.5
23	Eulers equations and the dynamics of rigid bodies, aircraft equations of motion, motion	CO 2	T1:4.5
24	Non-linear dynamics of aircraft motion,	CO 3	T1:5.3
25	Trimmed equations of motion	CO 2	T1:5.3
26	Induced aerodynamic forces and moments	CO 2	T1:5.3.2
27	Small perturbations and linearization	CO 3	T1:5.3.2
28	Linearizing the aerodynamic forces and moments	CO 3	R1:4.4
29	Stability derivative concept	CO 3	R1:4.4
30	Direct formulation in the stability axis,	CO 3	R1:4.4
31	Decoupled equations of motion	CO 3	T1:4.2.8
32	Decoupled equations of motion in terms of the stability axis aerodynamic derivatives	CO 3	T1:4.2.8
33	Decoupled equations of motion in terms of the stability axis aerodynamic derivatives.	CO 3	T1:4.2.8
34	Non-dimensional longitudinal and lateral dynamics.	CO 3	T2:4.2.8
35	Simplified state-space equations of longitudinal and lateral dynamics	CO 4	R1:8.1, 8.2
36	Simplified concise equations of longitudinal dynamics	CO 4	R1:8.1, 8.2
37	Simplified concise equations of lateral dynamics	CO 4	R1:8.1, 8.2
38	Numerical and problem solving exercises	CO 4	R1:8.3 - 8.6
39	Dynamic and static stability	CO 4	R1:8.3 - 8.6
40	Modal description of aircraft dynamics and the stability	CO 4	R1:8.3 - 8.6
41	Aircraft lift and drag estimation	CO 4	R1:8.3 - 8.6
42	estimating the longitudinal aerodynamic derivatives	CO 4	R1:8.7, 8.8
43	estimating the lateral aerodynamic derivatives	CO 4	R1:8.7, 8.8
44	Aircraft dynamic response	CO 4	R1:8.9
45	Numerical simulation and non-linear phenomenon longitudinal and lateral modal equations	CO 5	R2:11.2
46	Methods of computing aircraft dynamic response	CO 5	R2:11.3
47	Atmospheric disturbance	CO 5	R2:11.3
48	deterministic disturbances	CO 5	R2:11.4, 11.5
49	principles of random atmospheric disturbance modeling	CO 5	R2:11.7
50	Supersonic wind tunnel nozzle	CO 5	R2:11.7
51	Minimum length nozzles	CO 5	R2:11.8
52	Domain of dependence and range of influence	CO 5	R2:11.6

53	Application to atmospheric turbulence modeling	CO 5	T1:9.1, 9.2
54	Aircraft non-linear dynamic response phenomenon	CO 5	T1:9.3
55	Numerical Problems and solution for dynamic stability	CO 5	T4:9.4
56	Automatic flight control systems-An introduction	CO 6	T1: 9.5
57	functions of a flight control system	CO 6	T1: 9.6
58	integrated flight control system	CO 6	T1:9.7
59	flight control system design	CO 6	T1:9.8
60	Modern flight control systems like Fly by Wire and Fly by Optics	CO 6	T1:9.9
DISCUSSION OF QUESTION BANK			
1	Module: I- Discussion on principles of flight and Aerodynamics	CO 1	T1
2	Module: II- Discussion on question bank for aircraft performance like range and endurance	CO 2	T1, R1
3	Module: III- Discussion on stability and conditions of longitudinal and lateral stability	CO3,4	T1,R1
4	Module: IV- Longitudinal and linear dynamics and control systems terms and formulations	CO 5	R2
5	Module: V- Discussion on flight control systems and modern technology of controls	CO 6	T1

Signature of Course Coordinator **HOD,AE**
Dr.Y.D. Dwivedi, Assoc. Professor

INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal, Hyderabad - 500 043
COURSE DESCRIPTION

<table>
<tr><td>Branch</td><td colspan="5">AEROSPACE ENGINEERING</td></tr>
<tr><td>Course Title</td><td colspan="5">ENGINEERING ANALYSIS OF FLIGHT VEHICLES</td></tr>
<tr><td>Course Code</td><td colspan="5">BAEC14</td></tr>
<tr><td>Program</td><td colspan="5">M.Tech</td></tr>
<tr><td>Semester</td><td>II</td><td colspan="4">AE</td></tr>
<tr><td>Course Type</td><td colspan="5">CORE</td></tr>
<tr><td>Regulation</td><td colspan="5">IARE-PG21</td></tr>
<tr><td rowspan="3">Course Structure</td><td colspan="3">Theory</td><td colspan="2">Practical</td></tr>
<tr><td>Lecture</td><td>Tutorials</td><td>Credits</td><td>Laboratory</td><td>Credits</td></tr>
<tr><td>3</td><td>-</td><td>3</td><td>-</td><td>-</td></tr>
<tr><td>Course Coordinator</td><td colspan="5">Dr. Indradeep Kumar, Assistant Professor</td></tr>
</table>

I COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites
B.Tech	AAEB10	IV	Aerodynamics
B.Tech	AHSB11	II	Mathematical Transform Techniques
B.Tech	AAEB15	V	High Speed Aerodynamics
B.Tech	AAEB07	IV	Aerospace Structure

II COURSE OVERVIEW:

This course deals with the aircraft dynamics and static stability, dynamic performance of spacecraft and atmospheric entry of spacecraft with respect to non-rotating planets. It start with the equations of Motion for Rigid Flight Vehicles: Definitions, Vector and Scalar realizations of Newton's second law, The tensor of inertia, Choice of vehicle axes, Operation of the vehicle relative to the ground; flight determination, Gravitational terms in the equations of motion, The state vector. Followed by Numerical integration of ordinary differential equations, Equations of Motion of Launch Vehicles with respect to a rotating planet, Motion of Spacecraft with respect to a rotating planet. Dynamic Performance-Atmospheric Entry: Equation of motion, Approximate analysis of gliding entry into a planetary atmosphere.

III MARKS DISTRIBUTION:

Subject	SEE Examination	CIE Examination	Total Marks
Engineering Analysis of Flight Vehicles	70 Marks	30 Marks	100

IV DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✓	PPT	✓	Chalk & Talk	✓	Assignments	x	MOOC
x	Seminars	x	Others				

V EVALUATION METHODOLOGY:

Each theory course will be evaluated for a total of 100 marks, out of which 30 marks for Continuous Internal Assessment (CIA) and 70 marks for Semester End Examination (SEE). **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 three 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):
For each theory course the CIA shall be conducted by the faculty / teacher handling the course. CIA is conducted for a total of 30 marks, with 20 marks for Continuous Internal Examination (CIE), 05 marks for Assignment and 05 marks for Alternative Assessment Tool (AAT). Two CIE Tests are Compulsory and sum of the two tests, along with the scores obtained in the assignment / AAT shall be considered for computing the final CIA of a student in a given course.

The CIE Tests/Assignment /AAT shall be conducted by the course faculty with due approval from the HOD. Advance notification for the conduction of Assignment/AAT is mandatory and the responsibility lies with the concerned course faculty. CIA is conducted for a total of 30 marks (Table 1).

Component	Theory			Total Marks
Type of Assessment	CIE Exam	Assignment	AAT	
CIA Marks	20	05	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 five descriptive type questions out of which four 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 COURSE OBJECTIVES:

The students will try to learn:

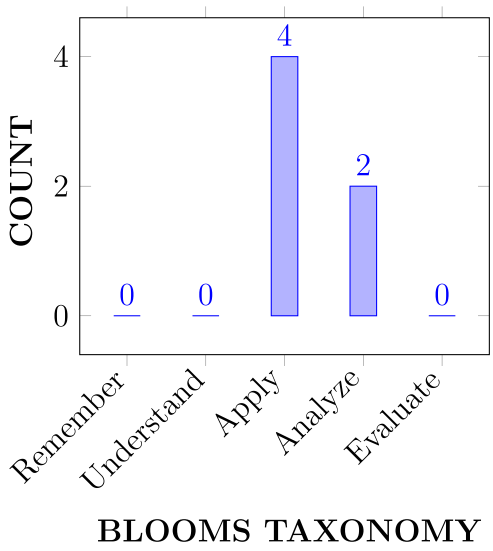
I	Analyze the key factors affecting vehicles configuration.
II	Understand the basic concepts of gravitational terms in the equations of motion.
III	Explain the concepts of static stability, trim static performance.
IV	Analyze dynamic performance of spacecraft with respect to non-rotating planets.

VII COURSE OUTCOMES:

After successful completion of the course, students should be able to:

CO 1	**Identify** the factors affecting vehicles configuration for determining its effect on flight characteristics.	Apply
CO 2	**Develop** the equation of motion for operation of vehicle relative to the ground and flight for rigid flight vehicles using Newton's laws.	Apply
CO 3	**Construct** the equation of motion of launch vehicle and spacecraft for static performance, impact of stability and control for the rotating planet.	Apply
CO 4	**Demonstrate** the perturbed longitudinal equation of motion for static and dynamic stability of rigid flight vehicles.	Apply
CO5	**Inspect** the impact of stability and design of longitudinal control of flight vehicles using numerical integration method.	Analyze
CO6	**Examine** the gliding re-entry vehicle with respect to a rotating planet using equations of motion of launch vehicles for dynamic performance.	Analyze

COURSE KNOWLEDGE COMPETENCY LEVEL



VIII PROGRAM OUTCOMES:

Program Outcomes	
PO 1	Identify, formulate, analyze and Design complex engineering problems, and design system components or processes by applying appropriate advanced principles of engineering activities and using modern tools
PO 2	Engage in life-long learning and professional development through self-study and continuing education in understanding the engineering solutions in global and management principles to manage projects in multidisciplinary environments.
PO 3	Demonstrate a degree of mastery in emerging areas of Aerospace Engineering such as Aerodynamics, Propulsion, Structure and Flight Dynamics
PO 4	Write and present a substantial technical report/document
PO 5	Independently carry out research/investigation and development work to solve practical problems
PO 6	Function effectively as a member or leader in diverse teams to carry out development work, produce solutions that meet the specified needs with frontier technologies and communicate effectively on complex engineering activities.

IX MAPPING OF EACH CO WITH PO(s):

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	✓	-	✓	-	-	-
CO 2	✓	-	✓	-	-	-
CO 3	✓	-	✓	-	-	-
CO 4	✓	-	✓	-	-	-
CO 5	✓	-	✓	-	-	-
CO 6	✓	-	✓	-	-	-

X COURSE ARTICULATION MATRIX (CO – PO MAPPING):

CO'S and PO'S on the scale of 0 to 3, 0 being no correlation, 1 being the low correlation, 2 being medium correlation and 3 being high correlation.

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	-	1	-	-	-
CO 2	3	-	1	-	-	-
CO 3	3	-	1	-	-	-

CO 4	3	-	3	-	-	-
CO 5	3	-	1	-	-	-
CO 6	3	-	1	-	-	-
TOTAL	18	-	8	-	-	-
AVERAGE	3	-	1.3	-	-	-

XI ASSESSMENT METHODOLOGY DIRECT:

CIE Exams	✓	SEE Exams	✓	Seminar and term paper	-
Laboratory Practices	-	Student Viva	-	Mini Project	-

XII ASSESSMENT METHODOLOGY INDIRECT:

✓	**End Semester OBE Feed Back**

XIII SYLLABUS:

MODULE I	**THE MORPHOLOGY OF FLIGHT VEHICLES**
	Introduction, Key factors affecting vehicles configuration, Some representative flight vehicles.
MODULE II	**EQUATIONS OF MOTION FOR RIGID FLIGHT VEHICLES AND INTRODUCTION TO VEHICLE AERODYNAMICS**
	Equations of Motion for Rigid Flight Vehicles: Definitions,Vector and Scalar realizations of Newton's second law, The tensor of inertia, Choice of vehicle axes, Operation of the vehicle relative to the ground; flight determination, Gravitational terms in the equations of motion,The state vector. Introduction to Vehicle Aerodynamics: Aerodynamics contributions to X, Y and M, dimensionless coefficients defined, equations of perturbed longitudinal motion.
MODULE III	**AIRCRAFT DYNAMICS AND STATIC STABILITY, TRIM STATIC PERFORMANCE AND RELATED SUBJECTS**
	Aircraft Dynamics: Equations of Motion of Aircraft including forces and moments of control surfaces, Dynamics of control surfaces. Static Stability, Trim Static Performance and Related Subjects: Impact of stability requirements on design and longitudinal control, Static performance.
MODULE IV	**DYNAMIC PERFORMANCE OF SPACECRAFT WITH RESPECT TO NON-ROTATING PLANETS**

	Introduction, Numerical integration of ordinary differential equations, Simplified treatment of boost from anon-rotating planet, An elementary look at staging, Equations of boost from a rotating planet.
MODULE V	**DYNAMIC PERFORMANCE OF SPACECRAFT AND DYNAMIC PERFORMANCE-ATMOSPHERIC ENTRY**
	Dynamic Performance of Spacecraft: Equations of Motion of Launch Vehicles with respect to a rotating planet, Motion of Spacecraft with respect to a rotating planet. Dynamic Performance-Atmospheric Entry: Equation of motion, Approximate analysis of gliding entry into a planetary atmosphere.

TEXTBOOKS

1. Holt Ashley, "Engineering Analysis of Flight Vehicles", Dover Publications, 1992.

REFERENCE BOOKS:

1. J. D. Anderson, "Fundamentals of Aerodynamics", McGraw-Hill, 5th Edition, 2001.
2. Argyris G. Panaras, "Aerodynamic Principles of Flight Vehicles", AIAA Inc, 1st Edition, 2012.
3. J. J. Bertin, R. M Cummings, "Aerodynamics for Engineers", Pearson, 5th Edition, 2009.

WEB REFERENCES:

1. https://mitpress.mit.edu/books/flight-vehicle-aerodynamics.
2. https://www.edx.org/course/flight-vehicle-aerodynamics-mitx-16-110x-0
3. https://www.mooc-list.com/course/16110x-flight-vehicle-aerodynamics-edx?static=true

E-Text Books:

1. http://www.freeengineeringbooks.com/AeroSpace/Aerodynamics-Books.php
2. http://www.booksamillion.com/p/Flight-Vehicle-Aerodynamics/Mark-Drela/Q685536838
3. https://www.overdrive.com/media/1553992/flight-vehicle-aerodynamics

XIV COURSE PLAN:

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

S.No	Topics to be covered	CO's	Reference
OBE DISCUSSION			
1	Course Description on Outcome Based Education (OBE): Course Objectives, Course Outcomes (CO), Program Outcomes (PO) and CO-PO Mapping	-	
CONTENT DELIVERY (THEORY)			
1	Introduction to the Morphology of Flight Vehicles	CO1	T1 : 1.1
2	Key factors affecting vehicle configuration	CO1	T1 : 1.2
3	Some representative flight vehicles	CO1	T1 : 1.3

4	Numericals	CO1	T1 : 1.4
5	Equations of Motion for Rigid Flight Vehicles	CO1	T1 : 2.1
6	Definitions; vector and scalar realizations of Newton's second law	CO1	T2: 2.1
7	Realizations of Newton's second law	CO1	T2: 2.1
8	The tensor of inertia	CO1	T1: 2.2
9	Choice of vehicle axes	CO1	T1: 2.3
10	Orientation of the vehicle relative to the ground;	CO2	T1:2.4
11	Flight-path determination	CO2	T1: 2.5,
12	The state vector,	CO2	T1: 2.6
13	Three significant phenomena that have been neglected	CO2	T1: 2.7
14	Gravitational terms in the equations of motion	CO2	T1: 2.5
15	Equations of motion d	CO2	T1: 2.5
16	Numericals	CO2	T1: 2.8
17	Introduction to Vehicle Aerodynamics	CO3	T1: 3.1
18	Aerodynamic contributions to X, Z, and MP	CO3	T1: 3.1
19	dimensionless coefficients defined	CO3	T1: 3.1
20	Equations of perturbed longitudinal motion	CO3	T1: 3.2
21	categories of problems in flight dynamics	CO3	T1: 3.2
22	Small-Perturbation Response	CO3	T1:6.1
23	Dynamic Stability of Flight Vehicles	CO3	T1:6.1
24	Equations of motion	CO3	T1:6.1
25	Aerodynamic approximations;	CO3	T1:6.1
26	Stability derivatives	CO3	T1:6.1
27	Dimensionless equations of motion	CO4	T1: 6.2
28	Estimation of stability derivatives	CO4	T1: 6.3
29	Estimation of longitudinal derivatives	CO4	T1: 6.3
30	Estimation of lateral derivatives: and Numericals	CO4	T1: 6.4
31	Numericals	CO4	T1: 6.5
32	Impact of stability requirements	CO4	T1: 8.1
33	Impact of stability requirements on design	CO4	T1: 8.1
34	Impact of stability requirements on longitudinal control.	CO4	T1: 8.2
35	Impact of stability requirements on Static performance.	CO4	T1: 8.2
36	Introduction to Numerical integration	CO5	T1: 9.2
37	Numerical integration of ordinary differential equations	CO5	T1: 9.2
38	Simplified treatment of boost from a nonrotating planet	CO5	T1: 9.3
39	An elementary look at staging	CO5	T1: 9.4
40	Equations of boost from a rotating planet	CO5	T1: 9.5
41	Numericals on Equations of boost	CO5	T1: 9.5
42	Dynamic Performance: Atmospheric Entry	CO5	T1:11.1
43	Introduction; equations of motion	CO5	T1:11.1

44	Approximate analysis of gliding entry into a planetary atmosphere	CO5	T1:11.2
45	Longitudinal stability and response; exact and approximate properties of the normal modes	CO5	T1:7.3
46	Numericals.	CO5	T1:7.4
47	Introduction to the Morphology of Flight Vehicles	CO5	T1 : 1.1
48	Key factors affecting vehicle configuration	CO5	T1 : 1.2
49	Some representative flight vehicles	CO6	T1 : 1.3
50	Numericals	CO6	T1 : 1.4
51	Equations of Motion for Rigid Flight Vehicles	CO6	T1 : 2.1
52	Definitions; vector and scalar realizations of Newton's second law	CO6	T2: 2.1
53	The tensor of inertia	CO2	T1: 2.2
54	Choice of vehicle axes	CO6	T1: 2.3
55	Orientation of the vehicle relative to the ground; flight-path determination, , The state vector, Three significant phenomena that have been neglected	CO6	T1:2.4, 2.5,2.6, 2.7
56	Gravitational terms in the equations of motion d	CO6	T1: 2.5,2
57	Gravitational terms in the equations of motion d	CO6	T1: 2.5,2
58	Numericals	CO6	T1: 2.8
59	Introduction to Vehicle Aerodynamics: Aerodynamic contributions to X, Z, and MP; dimensionless coefficients defined ,Equations of perturbed longitudinal motion; categories of problems in flight dynamics	CO6	T1: 3.1,3.2
60	Small-Perturbation Response and Dynamic Stability of Flight Vehicles: Equations of motion; aerodynamic approximations; stability derivatives	CO6	T1:6.1
DISCUSSION OF QUESTION BANK			
1	Module: I- Numerical on Flight Morphology	CO 1	T1
2	Module: II- Numerical on Equation of Motion	CO 2	T1
3	Module: III- Numerical on Static stability	CO3,4	T1
4	Module: IV- Numerical on Dynamic Performance	CO 5	T1
5	Module: V- Numerical on non-rotating planet	CO 6	T1

Signature of Course Coordinator **HOD,AE**
Dr. Indradeep Kumar, Assistant Professor

INSTITUTE OF AEROSPACE ENGINEERING

(Autonomous)

Dundigal, Hyderabad - 500 043

COURSE DESCRIPTION

Department	**AEROSPACE ENGINEERING**				
Course Title	**ROCKET AND MISSILES**				
Course Code	BAEC16				
Program	M.Tech				
Semester	II	AE			
Course Type	PROFESSIONAL ELECTIVE-III				
Regulation	IARE-PG21				
Course Structure	Theory			Practical	
	Lecture	Tutorials	Credits	Laboratory	Credits
	3	0	3		
Course Coordinator	Mr V. Phaninder Reddy, Assistant Professor				

I COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites
B.Tech	BAEC01	I	Space Propulsion
B.Tech	BAEC05	IV	Advance Computational Aerodynamics

II COURSE OVERVIEW:

This course deals with fundamental aspects of rockets and the current trends in rocket propulsion. This course includes the combustion process, propellants and various components of chemical rocket propulsion systems and their applications. It compares and contrasts various thrust vector control mechanisms of nozzle and cooling systems of combustion chamber. It discusses on various materials and its properties that are used for manufacturing of rocket and missiles. This course also covers the basic concepts of guidance of missile and various types of tactical guidance systems and techniques.

III MARKS DISTRIBUTION:

Subject	SEE Examination	CIE Examination	Total Marks
Rocket and Missiles	70 Marks	30 Marks	100

IV CONTENT DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✓	PPT	✓	Chalk & Talk	✓	Assignments	x	MOOC
x	Seminars	x	Others				

V EVALUATION METHODOLOGY:

Each theory course will be evaluated for a total of 100 marks, out of which 30 marks for Continuous Internal Assessment (CIA) and 70 marks for Semester End Examination (SEE). **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 three 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):
For each theory course the CIA shall be conducted by the faculty / teacher handling the course. CIA is conducted for a total of 30 marks, with 20 marks for Continuous Internal Examination (CIE), 05 marks for Assignment and 05 marks for Alternative Assessment Tool (AAT). Two CIE Tests are Compulsory and sum of the two tests, along with the scores obtained in the assignment / AAT shall be considered for computing the final CIA of a student in a given course.

The CIE Tests/Assignment /AAT shall be conducted by the course faculty with due approval from the HOD. Advance notification for the conduction of Assignment/AAT is mandatory and the responsibility lies with the concerned course faculty. CIA is conducted for a total of 30 marks (Table 1).

Component	Theory			Total Marks
Type of Assessment	CIE Exam	Assignment	AAT	
CIA Marks	20	05	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 five descriptive type questions out of which four 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 COURSE OBJECTIVES:

The students will try to learn:

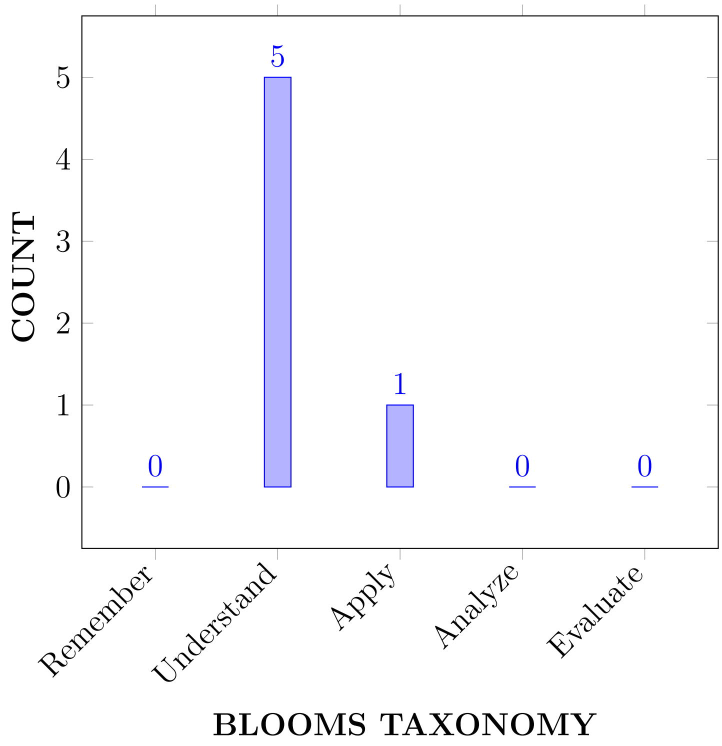
I	The fundamental concepts of various rocket propulsion systems, combustion process and forces/moments acting on the rocket under static and dynamic conditions.
II	The operating principle of guided missile, and the guidance, control and instrumentation needed to acquire the target.
III	Properties of different materials that are used in manufacturing of various rocket and missile components .

VII COURSE OUTCOMES:

After successful completion of the course, students should be able to:

CO 1	**Utilize** the working principle of different types of rocket propulsion systems for distinguishing them based on the mission requirement.	Apply
CO 2	**Discuss** different design concepts implemented in solid rocket motor and liquid rocket engine for selecting the best propellant	Understand
CO 3	**Identify** performance parameters of chemical rocket and propellants for relating thrust and burn characteristics.	Apply
CO 4	**Summarize** various combustion process and commonly used propellants of a chemical rocket engine for identifying the optimal combinations based on specific application	Understand
CO 5	**Categorize** various missiles and their appropriate guidance system to provide sufficient capability (speed, range, and maneuverability) and accomplish the mission planned for the system	Understand
CO 6	**Understand** selection criteria and properties of materials to perform under adverse conditions for design of new components as per the requirements.	Understand

COURSE KNOWLEDGE COMPETENCY LEVEL



VIII PROGRAM OUTCOMES:

Program Outcomes	
PO 1	**Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering 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.
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
PO 4	**Conduct Investigations of Complex Problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO 5	**Modern Tool Usage:** Create, select, and apply appropriate techniques, resources, and modern Engineering and IT tools including prediction and modelling to complex Engineering activities with an understanding of the limitations
PO 6	**The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

IX MAPPING OF EACH CO WITH PO(s):

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	✓	✓	-	-	-	
CO 2	✓	✓	-	-	-	-
CO 3	✓	✓	-	-	-	-
CO 4	✓	-	-	-	-	-
CO 5	✓	-	-	-	-	-
CO 6	✓	✓	-	-	-	-

X COURSE ARTICULATION MATRIX (PO MAPPING):

CO'S and PO'S on the scale of 0 to 3, 0 being no correlation, 1 being the low correlation, 2 being medium correlation and 3 being high correlation.

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	-	1	-	-	-
CO 2	3	-	1	-	-	-
CO 3	3	-	1	-	-	-
CO 4	3	-	3	-	-	-
CO 5	3	-	1	-	-	-
CO 6	3	-	1	-	-	-
TOTAL	18	-	8	-	-	-
AVERAGE	3	-	1.3	-	-	-

XI ASSESSMENT METHODOLOGY DIRECT:

CIE Exams	✓	SEE Exams	✓	Seminar and term paper	-
Laboratory Practices	-	Student Viva	-	Mini Project	-

XII ASSESSMENT METHODOLOGY INDIRECT:

✓	**End Semester OBE Feed Back**

XIII SYLLABUS:

MODULE I	**ROCKET SYSTEMS**
	Ignition system in rockets, types of igniters, igniter design considerations; Design consideration of liquid rocket combustion chamber, injector propellant feed lines, valves, propellant tanks and their outlets;Pressurized and turbine feed systems; Propellant slosh and propellant hammer; Elimination of geysering effect in missiles; Combustion system of solid rockets.
MODULE II	**AERODYNAMICS OF ROCKET AND MISSILES**
	Airframe components of rockets and missiles; Forces acting on a missile while passing through atmosphere; Classification of missiles; Method of describing aerodynamic forces and moments; Lateral aero dynamic moment; Lateral damping moment and longitudinal moment of a rocket; Lift and drag forces; Drag estimation; Body up wash and down wash in missiles; Rocket dispersion; Numerical problems.
MODULE III	**ROCKET MOTION IN FREE SPACE AND GRAVITATIONAL FIELD**
	One dimensional and two dimensional rocket motions in free space and homogeneous gravitational fields; Description of vertical, inclined and gravity turn trajectories. Determination of range and altitude; Simple approximations to burn out velocity.
MODULE IV	**STAGING AND CONTROL OF ROCKET AND MISSILES**
	Rocket vector control, methods, thrust termination; Secondary injection thrust vector control system; Multistage of rockets; Vehicle optimization; Stage separation dynamics; Separation techniques.
MODULE V	**MATERIALS FOR ROCKET AND MISSILES**
	Selection of materials; Special requirements of materials to perform under adverse conditions.

TEXTBOOKS

1. Sutton, G.P., et al., —Rocket Propulsion Elements, John Wiley Sons Inc., New York, 1993

2. Martin J.L Turner , Rocket Space Craft Propulsion, Springers oraxis publishing, 2001

REFERENCE BOOKS:

1. Mathur, M., and Sharma, R.P., —Gas Turbines and Jet and Rocket Propulsion, Standard Publishers, New Delhi 1998

2. Cornelisse, J.W., Rocket Propulsion and Space Dynamics, J.W., Freeman & Co. Ltd., London, 1982.

3. Parker, E.R., Materials for Missiles and Spacecraft, McGraw-Hill Book Co. Inc., 1982.

COURSE WEB PAGE:

XIV COURSE PLAN:

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

S.No	Topics to be covered	CO's	Reference
OBE DISCUSSION			
1	Course Description on Outcome Based Education (OBE): Course Objectives, Course Outcomes (CO), Program Outcomes (PO) and CO-PO Mapping	-	
CONTENT DELIVERY (THEORY)			
2	Classification of launch vehicles	CO 1	T2: 1.1-1.5, T1: 4.1
3	Classification of missiles and missiles developed by DRDO	CO 1	T2: 1.1-1.5, T1: 4.1
4	Rocket systems, airframe components, forces and moments acting on a rocket	CO 1	T2: 2.1-2.2, R1: 3.1
5	Aerodynamics, gravity, inertial and non-inertial frames	CO 1	T2: 2.3-2.4
6	Equations of motion for three-dimensional motion through atmosphere, and vacuum	CO 1	T2: 3.3
7	Cruise Missile and Ballistic missile along with examples and differences	CO 1	T2: 3.3
8	Specific impulse, Characteristic velocity, mass fraction, Total impulse, Effective exhaust velocity, Thrust coefficient	CO 1	T2: 3.3
9	Basic relations of motion, Effect of propulsion system on vehicle performance	CO 1	T2: 3.3
10	Solid propellant rockets, classification and components	CO	T2: 3.4
11	Propellant grain configurations and grain mechanical properties.	CO 1	T2: 3.3
12	Propellant classification, Propellant characteristics and Ingredients	CO 1	T2: 3.3
13	Types of nozzles, thrust vector control of SRM	CO 2	T2: 5.1
14	Pyrotechnic devices and systems, classification; Mechanisms and application of pyrotechnic devices in rockets and missiles	CO 2	T2: 5.2
15	Combustion instability of Solid rocket motor	CO 2	T2: 5.2
16	Pressure decay in the chamber after propellant burns out, Factors influencing the burn rate.	CO 2	T2: 4.5
17	Liquid propellant rockets, classification and components	CO 2	T2: 4.5
18	Pressure feed system, Propellant tanks and tank pressurization	CO 2	T2: 4.5
19	Turbopump feed system and Engine cycles, Valves and pipelines	CO 2	T2: 4.5

S.No	Topics to be covered	CO's	Reference
20	Different types of injectors in liquid rocket engine, TVC mechanisms in LRE	CO 2	T2: 4.5
21	Hydrazine as monopropellant, Bi propellant, gelled propellant and storable propellants, Liquid oxidizers and fuels	CO 2	T2: 4.5
21	Combustion instability in lquid rocket engines. Latest developments in LRE.	CO 2	T2: 4.5
22	Need for guidance system in missile and guidance phases of missile	CO 2	T1: 4.1
23	Classification of various guidance systems: Beamer rider guidance, Command guidance and Inertial guidance system, Homing guidance	CO 2	T1: 4.2
24	Missile control: Aerodynamic control, Thrust vector control, Elements of control system	CO 2	T1: 4.3
25	Design considerations of body of missile: Nose, Mid section and boat tail section	CO 3	T2: 5.2
26	Multistage of rockets ,Vehicle optimization techniques	CO 3	T2: 5.2
27	Stage separation system dynamics and techniques, Rocket flight dispersion numerical problems.	CO 3	T1: 7.2
28	Selection of materials for spacecraft for specific requirements, advance materials,	CO 3	T1: 7.5
29	Super alloys and composite materials	CO 3	T1: 7.5
30	Types of testing and evaluation of design and function	CO 3	R2:7.5
31	Heat Protection System of Spacecrafts and Missiles, Aerodynamic Heating and Solar Heating	CO 3	R2:7.5
32	Thrust of the engine in a vacuum, Determine the change in velocity if the spacecraft burns, mass fraction	CO 3	T2: 1.1-1.5, T1: 4.1
33	Calculate the duration of the burn, exhaust gas velocity relative to the rocket, Calculate the specific impulse,area of the nozzle exit	CO 3	T2: 3.4
34	Calculate the ideal density of a solid rocket propellant, grain geometry, propellant mass, mass flow rate	CO 3	R4: 2.8
35	Determine impulse provided by each stage of rocket and total propellant carried in it	CO 3	R4: T6.3.2
36	Heat generated from combustion of liquid hydrogen, mixture ratio, find whether the composition is fuel rich or oxyrich	CO 3	R4: T6.3.2
37	Maximum chamber pressure, mass of propellant silver initial equilibrum chamber pressure	CO 4	R4: T6.3.2
38	Determine the heat to be transferred in the regenerative cooling passages	CO 4	R4:5.2
39	Specific impulse of gas generator fed cryogenic rocket, mixture ratio at injection	CO 4	T2: 5.2

S.No	Topics to be covered	CO's	Reference
40	Heat release per kg of Hydrazine, Characteristic velocity, mass flow rate of Hydrazine	CO 4	T2: 13.1-13.2.5
41	Stage mass ratios, Ideal velocities, propulsive efficiency, structural mass fraction of each stage, Thrust at each stages	CO 4	T4: 11.2-11.4
42	Propellant performance neglecting dissocaiation of combustion products, molecular mass of combustion products	CO 4	T2: 13.2.6
43	Calculate performance of gas generator, expander and stageed combustion engine cycle	CO 4	T4:14.3-14.4
44	Variation of pressure and burn time of hollow cylindrical grain	CO 4	T4:14.3-14.4
45	Pressure decay in the combustion chamber after propellamt burns out.	CO 5	R2:7.5
46	Heat generated from combustion of liquid hydrogen, mixture ratio, find whether the composition is fuel rich or oxyrich	CO 5	R4: T6.3.2
47	Maximum chamber pressure, mass of propellant silver initial equilibrum chamber pressure	CO 5	R4: T6.3.2
48	Determine the heat to be transferred in the regenerative cooling passages	CO 5	R4:5.2
49	Specific impulse of gas generator fed cryogenic rocket, mixture ratio at injection	CO 5	T2: 5.2
50	Heat release per kg of Hydrazine, Characteristic velocity, mass flow rate of Hydrazine	CO 5	T2: 13.1-13.2.5
51	Specific Impulse, characteristic velocity, Ion rocket propulsion.	CO 5	T2: 1.1-1.5
52	Grain, Grain silver. progressive, neutral and regressive burn.	CO 5	T4:7.3
53	Gas generator cycle, expander cycle and staged combustion cycle.	CO 6	R4:5.1, T2: 6.3-6.4
54	Homing guidance, Beamer rider guidance, Multistage rocket, mass fraction and ideal velocity of multistage rocket.	CO 6	T1:7.5
55	Nickel and titanium based alloys, Ablate materials, silica phenolic composites,	CO 6	T1: 12.1
56	Ideal rocket equation, Working principle of rocket, cruise and ballistic missile	CO 6	T2: 1.1-1.5
57	Ammonium perchlorate, Double base and composite propellant. Pyrogen and Pyrotechnic igniter	CO 6	T4:7.3
58	Film cooling, Injector, Thrust vector control, Ullage, UDMH, Catalyst. Hypergolic, Cryogenic and Bi propellant propellant	CO 6	R4:5.1, T2: 6.3-6.4
59	Gguidance phases, Aerodynamic controls of missile, sloshing	CO 6	T1:7.5
60	Refractory materials, ceramics, Metal alloys with face centered structure	CO 6	T1: 12.1

S.No	Topics to be covered	CO's	Reference
DISCUSSION OF QUESTION BANK			
1	Module I:Rocket Systems	CO 1,2,3	R4:2.1
2	Module II:Aerodynamics Of Rocket and Missiles	CO 2,4	T4:7.3
3	Module III:Rocket Motion in Free Space and Gravitational Field	CO 2,4	R4:5.1
4	Module IV:Staging and Control Of Rocket and Missiles	CO 1,5	T1:7.5
5	Module V:Materials For Rocket and Missiles	CO 6	T1: 4.1

Signature of Course Coordinator **HOD,AE**

Mr. V Phaninder Reddy

INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal, Hyderabad - 500 043
COURSE DESCRIPTION

Branch	**AEROSPACE ENGINEERING**				
Course Title	**ATMOSPHERIC RE-ENTRY VEHICLES**				
Course Code	BAEC19				
Program	M.Tech				
Semester	II	AE			
Course Type	Elective				
Regulation	IARE-PG21				
Course Structure	Theory			Practical	
	Lecture	Tutorials	Credits	Laboratory	Credits
	3	-	3	-	-
Course Coordinator	Mr. Athota Rathan Babu, Assistant Professor				

I COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites
B.Tech	AMEB03	II	Aerodynamics
B.Tech	AHSB11	II	Mathematical Transform Techniques
B.Tech	AAEB04	III	High Speed Aerodynamics

II COURSE OVERVIEW:

This course deals with fundamental aspects of an anatomy of re-entry module and the current trends in airframe design. It includes the evolution of the re-entry module in space industry, aerodynamics and performance of the module with their applications. It compares and contrasts various thrust vector control mechanisms of different types of atmospheric re-entry. It discusses various materials and its properties that are used for manufacturing different parts of re-entry module. This course enriches the knowledge of connection between theoretical and practical methods for performing re-entry in atmosphere.

III MARKS DISTRIBUTION:

Subject	SEE Examination	CIE Examination	Total Marks
Atmospheric Re-entry Vehicles	70 Marks	30 Marks	100

IV DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✓	PPT	✓	Chalk & Talk	✓	Assignments	x	MOOC
x	Seminars	x	Others				

V EVALUATION METHODOLOGY:

Each theory course will be evaluated for a total of 100 marks, out of which 30 marks for Continuous Internal Assessment (CIA) and 70 marks for Semester End Examination (SEE). **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 three 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):
For each theory course the CIA shall be conducted by the faculty / teacher handling the course. CIA is conducted for a total of 30 marks, with 20 marks for Continuous Internal Examination (CIE), 05 marks for Assignment and 05 marks for Alternative Assessment Tool (AAT). Two CIE Tests are Compulsory and sum of the two tests, along with the scores obtained in the assignment / AAT shall be considered for computing the final CIA of a student in a given course.

The CIE Tests/Assignment /AAT shall be conducted by the course faculty with due approval from the HOD. Advance notification for the conduction of Assignment/AAT is mandatory and the responsibility lies with the concerned course faculty. 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).

Component	Theory			Total Marks
Type of Assessment	CIE Exam	Assignment	AAT	
CIA Marks	20	05	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 five descriptive type questions out of which four 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 COURSE OBJECTIVES:

The students will try to learn:

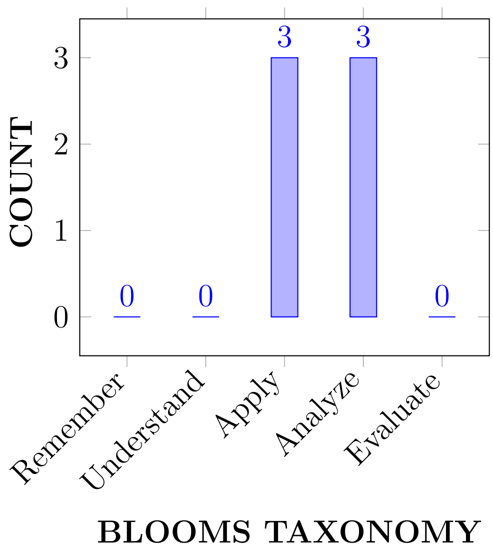
I	Understand the basic mechanism of reentry vehicle.
II	Define aerodynamic principles and flight dynamics
III	Solve the equations of motion for reentry vehicles.

VII COURSE OUTCOMES:

After successful completion of the course, students should be able to:

CO 1	**Develop** the concepts for designing the re-entry vehicle as per the desired mission.	Apply
CO 2	**Identify** the aerodynamic performance parameters of a re-entry module for different operational scenarios.	Apply
CO 3	**Compare** the design properties with international standard atmosphere for different flight mission.	Analyze
CO 4	**Examine** the stability techniques and limitations for recognizing safety measurements of Atmospheric Re-entry Vehicles.	Analyze
CO5	**Classify** the re-entry vehicles based on operational performance for their suitability in the mission	Analyze
CO6	**Make use of the** selection criteria and material properties for performing re-entry vehicles in adverse conditions.	Apply

COURSE KNOWLEDGE COMPETENCY LEVEL



VIII PROGRAM OUTCOMES:

Program Outcomes	
PO 1	Identify, formulate, analyze and Design complex engineering problems, and design system components or processes by applying appropriate advanced principles of engineering activities and using modern tools
PO 2	Engage in life-long learning and professional development through self-study and continuing education in understanding the engineering solutions in global and management principles to manage projects in multidisciplinary environments.
PO 3	Demonstrate a degree of mastery in emerging areas of Aerospace Engineering such as Aerodynamics, Propulsion, Structure and Flight Dynamics
PO 4	Write and present a substantial technical report/document
PO 5	Independently carry out research/investigation and development work to solve practical problems
PO 6	Function effectively as a member or leader in diverse teams to carry out development work, produce solutions that meet the specified needs with frontier technologies and communicate effectively on complex engineering activities.

IX MAPPING OF EACH CO WITH PO(s):

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	✓	-	✓	-	✓	-
CO 2	✓	-	✓	-	✓	-
CO 3	✓	-	✓	-	✓	-
CO 4	✓	-	✓	-	✓	-
CO 5	✓	-	✓	-	✓	-
CO 6	✓	-	✓	-	✓	-

X COURSE ARTICULATION MATRIX (PO – PSO MAPPING):

CO'S and PO'S on the scale of 0 to 3, 0 being no correlation, 1 being the low correlation, 2 being medium correlation and 3 being high correlation.

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	-	1	-	-	-
CO 2	3	-	1	-	-	-
CO 3	3	-	1	-	-	-

CO 4	3	-	3	-	-	-
CO 5	3	-	1	-	-	-
CO 6	3	-	1	-	-	-
TOTAL	18	-	8	-	-	-
AVERAGE	3	-	1.3	-	-	-

XI ASSESSMENT METHODOLOGY DIRECT:

CIE Exams	✓	SEE Exams	✓	Seminar and term paper	-
Laboratory Practices	-	Student Viva	-	Mini Project	-

XII ASSESSMENT METHODOLOGY INDIRECT:

✓	**End Semester OBE Feed Back**

XIII SYLLABUS:

MODULE I	**OVERVIEW AND INTRODUCTION**
	Classical point mass mechanics, mechanics of rigid bodies, topography and gravitation, the geodetic frame of reference, the terrestrial field of gravitation, models of atmosphere, main parameters and hypotheses, the isothermal exponential model, standard models of earth's atmosphere, martian models.
MODULE II	**AERODYNAMICS**
	Aerodynamic coefficients, modes of flow, continuous mode, rare field mode, qualities of flight, characteristics of a family of sphere cones, planetary entry capsule.
MODULE III	**SPECIAL TREATMENT FOR REENTRY VEHICLE**
	Inertial Models: Moments of inertia, cg offset and principal axis misalignment; Changing of Reference Frame:Direction cosine matrices, Euler angles, representations with four parameters Exoatmospheric phase: Movement of the center of mass, movement around mass center.
MODULE IV	**EQUATIONS OF MOTION**
	Six degree-of-freedom reentry: General equations of motion, solutions of general equations, zero angle of attacker entry; Allen's reentry results, influence of ballistic coefficient and flight path angle, influence of range; Decay of initial incidence: Zero spin rate, nonzero spin.

MODULE V	**FLIGHT DYNAMICS OF REENTRY VEHICLE**
	End of the convergence of the incidence: Linear equations, instantaneous angular movement, real angular motion; Roll-lock-in Phenomenon: Association of aerodynamic asymmetry and cg offset, isolated center of gravity, isolated principal axis misalignment, combined cg offset and principal axis misalignment, instabilities: static instabilities, dynamic instabilities; Reentry errors: Zeroangle-of-attack dispersions, nonzero angle of attack.

TEXTBOOKS

1. Patrick Gallais, "Atmospheric Re-Entry Vehicle Mechanics", Springer, 1st Edition, 2007.
2. W. Hankey, "Re-Entry Aerodynamics", AIAA Education series, 1st Edition, 1988.
3. Frank J. Regan "Dynamics of Atmospheric Re-Entry" American institute of astronautics and aeronautics publications, 1st Edition, 1993.

REFERENCE BOOKS:

1. Peter Fortes cue, "Spacecraft Systems Engineering" Wiley, 4th Edition,1992.
2. Vladimir A. Chobotov," Orbital Mechanics" AIAA Education series, 3rd Edition, 2002.

WEB REFERENCES:

1. http://spacecraft.ssl.umd.edu/academics/791S04/791S04.040302.text.pdf

E-TEXT BOOKS:

1. http://download.e-bookshelf.de/download/0000/0122/72/L-G-0000012272-0002345666.pdf
2. http://www.spaceatdia.org/uploads/mariano/ss1/Spacecraft-Systems-Engineering.pdf

XIV COURSE PLAN:

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

S.No	Topics to be covered	CO's	Reference
OBE DISCUSSION			
1	Course Description on Outcome Based Education (OBE): Course Objectives, Course Outcomes (CO), Program Outcomes (PO) and CO-PO Mapping	-	
CONTENT DELIVERY (THEORY)			
1	Classical point mass mechanics, mechanics of rigid bodies, topography and gravitation.	CO1	T1 : 18.1
2	The geodetic frame of reference, the terrestrial field of gravitation.	CO1	T1 : 13
3	Models of atmosphere, main parameters and hypotheses, the isothermal exponential model.	CO1	T1 : 18.2

4	Standard models of earth's atmosphere, martian models.	CO1	T1 : 18.2.1, 18.2.2
5	Aerodynamic coefficients.	CO1	T1 : 18.3.1, 18.3.2
6	Modes of flow, continuous mode, rare field mode.	CO1	T2: 4.1, 4.1.1
7	Qualities of flight, characteristics of a family of sphere cones.	CO1	T2: 4.1.5, 4.1.3
8	Planetary entry capsule.	CO1	T2: 4.1.4
9	Inertial Models: Moments of inertia, cg offset and principal axis misalignment.	CO1	T2:4.1.6, 4.1.8
10	Changing of Reference Frame: Direction cosine matrices.	CO1	T2: 4.5, 4.5.8
11	Euler angles, representations with four parameters.	CO2	T2:5.3, 5.3.2
12	Exoatmospheric phase: Movement of the center of mass.	CO2	T2:5.3.2, R4:4.4
13	Movement around mass center.	CO2	T2: 4.2.8
14	Six degree-of-freedom reentry: General equations of motion, solutions of general equations.	CO2	R1: 8.1, 8.2
15	Zero angle of attacker entry; Allen's reentry results	CO2	R1: 8.3 - 8.6
16	influence of ballistic coefficient and flight path angle, influence of range;	CO2	R1: 8.7, 8.8
17	Decay of initial incidence: Zero spin rate, nonzero spin	CO2	R2: 11.2,11.3
18	End of the convergence of the incidence: Linear equations, instantaneous angular movement, real angular motion	CO2	R2: 11.4, 11.5
19	Roll-lock-in Phenomenon: Association of aerodynamic asymmetry and cg offset	CO2	R2: 11.7
20	Under and over expanded nozzles, slip streamline.	CO2	R2:11.8
21	Isolated center of gravity, isolated principal axis misalignment	CO3	T2:9.1 - 9.3
22	Combined cg offset and principal axis misalignment	CO3	T2: 9.4 - 9.5
23	Instabilities: static instabilities, dynamic instabilities;	CO3	T2: 9.6
24	Reentry errors: Zero angle of attack	CO3	T1:9.7, 9.8
25	Dispersions, non-zero angle of attack.	CO3	T1:9.9
25	Introduction to compressible flow	CO3	T1:60
26	Brief review of thermodynamics and fluid mechanics	CO3	T1:488-499
27	Integral forms of conservation equations, differential conservation equations	CO3	T1:97-132

28	Continuum postulates	CO3	T1:58
29	Acoustic speed and Mach number	CO3	T1:560-564
30	Governing equations for compressible flows	CO3	T1:499-501
31	Shocks and expansion waves	CO4	T1:602-606
32	Development of governing equations for normal shock	CO4	T1:515-557
33	Stationery and moving normal shock waves,	CO4	T1:515-557
34	Applications to aircrafts	CO4	T1:580-581
35	Supersonic wind tunnel, shock tubes	CO4	T1:570-575
36	Shock polars, supersonic pitot probes	CO4	T1:570-575
37	Oblique shocks, governing equations, reflection of shock	CO4	T1:566-570
38	Prandtl-Meyer expansion flow	CO4	T1:590-596
39	Shock expansion method for flow over airfoil	CO4	T1:590-596
40	Introduction to shock wave boundary layer interaction	CO4	T1:870
41	Quasi one dimensional flow	CO5	T1:289
42	Isentropic flow in nozzles, area Mach relations, choked flow	CO5	T1:626-630
43	Under and over expanded nozzles, slip streamline.	CO5	T1:631-638
44	Theory of characteristics	CO5	T1:691-693
45	Determination of the characteristic lines	CO5	T1:691-693
46	Compatibility equations	CO5	T1:729-736
47	Supersonic nozzle design using method of characteristics	CO5	T1:729-736
48	Experimental methods Subsonic wind tunnels	CO6	T1:200-215
49	Supersonic wind tunnels	CO5	T1:200-215
50	Shock tunnels	CO5	T1:200-215
51	Free-piston shock tunnel	CO6	T1:200-215
52	Detonation-driven shock tunnels,	CO6	T1:200-215
53	Expansion tubes and characteristic features, their operation and performance	CO6	T1:486
54	Flow visualization techniques for compressible flows.	CO6	T1:486
55	Development of governing equations for normal shock	CO6	R2:11.8
56	Isolated center of gravity, isolated principal axis misalignment	CO6	T2:9.1 - 9.3
57	Combined cg offset and principal axis misalignment	CO6	T2: 9.4 - 9.5
58	Instabilities: static instabilities, dynamic instabilities;	CO6	T2: 9.6
59	Reentry errors: Zero angle of attack	CO6	T1:9.7, 9.8
60	Dispersions, non-zero angle of attack.	CO6	T1:9.9
DISCUSSION OF QUESTION BANK			
1	Module: I- Overvier and Introduction	CO1	T1
2	Module: II- Aerodynamics	CO2	T2, R1,
3	Module: III- Special treatment for Re-entry Vehicles	CO3,4	R1

4	Module: IV- Equation of motion	CO5	R2
5	Module: V- Flight Dynamics of Re-entry vehicles	CO6	T4

Signature of Course Coordinator **HOD,AE**
Mr. Athota Rathan Babu, Assistant Professor

INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal, Hyderabad - 500 043

AERONAUTICAL ENGINEERING
COURSE DESCRIPTION

Course Title	FLIGHT SIMULATION AND CONTROLS LABORATORY				
Course Code	BAEC23				
Program	M.Tech				
Semester	II	AE			
Course Type	Laboratory				
Regulation	IARE-PG21				
Course Structure	Theory			Practical	
	Lecture	Tutorials	Credits	Laboratory	Credits
	-	-	-	4	2
Course Coordinator	Dr. Bodavula Aslesha, Assistant Professor				

I COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites
B.Tech	AAEB03	IV	Aerodynamics
B.Tech	AAEC16	V	High Speed Aerodynamics
B.Tech	AAEC25	VI	Computational Aerodynamics

II COURSE OVERVIEW:

Flight simulation and Control is the science that investigates the stability and control of aircrafts and all other flying vehicles. From the advent of the first flight by the Wright Brothers, it was observed that flight without knowledge of stability and control was not viable. Since then, several different concepts for controlling aircraft flight have been devised including control surfaces, deformable surfaces, morphing of wings etc. This course introduces some of these concepts and describes their operation, as well as the degree of stability that these devices can provide. Modern aircraft control is ensured through automatic control systems known as autopilot. Their role is to increase safety, facilitate the pilot's task and improve flight qualities. The course will introduce modern aircraft stability and control and discuss some of its objectives and applications

III MARKS DISTRIBUTION:

Subject	SEE Examination	CIE Examination	Total Marks
Flight simulation and Controls Laboratory	70 Marks	30 Marks	100

IV DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✓	Demo Video	✓	Lab Worksheets	✓	Viva Questions	✓	Probing further Questions

V EVALUATION METHODOLOGY:

Each lab will be evaluated for a total of 100 marks consisting of 30 marks for internal assessment and 70 marks for semester end lab examination. Out of 30 marks of internal assessment, continuous lab assessment will be done for 20 marks for the day to day performance and 10 marks for the final internal lab assessment. The semester end lab examination for 70 marks shall be conducted by two examiners, one of them being a internal examiner and another is external examiner, both nominated by the Principal from the panel of experts recommended by Chairman, BOS.
All the drawing related courses are evaluated in line with lab courses. The distribution shall be 30 marks for internal evaluation (20 marks for day–to–day work, and 10 marks for internal tests) and 70 marks for semester end lab examination. There shall be ONE internal test for 10 marks each in a semester.
The emphasis on the experiments is broadly based on the following criteria given in Table: 1

	Experiment Based	Programming based
20 %	Objective	Purpose
20 %	Analysis	Algorithm
20 %	Design	Programme
20 %	Conclusion	Conclusion
20 %	Viva	Viva

Continuous Internal Assessment (CIA):

CIA is conducted for a total of 30 marks (Table 1), with 20 marks for continuous lab assessment during day to day performance, 10 marks for final internal lab assessment.

Component	**Laboratory**		**Total Marks**
Type of Assessment	**Day to day performance**	**Final internal lab assessment**	
CIA Marks	20	10	30

Continuous Internal Examination (CIE):

One CIE exams shall be conducted at the end of the 16th week of the semester. The CIE exam is conducted for 10 marks of 3 hours duration.

1. **Experiment Based**

Objective	Analysis	Design	Conclusion	Viva	Total
-	-	-	-	-	-

2. **Programming Based**

Objective	Analysis	Design	Conclusion	Viva	Total
2	2	2	2	2	10

VI COURSE OBJECTIVES:

The students will try to learn:

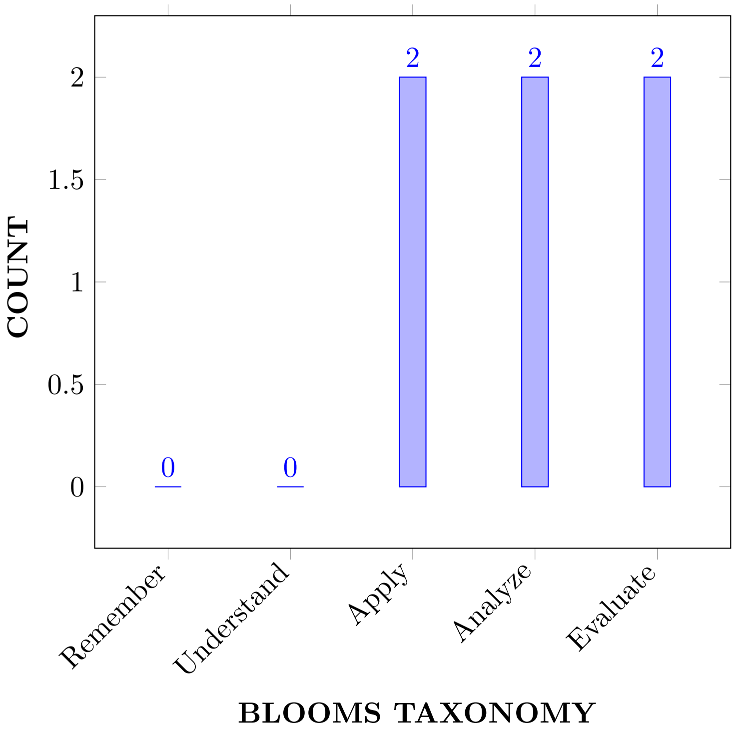
I	The basics simulation of un accelerated and accelerated level flight for climb and descend.
II	The takeoff and landing performance and ground roll for different modes of aircraft.
III	The basic controls and maneuver of in complex flight path.

VII COURSE OUTCOMES:

After successful completion of the course, students should be able to:

CO 1	**Choose** the appropriate flight path using flight simulator for simulating the un-accelerated and accelerated flights.	Apply
CO 2	**Estimate** the take-off velocity, ground roll distance, and landing distance using flight simulator for the Cessna aircraft.	Evaluate
CO 3	**Make use of** flight simulator's mission profiles for simulating the different flight manoeuvres.	Apply
CO 4	**Examine** the longitudinal and lateral perturbed stability of aircraft for obtaining desired operational ability.	Analyze
CO 5	**Analyze** lateral and directional coupled dynamic stability for a given aircraft to simulate spin recovery.	Anlayze
CO 6	**Determine** turn rates, radius and barrel roll by using flight simulator for assessing flight performance in given condition.	Evaluate

COURSE KNOWLEDGE COMPETENCY LEVEL



VIII PROGRAM OUTCOMES:

Program Outcomes	
PO 1	Identify, formulate, analyze and Design complex engineering problems, and design system components or processes by applying appropriate advanced principles of engineering activities and using modern tools
PO 2	Engage in life-long learning and professional development through self-study and continuing education in understanding the engineering solutions in global and management principles to manage projects in multidisciplinary environments.
PO 3	Demonstrate a degree of mastery in emerging areas of Aerospace Engineering such as Aerodynamics, Propulsion, Structure and Flight Dynamics
PO 4	Write and present a substantial technical report/document
PO 5	Independently carry out research/investigation and development work to solve practical problems
PO 6	Function effectively as a member or leader in diverse teams to carry out development work, produce solutions that meet the specified needs with frontier technologies and communicate effectively on complex engineering activities.

IX HOW PROGRAM OUTCOMES ARE ASSESSED:

Program		Strength	Proficiency Assessed by
PO1	Identify, formulate, analyze and Design complex engineering problems, and design system components or processes by applying appropriate advanced principles of engineering activities and using modern tools	2	CIE, SEE
PO3	Demonstrate a degree of mastery in emerging areas of Aerospace Engineering such as Aerodynamics, Propulsion, Structure and Flight Dynamics	2	CIE, SEE
PO4	Write and present a substantial technical report/document	1	CIE, SEE
PO 5	Independently carry out research/investigation and development work to solve practical problems	2	CIE, SEE

3 = High; 2 = Medium; 1 = Low

X MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	2	-	2	1	2	-
CO 2	2	-	2	1	2	-

CO 3	2	-	2	1	2	-
CO 4	2	-	2	1	2	-
CO 5	2	-	2	1	2	-
CO 6	2	-	2	1	2	-

XI ASSESSMENT METHODOLOGY DIRECT:

CIE Exams	✓	SEE Exams	✓	Seminars	-
Laboratory Practices	✓	Student Viva	✓	Certification	-

XII ASSESSMENT METHODOLOGY INDIRECT:

✓	Early Semester Feedback	✓	End Semester OBE Feedback
X	Assessment of Mini Projects by Experts		

XIII SYLLABUS:

WEEK I	**SIMULATION OF UNACCELERATED AND ACCELERATED LEVEL FLIGHT**
	Implement the following tasks 1. Simulation of steady flight. 2. Simulation of accelerated level flight at various altitudes.
WEEK II	**SIMULATION OF UNACCELERATED AND ACCELERATED CLIMB**
	Implement the following tasks 1. Simulation of steady climb 2. Simulation of accelerated climb at various climb rates
WEEK III	**SIMULATION OF UNACCELERATED AND ACCELERATED DESCENT**
	Implement the following tasks 1. Simulation of steady descent 2. Simulation of accelerated descent at various descentrates

WEEK IV	**SIMULATION OF TAKE-OFF PERFORMANCE**
	Implement the following tasks 1. Estimation of take off velocity for Cessna flight.
WEEK V	**SIMULATION OF LANDING PERFORMANCE**
	Implement the following tasks 1. Estimation of ground roll distance for Cessna flight 2. Estimation of total landing distance for Cessna flight
WEEK VI	**SIMULATION OF CONVENTIONAL FLIGHT PATH**
	Implement the following tasks 1. Perform the given mission profiles
WEEK VII	**STABILIZATION OF LONGITUDINAL PER TURBED AIRCRAFT**
	Implement the following tasks 1. Perform the operation from disturbed flight to trim flight 2. Perform long period and short period modes.
WEEK VIII	**STABILIZATION OF LATERAL PERTURBED AIRCRAFT**
	Implement the following tasks 1. Perform the operation from disturbed flight to trim flight 2. Simulate lateral directional modes.
WEEK IX	**SIMULATION OF SPIN RECOVERY**
	Implement the following tasks 1. Perform the operation of spin recovery
WEEK X	**SIMUILATION OF COORDINATED LEVEL TURN**
	Implement the following tasks 1. Perform the level turn at given turn rate. 2. Perform the level turn at given turn radius.
WEEK XI	**SIMUILATION OF BARREL ROLL MANEUVER**
	Implement the following tasks 1. Perform the barrel roll maneuver

WEEK XII	**SIMULATION OF A COMPLEX FLIGHT PATH**
	Implement the following tasks 1. Perform flight simulation for given mission profiles

TEXTBOOKS

1. Peter John Davison, —A summary of studies conducted on the effect of motion in flight simulator pilot training", 5th February, 2014.

REFERENCE BOOKS:

1. Vepa, R., —Flight Dynamics, Simulation and Control: For Rigid and Flexible Aircraft‖, CRC Press, Taylor and Francis Group, 2015.
2. Wayne Durham, —Aircraft Flight Dynamics and Control‖, CRC Press, 2nd Edition, 2013.
3. RobertF.Stengel —Flight Dynamics‖, CRC Press, 2nd Edition, 2013.

XIV COURSE PLAN:

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

S.No	Topics to be covered	CO's	Reference
1	simulation of unaccelerated and accelerated level flight	CO 1	T1: 2.3
2	simulation of unaccelerated and accelerated climb	CO 1	T1: 2.6
3	simulation of unaccelerated and accelerated descent	CO 1	T1: 2.6
4	simulation of take-off performance	CO 2	T1: 2.7
5	simulation of landing performance	CO 2	R1: 2.22
6	simulation of conventional flight path	CO 3	R1: 2.25
7	stabilization of longitudinal perturbed aircraft	CO 4	R1: 2.55
8	stabilization of lateral perturbed aircraft	CO 4	R1: 2.3
9	simulation of spin recovery	CO 5	R1: 2.6
10	simulation of coordinated level turn	CO 6	R1: 2.8
11	simulation of barrel roll maneuver	CO 6	R1:2.18
12	simulation of a complex flight path	CO 3	R3:5.22

XV EXPERIMENTS FOR ENHANCED LEARNING (EEL):

S.No	Design Oriented Experiments
1	Simulation of Acclerated and unacclerated flight during various flight conditions
2	Simulation of landing and take off performance of Cessna 172 Skyhawk

3	Simulation of Low level strike profile
4	Simulation of hall roll, split S and Loop profile flight
5	Simulation of cobra maneuvering

Signature of Course Coordinator **HOD,AE**
Dr. Bodavula Aslesha, Assistant Professor

INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal, Hyderabad - 500 043

AERONAUTICAL ENGINEERING
COURSE DESCRIPTION

Course Title	ADVANCED COMPUTATIONAL STRUCTURES LABORATORY				
Course Code	BAEC24				
Program	M.Tech				
Semester	II	AE			
Course Type	Laboratory				
Regulation	IARE-PG21				
Course Structure	Theory			Practical	
	Lecture	Tutorials	Credits	Laboratory	Credits
	-	-	-	4	2
Course Coordinator	Mr. A Rathan Babu, Assistant Professor				

I COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites
B.Tech	AAEC06	IV	Aerospace Structures

II COURSE OVERVIEW:

The major emphasis of this course is to solve a complex geometrical structures under a given loads, these methods does not have analytical solutions. Software‘s like ANSYS and NASTRAN is utilized to interpret results for complex geometries. Modeling of crack and composite structures help the students to solve realistic problems which are common in industries. Structural analysis on aircraft structures and Rocket components are delt to obtain the solution for bending and torsion under the applied aerodynamic loads

III MARKS DISTRIBUTION:

Subject	SEE Examination	CIE Examination	Total Marks
Advanced Computational Structures Laboratory	70 Marks	30 Marks	100

IV DELIVERY / INSTRUCTIONAL METHODOLOGIES:

x	Demo Video	✓	Lab Worksheets	✓	Viva Questions	✓	Probing further Questions

V EVALUATION METHODOLOGY:

Each laboratory will be evaluated for a total of 100 marks consisting of 30 marks for internal assessment and 70 marks for semester end lab examination. Out of 30 marks of internal assessment, continuous lab assessment will be done for 20 marks for the day today performance and 10 marks for the final internal lab assessment.

Semester End Examination (SEE): The semester end lab examination for 70 marks shall be conducted by two examiners, one of them being Internal Examiner and the other being External Examiner, both nominated by the Principal from the panel of experts recommended by Chairman, BOS. The emphasis on the experiments is broadly based on the following criteria given in Table: 1

	Experiment Based	Programming based
20 %	Objective	Purpose
20 %	Analysis	Algorithm
20 %	Design	Programme
20 %	Conclusion	Conclusion
20 %	Viva	Viva

Continuous Internal Assessment (CIA):

CIA is conducted for a total of 30 marks (Table 1), with 20 marks for continuous lab assessment during day to day performance, 10 marks for final internal lab assessment.

Component	**Laboratory**		**Total Marks**
Type of Assessment	**Day to day performance**	**Final internal lab assessment**	
CIA Marks	20	10	30

Continuous Internal Examination (CIE):

One CIE exams shall be conducted at the end of the 16th week of the semester. The CIE exam is conducted for 10 marks of 3 hours duration.

1. **Experiment Based**

Objective	Analysis	Design	Conclusion	Viva	Total
2	2	2	2	2	10

2. **Programming Based**

Objective	Analysis	Design	Conclusion	Viva	Total
-	-	-	-	-	-

VI COURSE OBJECTIVES:

The students will try to learn:

I	The utilization of ANSYS and NASTRAN software to obtain the solution for complex geometrical structures.

II	The mathematical methods involved in structural mechanics along with its strengths and weakness.
III	Modeling a structural crack in ANSYS and NASTRAN and determine its failure loads.
IV	Modeling a complex composite structures in ANSYS and NASTRAN and determine the stresses and strains.

VII COURSE OUTCOMES:

After successful completion of the course, students should be able to:

CO 1	**Develop**the appropriate method for predicting ultimate load on wing using ANSYS.	Apply
CO 2	**Estimate** the rocket motor case loading for the launch vehicle by using computational tools.	Analyze
CO 3	**Examine** the thermal and structural loading on exposed components during the flight mission for obtaining airworthiness suitability.	Analyze
CO 4	**Make use of** the structural fatigue concept for obtaining desired operational characteristics.	Analyze
CO 5	**Analyze** the effect of fracture during bird hit using L S Dyna simulation for failure rate of an aircraft.	Analyze
CO 6	**Determine** the failure mode during fracture of an aircraft component for assessing crack propagation.	Apply

VIII PROGRAM OUTCOMES:

Program Outcomes	
PO 1	Identify, formulate, analyze and Design complex engineering problems, and design system components or processes by applying appropriate advanced principles of engineering activities and using modern tools
PO 2	Engage in life-long learning and professional development through self-study and continuing education in understanding the engineering solutions in global and management principles to manage projects in multidisciplinary environments.
PO 3	Demonstrate a degree of mastery in emerging areas of Aerospace Engineering such as Aerodynamics, Propulsion, Structure and Flight Dynamics
PO 4	Write and present a substantial technical report/document
PO 5	Independently carry out research/investigation and development work to solve practical problems
PO 6	Function effectively as a member or leader in diverse teams to carry out development work, produce solutions that meet the specified needs with frontier technologies and communicate effectively on complex engineering activities.

IX HOW PROGRAM OUTCOMES ARE ASSESSED:

Program		Strength	Proficiency Assessed by
PO1	Identify, formulate, analyze and Design complex engineering problems, and design system components or processes by applying appropriate advanced principles of engineering activities and using modern tools	2	CIE, SEE
PO3	Demonstrate a degree of mastery in emerging areas of Aerospace Engineering such as Aerodynamics, Propulsion, Structure and Flight Dynamics	2	CIE, SEE
PO4	Write and present a substantial technical report/document	1	CIE, SEE
PO 5	Independently carry out research/investigation and development work to solve practical problems	2	CIE, SEE

3 = High; 2 = Medium; 1 = Low

X MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	2	-	2	1	2	-
CO 2	2	-	2	1	2	-
CO 3	2	-	2	1	2	-
CO 4	2	-	2	1	2	-
CO 5	2	-	2	1	2	-
CO 6	2	-	2	1	2	-

XI ASSESSMENT METHODOLOGY DIRECT:

CIE Exams	✓	SEE Exams	✓	Seminars	-
Laboratory Practices	✓	Student Viva	✓	Certification	-

XII ASSESSMENT METHODOLOGY INDIRECT:

X	Early Semester Feedback	✓	End Semester OBE Feedback
X	Assessment of Mini Projects by Experts		

XIII SYLLABUS:

WEEK I	**AEROSPACESTRUCTURALANALYSISUSINGANSYS-I**
	Implement the following task 1.Structural analysis of aircraft wing.
WEEK II	**EROSPACESTRUCTURALANALYSISUSINGANSYS-II**
	Implement the following task 1.Structural analysis of aircraft win g(composite material).
WEEK III	**AEROSPACESTRUCTURALANALYSISUSINGANSYS-III**
	Implement the following task 1.Analysis of fuselage.
WEEK IV	**AEROSPACESTRUCTURALANALYSISUSINGANSYS-IV**
	Implement the following task 1.Rocket motor case analysis
WEEK V	**AEROSPACESTRUCTURALANALYSISUSINGANSYS-V**
	Implement the following tasks 1.Structural and thermal analysis of rocket nozzles
WEEK VI	**AEROSPACESTRUCTURALANALYSISUSINGANSYS-VI**
	Implement the following task 1.Fractural mechanics of crack propagation.
WEEK VII	**AEROSPACESTRUCTURALANALYSISUSINGNASTRA-I**
	Implement the following task 1.Structural analysis of aircraft wi
WEEK VIII	**AEROSPACESTRUCTURALANALYSISUSINGNASTRA-II**
	Implement the following task 1.Structural analysis of aircraft wing (composite material).
WEEK IX	**AEROSPACESTRUCTURALANALYSISUSINGNASTRA-III**
	Implement the following task 1.Analysis off uselage.
WEEK X	**AEROSPACESTRUCTURALANALYSISUSINGNASTRA-IV**
	Implement the following tasks Rocket motor case analysis.
WEEK XI	**AEROSPACESTRUCTURALANALYSISUSINGNASTRA-V**
	Implement the following task 1.Structural and thermal analysis of rocket nozzles.
WEEK XII	**EROSPACESTRUCTURALANALYSISUSINGNASTRA-VI**
	Implement the following task 1.Fractural mechanics of crack propagation

TEXTBOOKS

1. Anderson, J.D., Jr., Computational Fluid Dynamics the Basics with Applications, McGraw-Hill Inc, 1st Edition, 1998.
2. Hoffmann, K. A. and Chiang, S. T., —Computational Fluid Dynamics for Engineers‖, 4th Edition, Engineering Education Systems (2000).

REFERENCE BOOKS:

1. Hirsch,C., —Numerical Computation of Internal and External Flows: The Fundamentals of Computational Fluid Dynamics‖, Vol. I, 2nd Edition, Butterworth-Heinemann (2007).

2. JAF.Thompson, Bharat K.Soni, NigelP. Weatherill, —Grid Generation‖, 1st Edition, 2000.

XIV COURSE PLAN:

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

S.No	Topics to be covered	CO's	Reference
1	Introduction to simulation software.	CO 1	R1: 1.2
2	Introduction to ANSYS.	CO 1	R2: 3.5
3	Verification of Bernoulli‘s theorem.	CO 1	R1: 3.4
4	Determination of 2-D, 3-D truss structures.	CO 2	R1: 2.2
5	Determine the static-structural analysis.	CO 2	R1: 2.4
6	Determine the Structural analysis of beams under different load condition.	CO 3	R3: 4.5
7	Determine the model analysis of beams and spring-mass system.	CO 3	R3: 4.6
8	Determine the non-linear analysis for large deflections.	CO 4	R2: 5.1
9	Determine the harmonic response analysis of simply-supported beam.	CO 5	R2: 5.2
10	Determine the harmonic response analysis of a spring-mass system	CO 5	R1: 7.1
11	Determine the structural analysis of aircraft wings, fuselage, and landing gear	CO 6	R1:7.2
12	Determine the analysis of composite structures	CO 6	R1:7.3

XV EXPERIMENTS FOR ENHANCED LEARNING (EEL):

S.No	Design Oriented Experiments
1	Determine the static-structural analysis
2	Determine the model analysis of beams and spring-mass system.
3	Determine the non-linear analysis for large deflections.
4	Determine the harmonic response analysis of simply-supported beam.
5	Determine the harmonic response analysis of a spring-mass system

Signature of Course Coordinator **HOD,AE**
Mr. A Rathan Babu, Assistant Professor

INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal, Hyderabad - 500 043

COURSE DESCRIPTION

Department	**AEROSPACE ENGINEERING**				
Course Title	**AIRPORT PLANNING AND OPERATIONS**				
Course Code	BAEC28				
Program	M.Tech				
Semester	III	AE			
Course Type	PE				
Regulation	IARE PG-21				
Course Structure	Theory			Practical	
	Lecture	Tutorials	Credits	Laboratory	Credits
	3	-	3	-	-
Course Coordinator	Ms. K Sai Priyanka, Assistant Professor				

I COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites
B.Tech	AAE001	III	Introduction To aerospace Engineering
B.Tech	AAE526	VI	Air transportation system

II COURSE OVERVIEW:

The aim is to understanding of relevant international and national regulations and the ability to explain their effects on airport business, planning, design, operations and safety management decisions.A critical awareness of the key issues that affect users of airport facilities.And to identify, analyse and design solutions in order to address a given research problem within the context of airport planning and management, having regard to regulatory constraints and commercial and environmental imperatives.

III MARKS DISTRIBUTION:

Subject	SEE Examination	CIE Examination	Total Marks
Airport Planning and Management	70 Marks	30 Marks	100

IV DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✓	PPT	✓	Chalk & Talk	✓	Assignments	x	MOOC
x	Seminars	x	Others				

V EVALUATION METHODOLOGY:

Each theory course will be evaluated for a total of 100 marks, out of which 30 marks for Continuous Internal Assessment (CIA) and 70 marks for Semester End Examination (SEE). **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 three 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):

For each theory course the CIA shall be conducted by the faculty / teacher handling the course. CIA is conducted for a total of 30 marks, with 20 marks for Continuous Internal Examination (CIE), 05 marks for Assignment and 05 marks for Alternative Assessment Tool (AAT). Two CIE Tests are Compulsory and sum of the two tests, along with the scores obtained in the assignment / AAT shall be considered for computing the final CIA of a student in a given course.

The CIE Tests/Assignment /AAT shall be conducted by the course faculty with due approval from the HOD. Advance notification for the conduction of Assignment/AAT is mandatory and the responsibility lies with the concerned course faculty. CIA is conducted for a total of 30 marks (Table 1).

Component	Theory			Total Marks
Type of Assessment	CIE Exam	Assignment	AAT	
CIA Marks	20	05	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 five descriptive type questions out of which four 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 COURSE OBJECTIVES:

The students will try to learn:

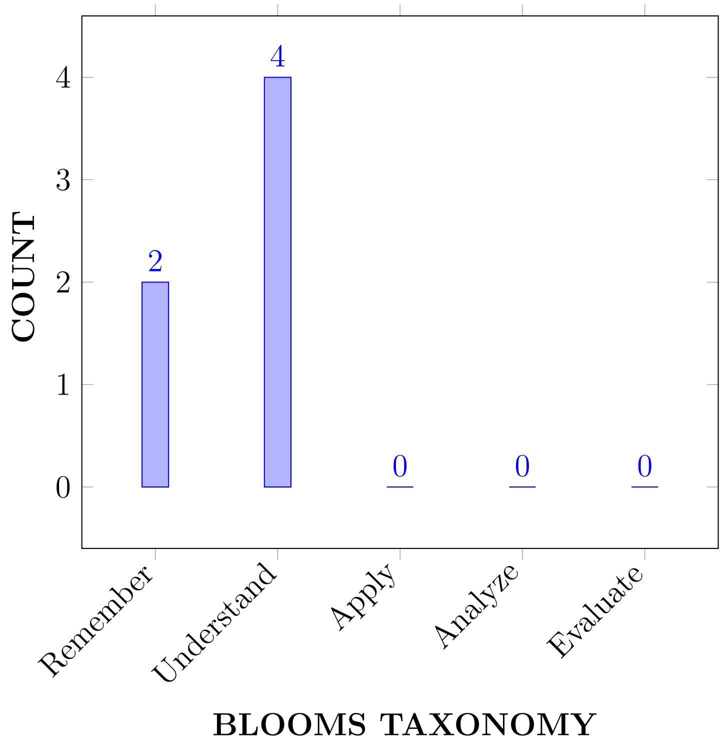
I	The various acts of legislation that have influenced the development and operation of airports since the early days of civil aviation
II	The knowledge on various facilities located on an airport's and types of airport runways airfield
III	The facilities within an airport terminal that facilitate the transfer of passengers and baggage to and from aircraft
IV	The technologies used to modernize air traffic control,hierarchical air traffic control management structure. .

VII COURSE OUTCOMES:

After successful completion of the course, students should be able to:

CO 1	**Explain** various acts of legislation that have influenced the development and operation of airports that have influenced civil aviation.	Apply
CO 2	**Describe** the importance of runway orientation with the airport's reference codes with navigational aids that exist on airfields	Apply
CO 3	**Describe** the history of the air traffic control system technologies used to modernize air traffic control	Understand
CO 4	**Discuss** development of airport terminals from the early days of commercial aviation to present-day terminal design concepts	Understand
CO 5	**Explain** the facilities within an airport terminal that facilitate the transfer of passengers and baggage to and from aircraft	Understand
CO 6	**Explain** Various modes of transportation that comprise airport ground access systems technologies that are being implemented to improve ground access to airports	Understand

COURSE KNOWLEDGE COMPETENCY LEVEL



VIII PROGRAM OUTCOMES:

Program Outcomes	
PO 1	**Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering 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.
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
PO 4	**Conduct Investigations of Complex Problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
PO 5	**Modern Tool Usage:** Create, select, and apply appropriate techniques, resources, and modern Engineering and IT tools including prediction and modelling to complex Engineering activities with an understanding of the limitations
PO 6	**The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

IX MAPPING OF EACH CO WITH PO(s):

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	✓	-	✓	-	-	-
CO 2	✓	-	✓	-	-	-
CO 3	✓	-	✓	-	-	-
CO 4	✓	-	✓	-	-	-
CO 5	✓	-	✓	-	-	-
CO 6	✓	-	✓	-	-	-

X COURSE ARTICULATION MATRIX (CO – PO MAPPING):

CO'S and PO'S on the scale of 0 to 3, 0 being no correlation, 1 being the low correlation, 2 being medium correlation and 3 being high correlation.

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	-	1	-	-	-
CO 2	3	-	1	-	-	-
CO 3	3	-	1	-	-	-
CO 4	3	-	3	-	-	-
CO 5	3	-	1	-	-	-
CO 6	3	-	1	-	-	-
TOTAL	18	-	8	-	-	-
AVERAGE	3	-	1.3	-	-	-

XI ASSESSMENT METHODOLOGY DIRECT:

CIE Exams	✓	SEE Exams	✓	Seminar and term paper	-
Laboratory Practices	-	Student Viva	-	Mini Project	-

XII ASSESSMENT METHODOLOGY-INDIRECT:

✓	**End Semester OBE Feed Back**

XIII SYLLABUS:

MODULE I	AIRPORT AS AN OPERATIONAL SYSTEM
	Private airports and public use airports, commercial service airports and primary commercial service airports, general aviation airports, reliever airports. Hub classification-large hubs, medium hubs, small hubs, non-hubs. Components of an airport-airside, landside. Airport as a system-function of the airport-complexity of airport operation

MODULE II	**GROUND HANDLING AND BAGGAGE HANDLING**
	Ground handling: Passenger handling; Ramp handling; Aircraft ramp servicing; Ramplay out; Departure control; Division of ground handling responsibilities; Control of ground handling efficiency; Baggage handling: Context, history and trends; Baggage handling processes; Equipment, systems and technologies, process and system design drivers; Organization; Management and performance metrics.
MODULE III	**PASSENGER TERMINAL AND CARGO OPERATIONS**
	Passenger terminal operations: Functions of the passenger terminal; Terminal functions; Philosophies of terminal management; Direct passenger services; Airline related passenger services; Airline related operational functions; Government requirements; Non-passenger related airportau thority functions; processing very important persons; Passenger information systems. Space components and adjacencies. Aids to circulation; Hubbind considerations; Cargo operations: The cargo market; Expediting the movement; Flow through the terminal; unit load devices; Handling within the terminal; Cargo apron operation; Facilitation; Examples of modern cargo terminal design and operation; Cargo operations by the integrated carriers.
MODULE IV	**AIRPORT TECHNICAL SERVICES AND ACCESS**
	Airport technical services: The scope of technical services; Safety management system; Air traffic control; Telecommunications; Meteorology; Aeronautical information; Airport access: Access as part of airport system; access users and modal choice; access interaction with passenger; access modes; In town and other off; airport terminals; Factors affecting access; mode choice.
MODULE V	**OPERATIONAL ADMINISTRATION AND PERFORMANCE**
	Operational administration and performance: Strategic context; Tactical approach to administration of airport operations; Managing operational performance; Key success factors for high; performance; airport operations control centers: The concept of airport operations; airport operations control system; the airport Operations consideration; airport performance monitoring; design and equipment considerations; organizational and human resources considerations; leading AOCCSs; best practices in airport operations

TEXTBOOKS

1. A.T. Wells, and S.B. Young, "Airport Planning and Management", 5th edition, McGraw-Hill, 2004

2. N. Ashford, H.P.M. Stanton, and C.A. Moore, "Airport Operations", McGraw-Hill, 1997

REFERENCE BOOKS:

1. A. Kazda and R.E Caves, "Airport Design and Operation", 2nd edition, Elsevier, 2007.

2. R. Horonjeff, F.X. Mc Kelvey, W.J. Sproule, and S.B. Young, "Planning and Design of Airports", 5th edition, McGraw-Hill, 2010.

WEB REFERENCES:

1. https://nptel.ac.in/courses/112105171/1

XIV COURSE PLAN:

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

S.No	Topics to be covered	CO's	Reference T1: 4.1
OBE DISCUSSION			
1	Course Description on Outcome Based Education (OBE): Course Objectives, Course Outcomes (CO), Program Outcomes (PO) and CO-PO Mapping	-	
CONTENT DELIVERY (THEORY)			
1	Define different types of airports	CO1	T1:1-1-1
2	Classification of hubs	CO1	T1:3-1-1 T2:5.4
3	Describe components of airport	CO1	T1:1.2
4	Function of an airport	CO1	T1:1.2
5	Define airport planning system	CO1	T1:1.1
6	Discussing different types of plans	CO1	T1:1.1
7	Define the term ramp, handling and layout	CO1	T1:4-1
8	Discuss responsibilities of ground handling	CO1	T1:4-2- T1:4-5
9	Discuss responsibilities of ground handling	CO2	T1:2-3
10	Discuss airline and passenger related operations	CO1	T1:2-7
11	Define airport authority	CO2	T1:5-1- T1:5-3
12	Define Federal aviation administration	CO2	T1:5-3
13	Define cargo operations and handling operations	CO2	T1:5-5
14	Discuss technical services of an airport	CO2	T1:2-7
15	International air transport services	CO3	T1:2-3
16	Explain airport access	CO3	T1:2-4
17	Indian Scenario An overview of Airport in Hyderabad Bangalore	CO3	T1:2-2
18	Indian Scenario An overview of Airport in Delhi Mumbai	CO3	T1:2-3- T1:2-7
19	Airport development fees, Rates and Tariffs.	CO3	T1:2-2
20	Role of DGCA Slot allocation	CO3	T1:2-7 T1:2-5
21	Methodology followed by ATC	CO3	T:5-4
22	Methodology followed by DGCA	CO3	T1:3-1-3
23	Management of bi-laterals, Economic Regulations	CO3	T1:4-6
24	Role of air traffic control	CO3	T1:2-7
25	Airspace and navigational aids	CO3	T1:4-1- T1:4-8
26	Control process for the air traffic management	CO3	T1:4-1- T1:4-8
27	Six cases in the airline industry.	CO3	T1:5

28	Seven phases in air traffic control.	CO4	T1:5
29	Air traffic control and communications	CO4	T1:2-2
30	Aircraft movement areas (wages and benefits) (runways, taxiways, taxi lanes)	CO4	T1:2-3
31	Performance of the ATM air traffic management System	CO4	T1:2-4
32	Approximations to aircraft transfer functions	CO4	T2:3.1-3.8R2:3.2
33	Control surface actuators-review	CO4	T2:4.1-4.2R2:3.2
34	Response of aircraft to elevator input, Response of aircraft to rudder input and Response of aircraft to aileron input to atmosphere	CO4	T2:4.2-4.3R2:3.2
35	Evaluate Main Characteristics of ATM Systems	CO4	T2:4.6
36	Autopilots Stability augmentation systems-pitch damper	CO4	T2:4.4-4.5R2:3.2
37	Autopilots Stability augmentation systems- yaw damper	CO4	T2:4.4-4.5R2:3.2
38	Constraint Analysis of different Airline companies in India	CO4	T2:4.7
39	The three types of control centers and the various air traffic control positions that monitor and serve a typical IFR (instrument flight rules) flights	CO5	T2:3.1-3.3
40	Airport Traffic Control Tower	CO5	T2:6.1
41	Flying quality requirements- frequency response and time-response specifications	CO5	T2:6.2
42	Role of the three principal types of ATM facilities in a typical flight.	CO5	T2:6.3
43	Terminal Airspace Control Center	CO5	T2:4.5
44	Current challenges in airline industry competition in Airline industry	CO6	T2:6.1
45	Airport development fees, Rates and Tariffs.	CO6	T2:4.6 T2:5.4
46	Discuss airline and passenger related operations	CO6	T1:2-7
47	Define airport authority	CO6	T1:5-1-T1:5-3
48	Define Federal aviation administration	CO6	T1:5-3
49	Define cargo operations and handling operations	CO6	T1:5-5
50	Role of DGCA Slot allocation	CO6	T1:2-7 T1:2-5
51	Methodology followed by ATC	CO6	T:5-4
52	Methodology followed by DGCA	CO6	T1:3-1-3
53	Management of bi-laterals, Economic Regulations	CO6	T1:4-6
54	Role of air traffic control	CO6	T1:2-7
55	Explain airport access	CO6	T1:2-4
56	Indian Scenario An overview of Airport in Hyderabad Bangalore	CO6	T1:2-2
57	Indian Scenario An overview of Airport in Delhi Mumbai	CO6	T1:2-3-T1:2-7

58	Airport development fees, Rates and Tariffs.	CO6	T1:2-2
59	Role of DGCA Slot allocation	CO6	T1:2-7 T1:2-5
60	Classification of hubs	CO6	T1:3-1-1 T2:5.4
DISCUSSION OF QUESTION BANK			
1	Unit:I-Explain Emirates Airlines Growth and Incorporation with graphs	CO 1	R4:2.1
2	Unit:II-Explain Airport privatization and give example of any Partial Privatization	CO 2	T4:7.3
3	Unit:III-Explain Design Principle, Dutch Aviation Tax , Overbooked or Cancelled Flights , Ticket taxes worldwide	CO 3	R4:5.1
4	Unit:IV- Explain Airside and Landside and runway works with the simple diagrams	CO3,4	T1:7.5
5	Unit:V- Explain about the Terminal Simulation Support Facility and Facility Control Office (FACO)	CO5,6	T1: 4.1

Signature of Course Coordinator **HOD,AE**
Ms. K Sai Priyanka, Assistant Professor

INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal, Hyderabad - 500 043

COURSE DESCRIPTION

Branch	AEROSPACE ENGINEERING				
Course Title	RESEARCH METHODOLOGY AND IPR				
Course Code	BHSC11				
Program	M.Tech				
Semester	III	AE			
Course Type	Core				
Regulation	IARE PG-21				
Course Structure	Theory			Practical	
	Lecture	Tutorials	Credits	Laboratory	Credits
	2	-	2	-	-
Course Coordinator	Ms. D Anitha, Assistant Professor				

I COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites
M.Tech	-	-	-

II COURSE OVERVIEW:

This course provides the basic concepts on research methodology and intellectual property rights. This course emphasis on sampling techniques, data collection, writing Reports, Projects, Dissertations, thesis and articles for publication in academic journals, avail the intellectual property rights of the inventors or owners for their assets like patents on innovative design, copy rights on literary and artistic works, trademark on goods & services and geographical indications on products famous for specific geographical areas.This course makes use of the potential future economic benefits to the intellectual property owner or authorized user.

III MARKS DISTRIBUTION:

Subject	SEE Examination	CIE Examination	Total Marks
Research Methodology and IPR	70 Marks	30 Marks	100

IV DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✓	Power Point Presentations	✓	Chalk & Talk	✓	Assignments	x	MOOC
x	Open Ended Experiments	✓	Seminars	x	Mini Project	x	Videos
✓	Others						

V EVALUATION METHODOLOGY:

Each theory course will be evaluated for a total of 100 marks, out of which 30 marks for Continuous Internal Assessment (CIA) and 70 marks for Semester End Examination (SEE). **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 three 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):

For each theory course the CIA shall be conducted by the faculty / teacher handling the course. CIA is conducted for a total of 30 marks, with 20 marks for Continuous Internal Examination (CIE), 05 marks for Assignment and 05 marks for Alternative Assessment Tool (AAT). Two CIE Tests are Compulsory and sum of the two tests, along with the scores obtained in the assignment / AAT shall be considered for computing the final CIA of a student in a given course.

The CIE Tests/Assignment /AAT shall be conducted by the course faculty with due approval from the HOD. Advance notification for the conduction of Assignment/AAT is mandatory and the responsibility lies with the concerned course faculty. CIA is conducted for a total of 30 marks (Table 1).

Component	Theory			Total Marks
Type of Assessment	CIE Exam	Assignment	AAT	
CIA Marks	20	05	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 five descriptive type questions out of which four 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 COURSE OBJECTIVES:

The students will try to learn:

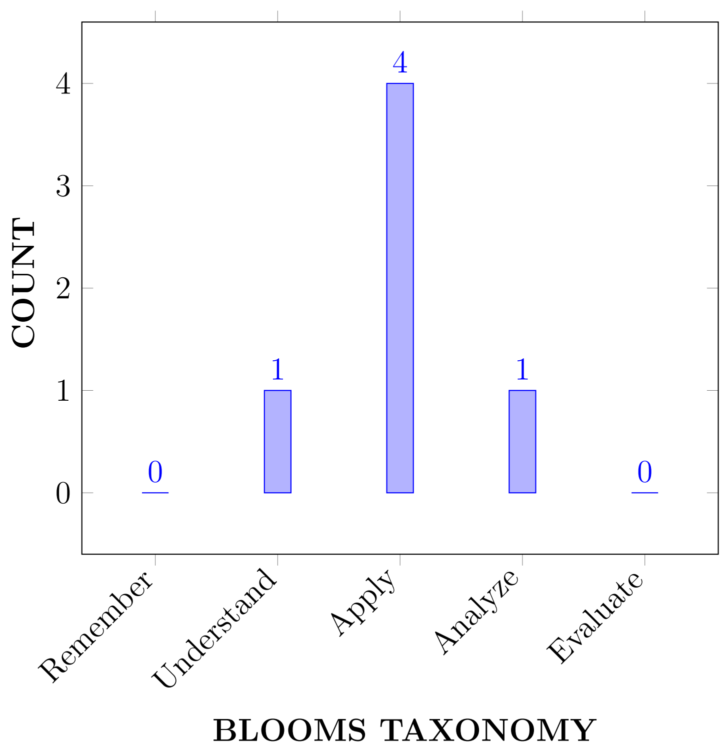
I	The knowledge on sources of research problem, data collection, analysis, and interpretation.
II	The importance of effective technical writing and analysis plagiarism.
III	The new developments in the law of intellectual property rights in order to bring progressive changes towards a free market society.

VII COURSE OUTCOMES:

After successful completion of the course, students will be able to:

CO 1	**Interpret** the technique of determining a research problem for a crucial part of the research study	Understand
CO 2	**Examine** the way of methods for avoiding plagiarism in research	Analyze
CO 3	**Apply** the feasibility and practicality of research methodology for a proposed project	Apply
CO 4	**Make use of** the legal procedure and document for claiming patent of invention.	Apply
CO 5	**Identify** different types of intellectual properties, the right of ownership, scope of protection to create and extract value from IP	Apply
CO 6	**Defend** Defend the intellectual property rights throughout the world with the involvement of World Intellectual Property Organization	Apply

COURSE KNOWLEDGE COMPETENCY LEVEL



VIII PROGRAM OUTCOMES:

Program Outcomes	
PO 1	Independently carry out research / investigation and development work to solve practical problems
PO 2	Write and present a substantial technical report / document.
PO 3	Demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level of higher than the requirements in the appropriate bachelor program.
PO 4	Apply the skills and knowledge needed to serve as a professional engineer skilful at designing embedded systems for effective use in communications, IoT, medical electronics and signal processing applications.
PO 5	Function on multidisciplinary environments by working cooperatively, creatively and responsibly as a member of a team.
PO 6	Recognize the need to engage in lifelong learning through continuing education and research.

IX MAPPING OF EACH CO WITH PO(s):

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	✓	✓	-	-	-	✓
CO 2	✓	-	-	-	-	✓
CO 3	✓	✓	-		-	-
CO 4	✓	✓	-		-	-
CO 5	✓	-	-	-		✓
CO 6	-	✓	-	-	-	-

X COURSE ARTICULATION MATRIX (CO-PO MAPPING):

CO'S and PO'S and CO'S and PSO'S on the scale of 0 to 3, 0 being no correlation, 1 being the low correlation, 2 being medium correlation and 3 being high correlation.

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	3	3	-	-	-	2
CO 2	2	-	-	-	-	1
CO 3	2	3	-	-	-	-
CO 4	3	2	-	-	-	-
CO 5	2	-	-	-	-	2
CO 6	-	3	-	-	-	-
TOTAL	12	11	-	-	-	5
AVERAGE	2.4	2.75	-	-	-	1.7

XI ASSESSMENT METHODOLOGY-DIRECT:

CIE Exams	✓	SEE Exams	✓	Seminar and term paper	-
Laboratory Practices	-	Student Viva	-	Mini Project	-

XII ASSESSMENT METHODOLOGY-INDIRECT:

✓	**End Semester OBE Feed Back**

XIII SYLLABUS:

MODULE I	**INTRODUCTION**
	Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations
MODULE II	**RESEARCH ETHICS**
	Effective literature studies approaches, analysis Plagiarism, Research ethics.
MODULE III	**RESEARCH PROPOSAL**
	Effective technical writing, how to write report, Paper Developing a Research Proposal. Format of research proposal, a presentation and assessment by a review committee
MODULE IV	**PATENTING**
	Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT
MODULE V	**PATENT RIGHTS**
	Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications. New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs

TEXTBOOKS

1. Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science and engineering students".
2. C R Kothari, "Research Methodology: Methods and techniques", New age international limited publishers, 1990 .
3. Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide for beginners"

REFERENCE BOOKS:

1. Halbert, "Resisting Intellectual Property", Taylor and Francis Ltd , 2007.
2. Mayall , "Industrial Design", McGraw Hill, 1992.
3. Niebel , "Product Design", McGraw Hill, 1974.

WEB REFERENCES:

1. Robert P. Merges, Peter S. Menell, Mark A. Lemley Age", 2016 , " Intellectual Property in New Technological Age", 2016

2. T. Ramappa, "Intellectual Property Rights Under WTO" S. Chand 2008
3. Peter-Tobias stoll, Jan busche, Katrianarend- WTO- Trade –related aspects of IPR-Library of Congress

COURSE WEB PAGE:

https://lms.iare.ac.in/index?route=course/details&course_id=367

XIV COURSE PLAN:

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

S.No	Topics to be covered	CO's	Reference
OBE DISCUSSION			
1	Course Description on Outcome Based Education (OBE): Course Objectives, Course Outcomes (CO), Program Outcomes (PO) and CO-PO Mapping		
CONTENT DELIVERY (THEORY)			
1	Introduction, Definition, types of research	CO 1	T1:2.1
2	Meaning of research problem	CO 1	T1:2.1
3	Sources of research problem	CO 1	T1:2.3
4	Criteria characteristics of good research problem	CO 1	T1:2.3.1
5	Research process	CO 1	T1:7.2
6	Research design	CO 1	T1:7.3
7	Errors in selecting a research problem	CO 1	T1:7.4
8	Scope and objectives of research problem	CO 1	T1:2.3
9	Approaches of investigation of solutions for research problem	CO 1	T1:7.4
10	Data collection	CO 1	T1:8.1
11	Analysis and interpretation of data	CO 1	T1:8.1.1
12	Necessary instrumentation's	CO 1	T1:8.1.1
13	Effective literature studies approaches	CO 2	T1:8.2
14	Literature	CO 2	T1:8.2
15	Literature review	CO 2	T1:8.2
16	Literature review techniques	CO 2	T1:8.2
17	Literature studies	CO 2	T1:8.2
18	Introduction to ethics, Importance of ethics	CO 2	T1:8.2
19	Ethical issues in conducting research	CO 2	T1:8.3
20	Principles of research ethics	CO 2	T1:8.4
21	Analysis	CO 2	T1:8.5
22	Plagiarism- types of plagiarism	CO 2	T1:8.6
23	Tips to avoid plagiarism	CO 2	T1:9.1
24	Other ethical issues	CO 2	T1:9.2, 9.3
25	Interpretation, Interpretation Techniques and precautions	CO 2	T2:9.3.4
26	Writing of report and steps involved	CO 3	T2:7.1
27	Layout of research report	CO 3	T2:7.2
28	Types of reports	CO 3	T2:7.3
29	Paper developing a research proposal	CO 3	T2:7.4
30	Format of research proposal	CO 4	T2:8.3

31	Presentation of report	CO 4	T2:8.4
32	Summary of findings	CO 4	T3:8.5
33	Assessment by review committee	CO 4	T3:8.6
34	Technical appendixes	CO 4	T3:8.6
35	Logical analysis of the subject matter	CO 4	T3:8.6
36	Statement of findings and recommendations	CO 4	T3:8.6
37	Introduction, Nature of Intellectual Property	CO 5	T3:10.1-10.6
38	Types of intellectual Property rights	CO 5	T3:10.1-10.6
39	Patents	CO 5	T3:11.10
40	Designs	CO 5	T3:11.10
41	Trademarks and copyrights: Definition, classification of trademarks	CO 5	T3:11.10
42	Process of Patenting and Development	CO 5	T3:11.14
43	Technical research, innovation, patenting	CO 5	T3:11.15
44	Developments in patenting	CO 5	T3:11.17
45	Patent Trademark Organization	CO 5	T3:11.17
46	International Organization, Agencies and Treaties	CO 5	T3:11.17
47	International scenario, international cooperation on Intellectual property	CO 5	T3:11.19
48	Procedure for grant of patents	CO 5	T3:11.21
49	procedure of copyright	CO 5	T1:8.1-8.3; R2: 7.4-7.5
50	Patenting under PCT, Provisional patent application	CO 5	T1-8.1-8.1.7
51	Patent protection for the invention	CO 5	T1-8.1-8.1.7
52	Patent Rights	CO 6	T3:12.1
53	Scope of Patent Rights	CO 6	T3:12.1
54	Licensing and transfer of technology	CO 6	T3:12.1
55	Patent information and databases	CO 6	T3:12.4
56	Geographical Indications	CO 6	T3:12.4
57	New Developments in IPR: Administration of Patent System	CO 6	T3:12.7
58	New developments in IPR, IPR of Biological Systems and Computer Software etc	CO 6	T3:12.10
59	Traditional knowledge Case Studies	CO 6	T3:12.13
60	IPR and IITs.	CO 6	T3:12.15
DISCUSSION OF QUESTION BANK			
61	Module – I: Research problem	CO 1	T1:2.1-2.3
62	Module – II: Research ethics	CO 2	T1:8.2
63	Module – III: Research proposal	CO 3, CO 4	T3:8.3; R2: 7.4-7.5

64	Module – IV: Patenting	CO 5	T3:10.1-10.6
65	Module – V: Patent rights	CO 6	T3:12.1-12.15

Signature of Course Coordinator **HOD, AE**
Ms. D Anitha, Assistamt Professor

INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal, Hyderabad - 500 043

COURSE DESCRIPTION

Branch	**AEROSPACE ENGINEERING**				
Course Title	**WASTE TO ENERGY**				
Course Code	BPSC30				
Program	M.Tech				
Semester	III	AE			
Course Type	Elective				
Regulation	IARE PG-21				
Course Structure	Theory			Practical	
	Lecture	Tutorials	Credits	Laboratory	Credits
	3	-	3	-	-
Course Coordinator	Mr. Selva Prakash, Assistant Professor				

I COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites
B.Tech	AHS009	II	Environmental Studies

II COURSE OVERVIEW:

The course is designed to create environmental awareness and consciousness among the present generation to become environmental responsible citizens. The course will discuss on the municipal solid waste composition, characteristics and to improve the methods to minimize municipal solid waste generation. This course deals with methods of disposal of solid waste by thermal biochemical processes and production of energy from different types of waste sand to know the environmental impacts of all types of municipal waste. This course will discuss the overall scenario of E-Waste management in India in comparison with other countries around the globe. This course will deals with E-waste legislation and government regulations on E-waste management.

III MARKS DISTRIBUTION:

Subject	SEE Examination	CIE Examination	Total Marks
Waste to Energy	70 Marks	30 Marks	100

IV DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✓	PPT	✓	Chalk & Talk	✓	Assignments	x	MOOC
x	Seminars	x	Others				

V EVALUATION METHODOLOGY:

Each theory course will be evaluated for a total of 100 marks, out of which 30 marks for Continuous Internal Assessment (CIA) and 70 marks for Semester End Examination (SEE). **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 three 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):
For each theory course the CIA shall be conducted by the faculty / teacher handling the course. CIA is conducted for a total of 30 marks, with 20 marks for Continuous Internal Examination (CIE), 05 marks for Assignment and 05 marks for Alternative Assessment Tool (AAT). Two CIE Tests are Compulsory and sum of the two tests, along with the scores obtained in the assignment / AAT shall be considered for computing the final CIA of a student in a given course.

The CIE Tests/Assignment /AAT shall be conducted by the course faculty with due approval from the HOD. Advance notification for the conduction of Assignment/AAT is mandatory and the responsibility lies with the concerned course faculty. CIA is conducted for a total of 30 marks (Table 1).

Component	Theory			Total Marks
Type of Assessment	CIE Exam	Assignment	AAT	
CIA Marks	20	05	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 five descriptive type questions out of which four 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 COURSE OBJECTIVES:

The students will try to learn:

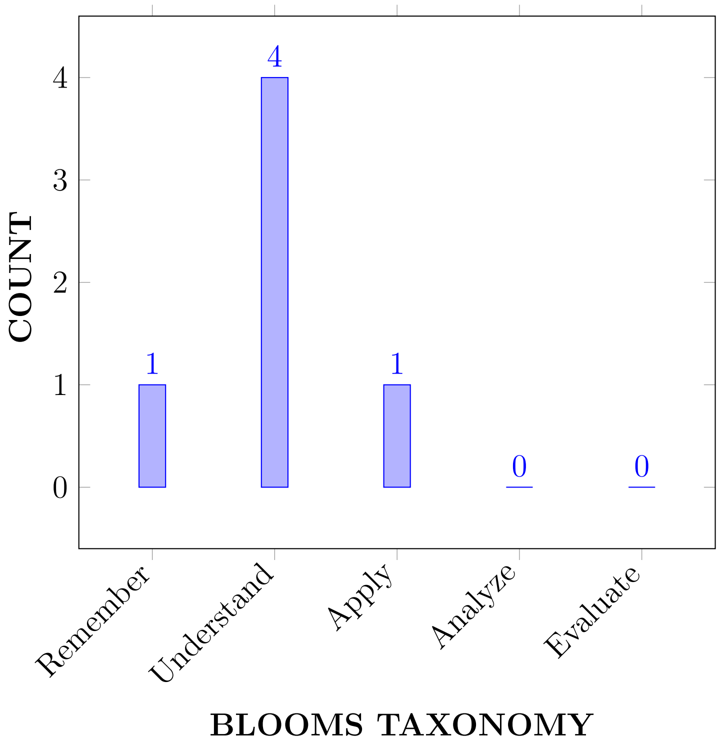
I	The principles of solid waste management in reducing and eliminating dangerous impacts of waste materials on human health and the environment to contribute economic development and superior quality of life.
II	The insight of the design and operations of a municipal solid waste landfill by collection, transfer and transportation of municipal solid waste for the final disposal.
III	The main operational challenges in operating thermal and biochemical energy from waste facilities and device processes involved in recovering energy from wastes.
IV	The scenario of E-Waste management in India and other countries around the globe and assess the impact of electronic waste on human, environment and society by informal recycling and management. The sustainable solution of E-Waste Management can be achieved by adopting modern techniques and Life-Cycle Analysis approach.

VII COURSE OUTCOMES:

After successful completion of the course, students should be able to:

CO 1	**Identify** the different sources and types of solid waste by the properties of municipal solid waste for segregation and collection of waste.	Remember
CO 2	**Explain** the energy generation technologies from waste treatment plants and disposal of solid waste by aerobic composting and incineration process.	Understand
CO 3	**Explain** the classification, preliminary design considerations of landfill and methods of landfill disposal of solid to control greenhouse gases.	Understand
CO 4	**Understand** the Composition, characteristics of leachate to control the emission of gases by monitoring the movement of landfill leachate.	Understand
CO 5	**Outline** the Biochemical conversion of biomass for energy generation by anaerobic digestion of solid waste.	Understand
CO 6	**Apply** the knowledge in planning and operations of waste to Energy plants by following legal legislation related to solid waste management.	Apply

COURSE KNOWLEDGE COMPETENCY LEVEL



VIII PROGRAM OUTCOMES:

Program Outcomes	
PO 1	Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems
PO 2	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..
PO 3	Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice
PO 4	Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development
PO 5	Recognize the need for and having the preparation and ability to engage in independent and life-long learning in the broadest context of technological change
PO 6	Function effectively as a member or leader in diverse teams to carry out development work, produce solutions that meet the specified needs with frontier technologies and communicate effectively on complex engineering activities.

IX MAPPING OF EACH CO WITH PO(s):

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	-	✓	✓	-	-	-
CO 2	✓	✓	-	✓	-	-
CO 3	-	✓	✓	-	-	-
CO 4	-	✓	✓	-	-	-
CO 5	✓	-	-	✓	-	-
CO 6	-	-	✓	-	-	-

X COURSE ARTICULATION MATRIX (CO – PO MAPPING):

CO'S and PO'S and CO'S and PSO'S on the scale of 0 to 3, 0 being no correlation, 1 being the low correlation, 2 being medium correlation and 3 being high correlation.

COURSE OUTCOMES	PROGRAM OUTCOMES					
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	-	1	3	-	-	-
CO 2	1	1	-	-	-	-
CO 3	-	1	1	-	-	-
CO 4	-	1	1	-	-	-
CO 5	3	-	-	-	3	-
CO 6	-	-	3	-	-	-
TOTAL	4	4	8	-	3	-
AVERAGE	2	1	2	-	3	-

XI ASSESSMENT METHODOLOGY DIRECT:

CIE Exams	✓	SEE Exams	✓	Seminar and term paper	-
Laboratory Practices	-	Student Viva	-	Mini Project	-

XII ASSESSMENT METHODOLOGY INDIRECT:

✓	**End Semester OBE Feed Back**

XIII SYLLABUS:

MODULE I	**WASTE SOURCES AND CHARACTERIZATION**
	Waste production in different sectors such as domestic, industrial, agriculture, postconsumer, waste etc. Classification of waste – agro based, forest residues, domestic waste, industrial waste (hazardous and non-hazardous). Characterization of waste for energy utilization. Waste Selection criteria
MODULE II	**TECHNOLOGIES FOR WASTE TO ENERGY**
	Biochemical Conversion – Energy production from organic waste through anaerobic digestion and fermentation. Thermo-chemical Conversion – Combustion, Incineration and heat recovery, Pyrolysis, Gasification; Plasma Arc Technology and other newer technologies..
MODULE III	**WASTE TO ENERGY AND ENVIRONMENTAL IMPLICATIONS**
	Environmental standards for Waste to Energy Plant operations and gas clean-up. Savings on nonrenewable fuel resources. Carbon Credits: Carbon foot calculations and carbon credits transfer mechanisms.
MODULE IV	**THERMO-CHEMICAL CONVERSION**
	Biogas production, land fill gas generation and utilization, thermo-chemical conversion: Sources of energy generation, gasification of waste using gasifies briquetting, utilization and advantages of briquetting, environmental benefits of bio-chemical and thermo-chemical conversion, comparison of various thermo-chemical conversion.
MODULE V	**CENTRALIZED AND DECENTRALIZED WASTE TO ENERGY PLANTS**
	Waste activities – collection, segregation, transportation and storage requirements. Location and Siting of Waste to Energy plants. Industry Specific Applications – In-house use – sugar, distillery, pharmaceuticals, Pulp and paper, refinery and petrochemical industry and any other industry. Centralized and Decentralized Energy production, distribution and use. Comparison of Centralized and decentralized systems and its operations.

TEXTBOOKS

1. Nicholas P Cheremisinoff, ―Handbook of Solid Waste Management and Waste Minimization Technologies‖, An Imprint of Elsevier, New Delhi, 2003.

2. P AarneVesilind, William A Worrell and Debra R Reinhart, ―Solid Waste Engineering‖, 2 nd edition 2002.

3. M Dutta , B P Parida, B K Guha and T R Surkrishnan, ―Industrial Solid Waste Management and Landfilling practice‖, Reprint Edition New Delhi, 1999.

4. RajyaSabha Secretariat, ―E-waste in India: Research unit‖, Reprint Edition, June, 2011.

REFERENCE BOOKS:

1. C Parker and T Roberts (Ed), ―Energy from Waste‖, An Evaluation of Conversion Technologies, Elsevier Applied Science, London, 1985.

2. KL Shah,"Basics of Solid and Hazardous Waste Management Technology", Prentice Hall, Reprint Edition, 2000.

3. M Datta, —"Waste Disposal in Engineered Landfill", Narosa Publishing House, 1997.

XIV COURSE PLAN:

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

S.No	Topics to be covered	CO's	Reference
OBE DISCUSSION			
1	Course Description on Outcome Based Education (OBE): Course Objectives, Course Outcomes (CO), Program Outcomes (PO) and CO-PO Mapping	-	
CONTENT DELIVERY (THEORY)			
1	Summarize about solid waste sources and its importance.	CO 1	T1:3.3, T2:1.2, R2: 2.2
2	Discuss solid waste properties and its composition.	CO 1	T1:3.4, T2:1.4
3	Provides the information regarding collection and transfer of solid waste.	CO 1	T1:3.5, R2:1.5
4	Discuss the need of waste minimization and recycling	CO 1	T1:3.7, R2:1.8
5	Discuss the need of segregating waste and managing solid waste.	CO 1	T1: 3.9, R3: 1.10
6	Acquire the knowledge about the technologies for generation of energy from solid waste.	CO 1	T1:5.5, T2:6.2, R3:4.8
7	Acquire the knowledge about the technologies for generation of energy from biomedical waste.	CO 1	T1:5.6, T2:6.3, R3:7.5
8	Discuss the environmental impacts of incineration process.	CO 1	T1:4.3, T2:5.2, R2: 5.7
9	Illustrate the importance of landfill method of disposal.	CO 1	T1: 4.4, R1:3.3
10	Discuss the types of land fill disposal and classification of land fill sites.	CO 1	T1:4.5, T2: 5.4, R3: 7.3
11	Analyze the layout and preliminary design of landfills.	CO 2	T1:4.6, T2:5.5
12	Summarize the properties and characteristics of landfills.	CO 2	T1: 4.5.2., T2: 5.6
13	Acquire the knowledge of generating energy from landfills.	CO 2	T1:4.6, T2:5.5

14	Discuss the emission of gasses and leach ate from landfills.	CO 2	T1:4.6.2, T2:5.5.2
15	Discuss the environmental monitoring system for land fill gases.	CO 2	T1:4.7, T2:5.6
16	Discuss about the biochemical conversion and their advantages.	CO 2	T1:4.7, T2:5.8
17	Illustrate the sources of biochemical conversion process.	CO 2	T1:4.7.2, T2:5.8.2
18	Analyze anaerobic digestion of sewage and municipal waste.	CO 2	T1:4.8, T2:5.9
19	Analyze direct combustion of Municipal solid waste.	CO 2	T1:4.9, T2:5.7
20	Discuss about refuse derived solid fuel and their importance in energy generation.	CO 3	T1:6.2, T2:5.6
21	Discuss about industrial waste and agro residues.	CO 3	T1:6.3, T2:5.7
22	Understand the concept of Thermo-chemical Conversion.	CO 3	T1:6.4, T2:5.8
23	Discuss about Biogas production and generation of energy by Biogas.	CO 3	T1:6.5, T2:5.3
24	Explain the land fill gas generation and utilization of landfill gas for various purposes.	CO 3	T1:6..6, T2:5.2
25	Illustrate sources of thermo chemical energy generation	CO 3	T1:6.7, T2:5.3
26	Explain gasification of waste using gasifies briquetting process.	CO 3	T1:6.5, T2:7.5
27	Discuss utilization of various municipal solid wastes by recycling, refuse and reuse techniques.	CO 3	T1: 6.2, 6.3, R2: 7.9
28	Discuss advantages and disadvantages of briquetting process.	CO 3	T1: 6.2
29	Summarize environmental benefits of bio-chemical conversion	CO 4	T1:6.2, T2:7.2
30	Summarize environmental benefits of thermo- chemical conversion	CO 4	T1:6.3, T2:7.3
31	Outline the Growth of electrical and electronics industry in India.	CO 4	T1:6.4, T2:7.5
32	Summarize the E-waste generation in India and in the global context.	CO 4	T1: 6.2, T2: 5.6
33	Understand the Growth of E waste generated from electrical and electronics industry in India	CO 4	T1:6.3, T2: 5.7
34	Identify environmental concerns and health hazards	CO 4	T1:6.4, T2:5.8
35	Determine recycling concept of E-Waste and advantages of E-waste.	CO 5	T1:2.1, T2:9.1

36	Discuss A thriving economy of the unorganized sector of E-waste	CO 5	T1:2.2, T2:9.2
37	Discuss the global trade in hazardous waste and their impact on the environment	CO 5	T1: 2.1, R2: 9.1
38	Discuss impact of hazardous E-waste in India and effects on human health	CO 5	T1:2.6, R1:5.1
39	Understand the management processes of E-waste and the importance of formal recycling of E-waste	CO 5	T1:2.7, R1:5.2
40	Outline E-waste legislation for the recycling and disposal	CO 5	T1:2.8, R1:5.5
41	Summarize government regulations on E-waste management	CO 5	T1:2.1, R1:5.6
42	Outline international E-waste management and the guidelines imposed for formal disposal	CO 5	T1:2.2, R1:5.4
43	Explain the need for stringent health safeguards of human health and their effects	CO 5	T1:2.4,R1:5
44	Discuss the need for environmental protection laws and	CO 5	T1:2.4, R1:5.5
45	Outline environmental protection laws of India with respect to E-waste management.	CO 5	T1:2.4, R1:5.5
46	Summarize about solid waste sources and its importance.	CO 6	T1:3.3, T2:1.2, R2: 2.2
47	Discuss solid waste properties and its composition.	CO 6	T1:3.4, T2:1.4
48	Provides the information regarding collection and transfer of solid waste.	CO 6	T1:3.5, R2:1.5
49	Discuss the need of waste minimization and recycling	CO 6	T1:3.7, R2:1.8
50	Discuss the need of segregating waste and managing solid waste.	CO 6	T1: 3.9, R3: 1.10
51	Acquire the knowledge about the technologies for generation of energy from solid waste.	CO 6	T1:5.5, T2:6.2, R3:4.8
52	Acquire the knowledge about the technologies for generation of energy from biomedical waste.	CO 6	T1:5.6, T2:6.3, R3:7.5
53	Discuss the environmental impacts of incineration process.	CO 6	T1:4.3, T2:5.2, R2: 5.7
54	Illustrate the importance of landfill method of disposal.	CO 6	T1: 4.4, R1:3.3
55	Discuss the types of land fill disposal and classification of land fill sites.	CO 6	T1:4.5, T2: 5.4, R3: 7.3

55	Analyze the layout and preliminary design of landfills.	CO 6	T1:4.6, T2:5.5
56	Summarize the properties and characteristics of landfills.	CO 6	T1: 4.5.2., T2: 5.6
57	Acquire the knowledge of generating energy from landfills.	CO 6	T1:4.6, T2:5.5
58	Discuss the emission of gasses and leach ate from landfills.	CO 6	T1:4.6.2, T2:5.5.2
59	Discuss the environmental monitoring system for land fill gases.	CO 6	T1:4.7, T2:5.6
60	Summarize the properties and characteristics of landfills.	CO 6	T1: 4.5.2., T2: 5.6
DISCUSSION OF QUESTION BANK			
61	Module: I-Waste sources and characterization	CO 1	T1
62	Module: II- Technologies for waste to energy	CO 2	T2, R1
63	Module: III- Waste to energy and implications	CO3,4	R1
64	Module: IV- Thermo chemical conversion	CO 5	R2
65	Module: V-Centralized and decentralized waste to energy	CO 6	T2

Signature of Course Coordinator **HOD, AE**
Mr. Selva Prakash, Assistant Professor