INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad - 500 043

AERONAUTICAL ENGINEERING

COURSE DESCRIPTION FORM

Course Title	**ADVANCED COMPUTATIONAL AERODYNAMICS**			
Course Code	**A72116**			
Class	**IV B.Tech I Semester**			
Regulation	**R15 - JNTUH**			
Course Structure	**Lectures**	**Tutorials**	**Practicals**	**Credits**
	4	**-**	**-**	**4**
Course Coordinator	**Ms. D. Anitha, Assistant Professor, Dept of AE.**			
Team of Instructors	**Ms. D. Anitha, Assistant Professor, Dept of AE.**			

I. COURSE OVERVIEW

This course introduces the basic concepts of circuit analysis which is the foundation for all subjects of the Control Engineering discipline. The emphasis of this course if laid on the basic analysis of circuits which includes single phase circuits, open loop system, closed loop system, system time response, autopilot control feedback block diagrams.

II. PREREQUISITE(S)

Level	Credits	Periods	Prerequisite
UG	4	5	Introduction to Aerospace engineering
UG	4	5	Computational fluid dynamics
UG	4	5	Aerodynamics-I
UG	4	5	Aerodynamics-II

III. MARKS DISTRIBUTION

Sessional Marks	University End Exam Marks	Total Marks
There shall be 2 midterm examinations. Each midterm examination consists of subjective test. The subjective test is for 20 marks, with duration of 2 hours. Subjective test of each semester shall contain 5 one mark compulsory questions in part-A and part-B contains 5 questions, the student has to answer 3 questions, each carrying 5 marks. First midterm examination shall be conducted for the first two and half units of syllabus and second midterm examination shall be conducted for the remaining portion. Five marks are earmarked for assignments. There shall be two assignments in every theory course. Marks shall be awarded considering the average of two assignments in each course.	75	100

IV. EVALUATION SCHEME

S. No	Component	Duration	Marks
1	I Mid examination	80 minutes	20
2	I Assignment	--	05
3	II Mid examination	80 minutes	20
4	II Assignment	--	05
5	External examination	3 hours	75

V. COURSE OBJECTIVES

The objective of the teacher is to impart knowledge and abilities to the students to:

I. Describe basic formulation techniques , boundary condition , physical considerations .
II. Develop fundamentals including compressibility and viscosity , Two-dimensional constant-strength singularity elements-sources, doublets and vortices.
III. Demonstrate to write and solve implicit and explicit equations including stability of the solution.
IV. Understand the solution methodology for flat plate boundary layer.
V. Summarize various types of equations, their solution techniques including their stability

VI. COURSE OUTCOMES

At the end of the course the students are able to:

1. Understand the basic aerodynamic concepts, including compressibility, viscosity, boundary layer etc.
2. Differentiate the various solutions for solving techniques.
3. Apply the implicit and explicit equations to the stability of the solution.
4. Demonstrate the supersonic nozzle design by the method of characteristics-supersonic wind tunnel nozzle, minimum length nozzles
5. Understand the Concept of dummy cells, Solid wall-inviscid flow, Viscous flow, Farfield-concept of characteristic variables
6. Illustrate the concepts of discretization and its application for implicit difference equation.
7. Emphasize on basic schemes to solve the differential equations.
8. Solve the numerical solution of transonic small disturbance equation at stable and unstable conditions.
9. Develop approximate factorization schemes for numerical solutions.
10. Solve thin airfoil with lumped vortex filament, accounting for effects of compressibility and viscosity.
11. Describe the Lax- Wendroff scheme, McCormack two step predictor-corrector method and time split methods.
12. Understand the Lax method- leapfrog method, Lax method-implicit methods- Euler's FTCS, Crank-Nicolson method.

VII. HOW PROGRAM OUTCOMES ARE ASSESSED

Program outcomes		Level	Proficiency assessed by
PO1	**General knowledge:** An ability to apply the knowledge of mathematics, science and Engineering for solving multifaceted issues of Aeronautical Engineering	S	Assignments
PO2	**Problem Analysis**: An ability to communicate effectively and to prepare formal technical plans leading to solutions and detailed reports for Aeronautical systems	S	Exercise
PO3	**Design/Development of solutions**: To develop Broad theoretical knowledge in Aeronautical Engineering and learn the methods of applying them to identify, formulate and solve practical problems involving Aerodynamics	H	Discussion
PO4	**Conduct investigations of complex problems**: An ability to apply the techniques of using appropriate technologies to investigate, analyze, design, simulate and/or fabricate/commission complete systems involving complex aerodynamics flow situations.	H	Exercise
PO5	**Modern tool usage**: An ability to model real life problems using different hardware and software platforms, both offline and real-time with the help of various tools along with upgraded versions.	------	------
PO6	**The engineer and society**: An Ability to design and fabricate modules, control systems and relevant processes to meet desired performance needs, within realistic constraints for social needs	S	Exercise
PO7	**Environment and sustainability**: An ability To estimate the feasibility, applicability, optimality and future scope of power networks and apparatus for design of eco-friendly with sustainability	------	------

PO8	**Ethics**: To Possess an appreciation of professional, societal, environmental and ethical issues and proper use of renewable resources	------	------
PO9	**Individual and team work**: An Ability to design schemes involving signal sensing and processing leading to decision making for real time Aeronautical systems and processes at individual and team levels.	------	------
PO10	**Communication**: an Ability to work in a team and comprehend his/her scope of work, deliverables, issues and be able to communicate both in verbal, written for effective technical presentation	------	------
PO11	**Project management and finance**: To be familiar with project management problems and basic financial principles for a multi-disciplinary work	------	-----
PO12	**Life-long learning**: An ability to align with and upgrade to higher learning and research activities along with engaging in life-long learning.	S	Prototype, Discussions

S – Supportive **H - Highly related**

VIII. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED

Program Specific Outcomes		Level	Proficiency assessed by
PSO:1	**Professional skills:** Able to utilize the knowledge of aeronautical/aerospace engineering in innovative, dynamic and challenging environment for design and development of new products	H	Lectures, Assignments
PSO:2	**Problem solving skills:** imparted through simulation language skills and general purpose CAE packages to solve practical, design and analysis problems of components to complete the challenge of airworthiness for flight vehicles	S	Tutorials
PSO:3	**Practical implementation and testing skills:** Providing different types of in house and training and industry practice to fabricate and test and develop the products with more innovative technologies	-----	-----
PSO:4	**Successful career and entrepreneurship:** To prepare the students with broad aerospace knowledge to design and develop systems and subsystems of aerospace and allied systems and become technocrats	-----	-----

S – Supportive **H - Highly related**

IX.SYLLABUS

UNIT-I:
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. Two-dimensional constant-strength singularity elements-sources, doublets and vortices, Two-dimensional constant strength singularity solutions using Neumann and Dirichlet boundary conditions-constant source, doublet and vortex methods.

UNIT-II:
METHOD OF CHARACTERISTICS, BOUNDARY CONDITIONS

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.

Concept of dummy cells, Solid wall-inviscid flow, Viscous flow, Farfield-concept of characteristic variables, modifications for lifting bodies, Inlet/output boundary, Injection boundary, symmetry plane, coordinate cut, periodic boundaries, interface between grid blocks, flow gradients at boundaries of unstructured grids.

UNIT-III:
NUMERICAL SOLUTION OF TRANSONIC SMALL DISTURBANCE EQUATION

Physical aspects of transonic flows-critical Mach number, drag divergence Mach number, area rule, supercritical airfoils, theoretical aspects of transonic flows-transonic similarity.

Derivation of Transonic Small Disturbance(TSD) equation, finite difference formulation of TSD equation, Murman- Cole switching/upwinding in supersonic flow regions, boundary conditions, iterative solution methods for discretized TSD equation.

UNIT-IV:
NUMERICAL METHODS FOR EULER EQUATIONS, BOUNDARY LAYER 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- Godunov's first order upwind method, Roe's first order upwind method.

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.

UNIT-V:
TIME DEPENDENT METHODS
Stability of solution, explicit methods, FTFS, FTCS, FTBS, Lax method- 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.

TEXT BOOK

1. Tannehill, John C , Anderson, Dale A, , Pletcher Richard H., *Computational Fluid Mechanics and Heat Transfer,* Second Edition, Taylor & Francis, 1997
2. Chung, T. G., *Computational Fluid Dynamics*, Second Edition, Cambridge University Press, 2010

REFERENCES

1 Katz, Joseph and Plotkin, Allen, *Low-Speed Aerodynamics,* Second Edition, Cambridge University Press, 2006.
2 Anderson, J. D., *Modern Compressible Fluid Flow,* McGraw Hill, 1982.
3 Anderson, J. D., *Fundamentals of Aerodynamics*, Fifth Edition, Tata McGraw Hill, 2010
4 Anderson, J. D., *Computational Fluid Dynamics,* McGraw Hill
5 Rathakrishnan, E., *Gasdynamics*, Prentice-Hall India, 2004
6 Laney, C. B., *Computational Gasdynamics,* Cambridge University Press, 1998
7 Schlichting, H. and Gersten, K., *Boundary-Layer Theory,* Springer, 2000
8 Blazek, J., *Computational Fluid Dynamics: Principles and Applications,* 2nd Edition, Elsevier, 2007

X. COURSE PLAN:

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

Lecture No.	Course Learning Outcomes	Topics to be covered	Reference
1	Explain the basics of panel Technique, boundary conditions	**UNIT-I** Basic formulation, boundary conditions	R1:9.1-9.2
2	Knowing the Concept of reducing of a problem to linear algebraic equations.	physical considerations, reduction of a problem to a set of linear algebraic equations, aerodynamic loads	R1:9.3-9.5
3	Differentiate preliminary considerations and steps towards constructing a numerical solution.	preliminary considerations prior to establishing numerical solution, steps toward constructing a numerical solution	R1:9.6-9.7
4	Explain Solution of thin airfoil with lumped vortex filament	Solution of thin airfoil with lumped vortex filament	R1:9.8
5-6	Discuss accounting for effects of compressibility and viscosity	Accounting for compressibility and viscosity effects.	R1:9.9
7	Explain Two-dimensional constant-strength singularity elements-sources, doublets and vortices.	Two-dimensional constant- strength singularity elements- sources, doublets and vortices	R1:10.2
8-10	Apply boundary condition; obtain two dimensional constant strength singularity solutions.	Two-dimensional constant strength singularity solutions using Neumann and Dirichlet boundary conditions-constant source,doublet and vortex methods.	R1:10.3
11	Explain Philosophy of method of characteristics.	**UNIT-II** Philosophy of method of characteristics, determination of characteristic lines-two-dimensional irrotational flow	T1:6.2
12	Knowing determination of compatibility equations	determination of compatibility equations	T1:6.2.2
13	Apply the concept of method of characteristics.	supersonic nozzle design by the method of characteristics- supersonic wind tunnel nozzle	T1:6.2.3
14	Solve for the nozzle using method of characteristics.	Concept of minimum length nozzle.	T1:6.2.5-6.2.6
15	Knowing Domain of dependence and range of influence.	Domain of dependence and range of influence.	T1:6.2.7
16-19	Knowing the dummy cell concept, in viscid flow concept, viscous flow, and far-field concept	Concept of dummy cells, Solid wall-inviscid flow, Viscous flow, Farfield-concept of characteristic variables	T1:6.3
20	Knowing Concept modifications for lifting bodies	Concept of modifications for lifting bodies	T1:6.3.2
21-22	Knowing Inlet/output boundary, Injection boundary, symmetry plane	Inlet/output boundary, Injection boundary, symmetry plane	T1:6.3.4-6.3.5
23	Knowing interface between grid blocks, flow gradients at boundaries of unstructured grids	interface between grid blocks, flow gradients at boundaries of unstructured grids	T1:6.3.6-6.3.7
24	Knowing Physical aspects of transonic flows-critical Mach number	**UNIT-III** Physical aspects of transonic flows-critical Mach number	T1:3.1

25	Explain drag divergence Mach number, area rule, supercritical airfoils, theoretical aspects of transonic flows-transonic similarity	drag divergence Mach number, area rule, supercritical airfoils, theoretical aspects of transonic flows-transonic similarity	T1:3.2
26-28	Derive Transonic Small Disturbance(TSD) equation	Derivation of Transonic Small Disturbance(TSD) equation, finite difference formulation of TSD equation	T1:3.3
29-31	Derive Murman- Cole switching / upwinding in supersonic flow regions,	Murman- Cole switching/upwinding in supersonic flow regions,	T1:1.1-1.5
32-34	List the boundary conditions	boundary conditions, iterative solution methods for discretized TSD equation	T1:1.6
35-36	Introduce the Flux approach- Lax-Wendroff method	**UNIT-IV** Flux approach- Lax-Wendroff method	T1:4.1.1
37	List the basic principles	Basic principles of upwind schemes,	T1:4.1.2
38-40	Derive Flux-vector splitting- Steger-Warming flux vector splitting, Van Leer flux vector splitting,	Flux-vector splitting- Steger-Warming flux vector splitting, Van Leer flux vector splitting,	T1:6.4.1-6.4.2
41-43	Describe Upwind reconstruction-evolution- Godunov’s first order upwind method, Roe’s first order upwind method	Upwind reconstruction- evolution-Godunov’s first order upwind method, Roe’s first order upwind method	T1:6.4.3-6.4.4,6.5
44-45	Introduce the boundary layer equation	Setting up the boundary layer equations- flat plate boundary layer solution,	T1:5.3.1
46-48	Differentiate the discretization methods	Boundary-layer transformations-explicit and implicit discretization- solution of the implicit difference equations-	T1:4.2.1-4.2.4
49-51	Derive Integration of the continuity equation.	Integration of the continuity equation. Boundary layer edge and wall shear stress, Keller-box scheme.	T1:4.2.8
52-53	Introduce the Stability of solution	**UNIT-V** Stability of solution, explicit methods,	T1:4.1.1
54-56	List the methods	FTFS, FTCS, FTBS,	T1:4.1.2
57-60	Derive Lax method- leapfrog method	Lax method- leapfrog method, Lax method-implicit methods- Euler’s FTCS, Crank-Nicolson method.	T1:4.1.3-4.1.5,4.2.4
61-63	Describe Lax- Wendroff scheme, McCormack two step predictor-corrector method,	Description of Lax- Wendroff scheme, McCormack two step predictor-corrector method,	T1:4.5.10
64-65	Describe time split methods, Approximate factorization schemes.	Description of time split methods, Approximate factorization schemes.	T1:4.1.8

XI. MAPPING COURSE OBJECTIVES LEADING TO THE ACHIEVEMENT OF THE PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES

Course Objectives	Program Objectives												Program Specific Outcomes			
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
I	S		H			S						H	H	S		
II	H			H												
III	S		S										H			
IV			H			S								S		
V	H	S				H						H	H			

S – Supportive **H - Highly related**

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

Course Outcomes	Program Outcomes												Program Specific Outcomes			
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3	PSO4
1	H	S		S								S	H	S		
2	S			S									S	H		
3		H		S									S	S		
4	S	H	S										S	H		
5			H			S										
6			S										H			
7			H			S						H	S			
8	H			S									H	S		
9				S												
10		H			S							S				
11		S														
12			H			S						H	S			

S – Supportive **H - Highly related**

Prepared by: Ms. D. Anitha, Assistant Professor

HOD, AE