AOT393	HIGH SPEED AND HIGH ENTHALPY AERODYNAMICS	CATEGORY	L	T	P	CREDIT
		VAC	3	1	0	4

Preamble: The course is meant to give the learners an introduction to high speed chemically reacting aerodynamics

Prerequisite: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Explain and use basic theorems unsteady compressible fluid dynamics and able to solve unsteady complex problems.
CO 2	Understand the concepts of steam function velocity potential function and boundary layer theory in a compressible flow field and able to solve complex problems
CO 3	Understand the concepts of invicid hypersonic flow and simple flows and able to solve complex problems
CO 4	Apply the design concepts of highspeed aerodynamics theories
CO 5	Understand the concepts of boundary layer interaction with shockwave and hypersonic flows

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12
CO 1	3	2	1									
CO 2	3	2	1									
CO 3	3	2	1									
CO 4	3	2	1									
CO 5	3	2	1									

Assessment Pattern

Bloom's Category	Continuous Assessment Tests		End Semester Examination
	1	2	
Remember	10	10	10
Understand	20	20	20
Apply	20	20	70
Analyse			
Evaluate			
Create			

Mark distribution

Total Marks	CIE	ESE	ESE Duration
150	50	100	3 hours

Continuous Internal Evaluation Pattern:

Attendance	: 10 marks
Continuous Assessment Test (2 numbers)	: 25 marks
Assignment/Quiz/Course project	: 15 marks

End Semester Examination Pattern: There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Explain the working of blow down supersonic wind tunnel with suitable figure. How the testing time can be improved.
2. A wedge of constant wedge angle is place in a decelerating unsteady flow. Explain the characteristics of shock wave with figure
3. Explain how a moving shock wave problem can be solved.

Course Outcome 2 (CO2)

1. Derive an expression for circulation in a compressible flow field according to Kelvin's theorem.
2. Derive Euler's momentum equation for the steady adiabatic inviscid flow of a compressible fluid.
3. Derive the speed of sound equation.

Course Outcome 3(CO3):

1. Derive the expressions for the flow field parameters in a hypersonic free stream?
2. Explain why the centrifugal correction is required?
3. Explain Newton's sine square law and derive an expression for coefficient of pressure.

Course Outcome 4 (CO4):

1. Why the hypersonic boundary layers are thicker?
2. Why delta wings are suitable for supersonic airplanes
3. Explain the similarity parameters in a hypersonic boundary layer

Course Outcome 5 (CO5):

1. Derive an expression for the collision frequency and mean free path of molecules.
2. Explain notes on non-equilibrium blunt-body flows with sketches.
3. Derive the boundary layer equation for chemically reacting flow.

Model Question paper

QP CODE: **Reg No: -------------------------**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY FIFTH SEMESTER (HONS.) B. TECH DEGREE EXAMINATION

MONTH & YEAR

Course Code: AOT393

HIGH SPEED AND HIGH ENTHALPY AERODYNAMICS

Max.Marks:100 **Duration: 3 Hours**

PART A

Answer all Questions.

(Each question carries 3 Marks)

1. What happened to an oblique shock when the free stream supersonic flow decelerated to subsonic flow?
2. What happened to the mass flow in a convergent nozzle when the total pressure falls down?
3. Explain why the shock wave cannot penetrate in to the subsonic region of the boundary layer formed in a supersonic flow?
4. What is the physical interpretation of stream function?
5. Why the hypersonic flow exists in lower Mach number when the free stream static pressure is decreased?
6. What happened to the density ratio across a shock wave when the free stream Mach number tent to infinity? What do this interpret?
7. What is the effect of entropy layer on aerodynamic heating?
8. Explain what are the effects of strong interaction of boundary layer?
9. Explain why the temperature distribution in a chemically equilibrium flow is higher than in a frozen flow in the nozzle flow?
10. Explain why the flow through hypersonic shock layer is diabatic?

PART B

Answer any one full question from each module.

(Each question carries 14 Marks)

Module 1

11. An air bottle of 10 liters consists of air at 20 bar pressure. A leak of air through a 5mm hole is observed. Find the time taken to discharge the bottle pressure to 10bar assume the expansion process is isothermal (14)

12. a) Explain with suitable figure how a supersonic is working of a supersonic wind tunnel (10)

    b)Why a secondary throat is required in a supersonic wind tunnel? (4)

Module 2

13. a) Define homenergetic flow, isentropic and homentropic flow and homentropic homenergetic flow? (6)

    b) Consider a velocity potential function Φ derive the equation of motion in terms of Φ, (8)

14. The supersonic inlet contains an oblique shock followed by a normal shock wave. If the free stream Mach number and the flow deflection angle are 3 and 18 deg respectively, find the stagnation pressure, stagnation temperature, static pressure, temperature and density downstream of the normal shock wave. (14)

Module 3

15. Derive an expression for Cp as per modified Newtonian-Busemann theory and its accuracy. (14)

16. a) From Newtonian theory prove that the drag coefficient for a sphere is 1 (6)

    b)Derive hypersonic shock relation in terms of hypersonic similarity parameter (8)

Module 4

17. A flat plate 2m chord and planform area of 40sq m with zero incidence is tested under the condition, at an altitude of 30 Km from international standard condition in a hypersonic velocity of 3402m/s. Calculate the local shear stress on the plate about 0.7m from the leading edge. Assume laminar flow, wall temperature is adiabatic wall temperature (14)

18. a) Derive an expression for the pressure ratio in terms of growth of boundary layer thickness in a hypersonic viscus flow. (8)

    (b) Explain how the entropy layer effects on aerodynamic heating (6)

Module 5

19. Derive an expression for emission coefficient radiative heat transfer process and its solution (14)

20. Explain the temperature distribution in a chemically reacting non-equilibrium flowthrough a convergent divergent nozzle and compare with equilibrium and frozen flow? (14)

Syllabus

Module 1

Basics of compressible fluid dynamics: - Isentropic flow through variable area passage, unsteady flow through variable area passage in both isothermal and isentropic expansion, normal and oblique shockwaves under these conditions, supersonic wind tunnels and its starting, conical flow. (Simple numerical examples).

Module 2

Basics of steady multidimensional adiabatic flow in an inviscid compressible fluid: -Introduction and basics, rotation, Kelvin’s theorem, Helmoltz’s vorticity theorem, Crocco’s theorem, equation of state and velocity of sound, stream function and velocity potential function, relation between stream function and potential function.

Module 3

Introduction, hypersonic shock and expansion wave relations, Newtonian flow model for both 2-D and 3-D flow, modified Newtonian theory, centrifugal correction to Newtonian theory, tangent wedge tangent cone and shock expansion method, Mach number independence, hypersonic small disturbance equation, hypersonic similarity, equivalence and blast wave theory, thin shock wave theory, (Simple numerical examples).

Module 4

Hypersonic boundary layer: - similarity parameters, boundary layer equation, self-similar solution, non-similar hypersonic boundary layer, transition, turbulent boundary layer, aerodynamic heating, viscus interaction, shock wave boundary layer interaction. (Simple numerical examples).

Module 5

Basics on statistical thermodynamics, kinetic theory, equilibrium and non-equilibrium inviscid flows:- equilibrium normal and oblique shock wave, chemically equilibrium 1-D nozzle flows, speed of sound in equilibrium flow, equilibrium conical flow, and equilibrium flows on blunt bodies, non-equilibrium normal and oblique shock wave, chemically non-equilibrium 1-D nozzle flows, speed of sound in non-equilibrium flows, non-equilibrium conical flow, and non-equilibrium flows on blunt bodies, binary scaling, introduction to radiative gas dynamics.

Text Books

1. Fundamentals of Aerodynamics John D Anderson.
2. Anderson, J. D, "Modern Compressible Flow", McGraw-Hill & Co.
3. John D Anderson “Hypersonic and High Temperatures Gas Dynamics “

Data Book (Approved for use in the examination):

1. Rathakrishnan E, Gas Tables, Orient Blackswan Private Limited - New Delhi (2013).
2. S M Yahya, Gas Tables for Compressible Flow Calculations, New Age International Publishing, (2011).

Reference Books

1. Gas dynamics by Maurice J Zucrow, Jow D. Hoffman.

2. Aerodynamics for Engineers by John J Bertin and Russel M.
3. Shapiro, A. H., "Dynamics and Thermodynamics of Compressible Fluid Flow", Ronald Press, 1982.
4. OosthuizenP.H., &CarscallenW.E., "Compressible Fluid Flow", McGraw- Hill & Co.,1997.

Course Contents and Lecture Schedule

No	TOPIC	No. of Lectures
1	**Module 1**	
1.1	Basics of compressible fluid dynamics: - Isentropic flow through variable area passage, unsteady flow through variable area passage in both isothermal and isentropic expansion,	3
1.2	Normal and oblique shockwaves under unsteady flow condition conditions, supersonic wind tunnels and its starting,	3
1.3	Conical flow	2
2	**Module 2**	
2.1	Basics of steady multidimensional adiabatic flow in an inviscid compressible fluid:-Introduction and basics, rotation, Kelvin’s theorem, Helmoltz’s vorticity theorem.	3
2.2	Crocco’s theorem, equation of state and velocity of sound, stream function and velocity potential function,	4
2.3	Relation between stream function and potential function	1
3	**Module 3**	
3.1	Introduction, hypersonic shock and expansion wave relations, Newtonian flow model for both 2-D and 3-D flow, modified Newtonian theory,	4
3.2	Centrifugal correction to Newtonian theory, tangent wedge tangent cone and shock expansion method, Mach number independence,	3
3.3	Hypersonic small disturbance equation, hypersonic similarity, equivalence and blast wave theory, thin shock wave theory,	2
4	**Module 4**	
4.1	Hypersonic boundary layer: - similarity parameters, boundary layer equation, self-similar solution,	4
4.2	Non-similar hypersonic boundary layer, transition, turbulent boundary layer,	4
4.3	Aerodynamic heating, viscus interaction, hypersonic shock wave boundary layer interaction.	3
5	**Module 5**	
5.1	Basics on statistical thermodynamics, kinetic theory, equilibrium and non-equilibrium inviscid flows:- equilibrium normal and oblique shock wave, chemically equilibrium 1-D nozzle flows, speed of sound in equilibrium flow, equilibrium conical flow, and equilibrium flows on blunt bodies,	4
5.2	Non-equilibrium normal and oblique shock wave, chemically non-equilibrium 1-D nozzle flows, speed of sound in non-equilibrium flows, non-equilibrium conical flow, and non-equilibrium flows on blunt bodies,	4
5.3	Binary scaling, introduction to radiative gas dynamics	1