## HYPERSONIC AND HIGH-TEMPERATURE GAS DYNAMICS

BAEB17      Elective      3      -      3      30      70      10        Contact Classes: 45      Tutorial Classes: Nil      Practical Classes: Nil      Total Classes: 45        COURSE OVERVIEW:      This particular course has been deigned to cover aerodynamic features of hypersonic flows with their ba governing equations and their applications in various flow fields. It also provides a comprehensive traini experience in the basic principles, technologies and methodologies pertaining to the multi-disciplined realm hypersonic flight environment on vehicle loads and performance, including a consideration of be continuum flow and rarefied flow aerodynamic effects.        L COUSRE OBJECTIVES:        The course should enable the students to:        Provide a fundamental features of hypersonic flow phenomena, including aerodynamic heating and non-equilibrium real-gas effects.        L Explain the fundamental features of hypersonic flows, and how these differ from other flows.        I. Infer the importance and influence of non-equilibrium real-gas effects in high temperature flows.        V. Illustrate the physical mechanisms causing aerodynamic flow and their characteristics      Understand        CO1      Summarize the fundamental aspect of hypersonic flow and their characteristics      Understand        CO3      Make a use of equivalence principle and various theories to model shock apply      Apply        CO4      Build the governing equation for viscous hypersonic laminar and		rse Code	Category	Hours / Week			Credits	Maximum Marks		
3      -      -      3      30      70      10        Contact Classes: Si Tutorial Classes: Nil      Practical Classes: Nil      Total Classes: 45        COURSE OVERVIEW:        This particular course has been deigned to cover aerodynamic features of hypersonic flows with their bag governing equations and their applications in various flow fields. It also provides a comprehensive train hypersonic flight. Participants will acquire a sound understanding of hypersonic aero physics and the effects the hypersonic flight environment on vehicle loads and performance, including a consideration of be continuum flow and rarefied flow aerodynamic effects.        LOUSRE OBJECTIVES:        The course should enable the students to:        • • • • • • • • • • • • • • • • • • •	DA	FD17		L	Т	Р	С	CIA	SEE	Tota
COURSE OVERVIEW:      This particular course has been deigned to cover aerodynamic features of hypersonic flows with their bagoverning equations and their applications in various flow fields. It also provides a comprehensive trainit experience in the basic principles, technologies and methodologies pertaining to the multi-disciplined realm hypersonic flight. Participants will acquire a sound understanding of hypersonic are ophysics and the effects the hypersonic flight environment on vehicle loads and performance, including a consideration of be continuum flow and rarefied flow aerodynamic effects.      I. COUSRE OBJECTIVES:      The course should enable the students to:      Provide a fundamental description of hypersonic flow phenomena, including aerodynamic heating and non-equilibrium real-gas effects.      I. Explain the fundamental description of hypersonic flows, and how these differ from other flows.      II. Infer the importance and influence of non-equilibrium real-gas effects in high temperature flows.      V. Illustrate the physical mechanisms causing aerodynamic heating of high-speed vehicles.      III. COURSE OUTCOMES:      CO 1    Summarize the fundamental aspect of hypersonic flow and their characteristics    Understand or solving the hypersonic flow ver arbitrary shape.      CO 2    Construct the equation for variation flow properties for shock and expansion waves in hypersonic flow field.    Apply      CO 3    Make a use of equivalence principle and various theories to model shock how.    Apply      CO 4    Build the governing equation for	BA	EB1/	Elective	3	-	-	3	30	70	100
This particular course has been deigned to cover aerodynamic features of hypersonic flows with their bagoverning equations and their applications in various flow fields. It also provides a comprehensive traini experience in the basic principles, technologies and methodologies pertaining to the multi-disciplined realm syspersonic flight Participants will acquire a sound understanding of hypersonic aero physics and the effects he hypersonic flight environment on vehicle loads and performance, including a consideration of be continuum flow and rarefied flow aerodynamic effects.      IL COUSRE OBJECTIVES:    The course should enable the students to:      Provide a fundamental description of hypersonic flow phenomena, including aerodynamic heating and non-equilibrium real-gas effects.      IL Explain the fundamental features of hypersonic flows, and how these differ from other flows.      II. Infer the importance and influence of non-equilibrium real-gas effects in high temperature flows.      V. Illustrate the physical mechanisms causing aerodynamic heating of high-speed vehicles.      CO 1    Summarize the fundamental aspect of hypersonic flow and their characteristics for solving the hypersonic flow over arbitrary shape.    Understand      CO 2    Construct the equation for variation flow properties for shock and expansion waves in hypersonic flow.    Apply      CO 3    Make a use of equivalence principle and various theories to model shock Apply boundary layer.    Apply      CO 4    Build the governing equation for viscous hypersonic laminar and turbulent Apply boundary layer.    Apply	Contact	act Classes: 45 Tutorial Classes: Nil Practical Classes: Nil Total Cla					asses: 45	;		
CO 1Summarize the fundamental aspect of hypersonic flow and their characteristics for solving the hypersonic flow over arbitrary shape.UnderstandCO 2Construct the equation for variation flow properties for shock and expansion waves in hypersonic flow.ApplyCO 3Make a use of equivalence principle and various theories to model shock interaction in hypersonic flow field.ApplyCO 4Build the governing equation for viscous hypersonic laminar and turbulent boundary layer.ApplyCO 5Select suitable computational fluid dynamic model to solve hypersonic viscous flow.ApplyCO 6Construct the governing equation for high temperature inviscid equilibrium and non-equilibrium flow over an arbitrary body.ApplyIV. SYLLABUS:IV. SYLLABUS:IV. SYLLABUS:	experience hypersoni the hyper continuum I. COUS The cours . Provie non-e I. Expla II. Infer V. Illustr III. COU	e in the basic c flight. Parti- rsonic flight n flow and ran <b>RE OBJECT</b> <b>se should ena</b> de a fundame: quilibrium rea- tin the fundam the importance rate the physic <b>RSE OUTCO</b>	principles, technologies cipants will acquire a so environment on vehicl refied flow aerodynamic <b>TVES:</b> <b>ble the students to:</b> ntal description of hype al-gas effects. nental features of hypers we and influence of non- cal mechanisms causing <b>DMES:</b>	s and m bund un le load c effects rsonic fl sonic fl equilibr g aerody	nethodo iderstar s and s. flow ph ows, ar rium re vnamic	logies p iding of perform enomen id how t al-gas e heating	bertaining to hypersonic hance, inclu- ha, including hese differ f ffects in hig of high-spec	the multi-dise aero physics a ding a consid aerodynamic rom other flow h temperature	ciplined r and the ef deration heating a ws.	ealm of fects of of bot
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CO 3    interaction in hypersonic flow field.    Apply      CO 4    Build the governing equation for viscous hypersonic laminar and turbulent boundary layer.    Apply      CO 5    Select suitable computational fluid dynamic model to solve hypersonic viscous flow.    Apply      CO 6    Construct the governing equation for high temperature inviscid equilibrium and non-equilibrium flow over an arbitrary body.    Apply      IV. SYLLABUS:    IV. SYLLABUS:    IV. SYLLABUS:	CO 2	Construct the equation for variation flow properties for shock and expansion				Арр	oly			
CO 4    boundary layer.    Apply      CO 5    Select suitable computational fluid dynamic model to solve hypersonic viscous flow.    Apply      CO 6    Construct the governing equation for high temperature inviscid equilibrium and non-equilibrium flow over an arbitrary body.    Apply      IV. SYLLABUS:    Image: Construct temperature inviscid equilibrium and non-equilibrium flow over an arbitrary body.    Image: Construct temperature inviscid equilibrium and non-equilibrium flow over an arbitrary body.	CO 3	interaction in hypersonic flow field.				Арр	ly			
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CO 6  non-equilibrium flow over an arbitrary body.  Apply    IV. SYLLABUS:	004		able computational flui	d dyna	mic mo	del to s	solve hypers	onic viscous	Арр	ly
		flow.								
	CO 5	Construct	<u> </u>			erature	inviscid equ	uilibrium and	Арр	ly
UNIT-I OVERVIEW AND INTRODUCTION Classes: 08	CO 5 CO 6	Construct non-equilit	<u> </u>			oerature	inviscid equ	iilibrium and	Арр	ly

UNIT-II	SURFACE INCLINATION METHODS AND THEORIES
Local surfa	ce inclination methods: Newtonian flow, modified Newtonian law, centrifug
Noutonian	theory tangent wedge tangent cone methods shock expansion method. Hy

Classes: 10

Local surface inclination methods: Newtonian flow, modified Newtonian law, centrifugal force corrections to Newtonian theory, tangent-wedge tangent-cone methods, shock-expansion method; Hypersonic inviscid flow fields: Approximate methods: Governing equations, Mach-number independence, hypersonic small- disturbance equations, hypersonic similarity; Hypersonic small-disturbance theory: Some results, hypersonic equivalence principle and blast-wave theory, thin shock-layer theory; Hypersonic inviscid flow fields: Exact methods: method of characteristics, time-marching finite difference method, correlations for hypersonic shock- wave shapes, shock–shock interactions, space-marching finite difference method.

# UNIT-III VISCOUS FLOW AND HYPERSONIC VISCOUS INTERACTIONS

Classes: 10

Viscous flow: Basic aspects boundary layer results and aerodynamic heating: Governing equations for viscous flow: Navier–stokes equations, boundary-layer equations for hypersonic flow, hypersonic boundary-layer theory, non-similar hypersonic boundary layers, hypersonic transition, hypersonic turbulent boundary layer, reference temperature method.

Hypersonic viscous interactions: Strong and weak viscous interactions, role of x in hypersonic viscous interaction, hypersonic shock-wave/boundary-layer interactions, computational-fluid-dynamic solutions of hypersonic viscous flows, viscous shock-layer technique, Parabolized Navier–stokes solutions, fullnavier–stokes solutions.

## UNIT-IV HIGH-TEMPERATURE GAS DYNAMICS

Importance of high-temperature flows, nature of high-temperature flows; Chemical effects in air: The velocityaltitude map; Elements of kinetic theory: Perfect-gas equation of state, collision frequency and mean free path, velocity and speed distribution functions, definition of transport phenomena, transport coefficients, mechanism of diffusion, energy transport by thermal conduction and diffusion, transport properties for high-temperature air.

# UNIT-V INVISCID HIGH-TEMPERATURE EQUILIBRIUM FLOWS AND NONEQUILIBRIUM FLOWS

Classes: 08

Classes: 09

Governing equations for inviscid high-temperature equilibrium flow, equilibrium normal and oblique shockwave flows, equilibrium quasi-one-dimensional nozzle flows, frozen and equilibrium flows, equilibrium and frozen specific heats, equilibrium speed of sound, equilibrium conical flow, equilibrium blunt-body flows, governing equations for inviscid, non-equilibrium flows, non-equilibrium normal and oblique shock-wave flows, non-equilibrium quasi-one-dimensional nozzle flows, non-equilibrium blunt- body flows, binary scaling, non-equilibrium flow over other shapes: non-equilibrium method of characteristics.

#### **Text Books :**

John D. Anderson, "Hypersonic and High Temperature Gas Dynamics", McGraw Hill, 2<sup>nd</sup> Edition, 1989.
 John J. Berlin, "Hypersonic Aerodynamics" AIAA Education series, 1<sup>st</sup> Edition, 1994.

## **Reference Books:**

W. D. Hayes, Ronalds F. Probstein, "Hypersonic Flow Theory" Academic Press, 1<sup>st</sup> Edition, 1959.
 H. W. Liepman, A. Roshko, "Elements of Gas Dynamics" John Wiley and Sons Inc., 4<sup>th</sup> Edition, 2002.

## Web References:

1.http://www.southampton.ac.uk/engineering/undergraduate/UNITs/sesa6074\_hypersonic\_and\_high\_temperatur e\_gas\_dynamics.page#aims\_and\_objectives

## **E-Text Books:**

1. https://www.scribd.com/doc/248036966/Anderson-Hypersonic-and-High-Temperature-Gas-Dynamics