HYPERSONIC AND HIGH-TEMPERATURE GAS DYNAMICS

II Semester: AE

Course Code	Category	Hours / Week			Credits	Maximum Marks		
		L	T	P	C	CIA	SEE	Total
BAEB17	Elective	3	-	-	3	30	70	100
Contact Classes: 45	Tutorial Classes: Nil	Practical Classes: Nil				Total Classes: 45		

I. COURSE OVERVIEW:

This particular course has been deigned to cover aerodynamic features of hypersonic flows with their basic governing equations and their applications in various flow fields. It also provides a comprehensive training experience in the basic principles, technologies and methodologies pertaining to the multi-disciplined realm of hypersonic flight. Participants will acquire a sound understanding of hypersonic aero physics and the effects of the hypersonic flight environment on vehicle loads and performance, including a consideration of both continuum flow and rarefied flow aerodynamic effects.

II. COUSRE OBJECTIVES:

The course should enable the students to:

I. Provide a fundamental description of hypersonic flow phenomena, including aerodynamic heating and non-equilibrium real-gas effects.
II. Explain the fundamental features of hypersonic flows, and how these differ from other flows.
III. Infer the importance and influence of non-equilibrium real-gas effects in high temperature flows.
IV. Illustrate the physical mechanisms causing aerodynamic heating of high-speed vehicles.

III. COURSE OUTCOMES:

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

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 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:

UNIT-I	OVERVIEW AND INTRODUCTION	Classes: 08

Hypersonic flight: Some historical firsts; Hypersonic flow: why is it important, what is it; Fundamental sources of aerodynamic force and aerodynamic heating; Hypersonic flight paths: velocity-altitude map; Hypersonic shock and expansion-wave relations: hypersonic shock and expansion-wave relations, hypersonic shock relations in terms of the hypersonic similarity parameter, hypersonic expansion-wave relations.

UNIT-II	SURFACE INCLINATION METHODS AND THEORIES	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**	**Classes: 09**
Importance of high-temperature flows, nature of high-temperature flows; Chemical effects in air: The velocity-altitude 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**
Governing equations for inviscid high-temperature equilibrium flow, equilibrium normal and oblique shock-wave 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 :

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

Reference Books:

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

Web References:

1.http://www.southampton.ac.uk/engineering/undergraduate/UNITs/sesa6074_hypersonic_and_high_temperature_gas_dynamics.page#aims_and_objectives

E-Text Books:

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