COURSE CONTENT

HIGH TEMPERATURE GAS DYNAMICS								
VI Semester: AE								
Course Code	**Category**	**Hours / Week**			**Credits**	**Maximum Marks**		
AAED34	**Elective**	**L**	**T**	**P**	**C**	**CIA**	**SEE**	**Total**
		3	0	-	3	40	60	100
Contact Classes: 48	**Tutorial Classes: Nil**	**Practical Classes: Nil**				**Total Classes: 48**		
Prerequisite: Nil								

I. COURSE OVERVIEW:

This 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. COURSES OBJECTIVES:

The students will try to learn

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

III. COURSE OUTCOMES:

At the end of the course students should be able to:

CO 1 Summarize the fundamental aspect of hypersonic flow and their characteristics for solving the hypersonic flow over arbitrary shape.
CO 2 Construct the equation for variation flow properties for shock and expansion waves in hypersonic flow.
CO 3 Make a use of equivalence principle and various theories to model shock interaction in hypersonic flow field.
CO 4 Build the governing equation for viscous hypersonic laminar and turbulent boundary layer.
CO 5 Select suitable computational fluid dynamic model to solve hypersonic viscous flow.
CO 6 Construct the governing equation for high temperature inviscid equilibrium and non-equilibrium flow over an arbitrary body.

IV. COURSE CONTENT:

MODULE-I: INTRODUCTION TO HYPERSONIC AERODYNAMICS (08)

Peculiarities of Hypersonic flows - thin shock layers - entropy layers - low density and high-density flows - hypersonic flight similarity parameters - shock wave and expansion wave relations of inviscid hypersonic flows - velocity vs altitude map for hypersonic vehicles.

MODULE-II: SURFACEINCLINATIONMETHODSANDTHEORIES (11)

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 flowfields: 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.

MODULE-III: VISCOUS FLOW AND HYPERSONIC VISCOUS INTERACTIONS (11)

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 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, full Navier-stokes solutions.

MODULE-IV: HIGH ENTHALPY GASDYNAMICS (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.

MODULE-V: INVISCID HIGH ENTHALPY EQUILIBRIUM FLOWS AND NON-EQUILIBRIUM FLOWS (09)

Governing equations for in viscid 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-equilibriumflowoverothershapes:non-equilibriummethod of characteristics.

V. TEXT BOOKS:

1. Ethirajan Rathakrishnan, “High Enthalpy Gas Dynamics”, Wiley & McGraw Hill, 1st Edition 2015
2. John D. Anderson, “Hypersonic and High Temperature Gas Dynamics”, McGraw Hill, 2nd Edition, 1989.
3. John J.Berlin, “Hypersonic Aerodynamics”, AIAA Education series,1st Edition, 1994.

VI. REFERENCE BOOKS:

1. W.D. Hayes, Ronalds F. Probstein, “Hypersonic Flow Theory”, Academic Press, 1st Edition, 1959.

2. A. Roshko, “Elements of Gas Dynamics”, John Wiley and Sons Inc., 4th Edition, 2002.

VII. ELECTRONICS RESOURCES:

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

VIII. MATERIALS ONLINE

1. Course template
2. Tutorial question bank
3. Tech talk topics
4. Open end experiments
5. Definitions and terminology
6. Assignments
7. Model question paper – I
8. Model question paper - II
9. Lecture notes
10. E-learning readiness videos (ELRV)
11. Power point presentation