Department of Space Engineering and Rocketry

Birla Institute of Technology, Mesra, Ranchi - 835215 (India)

Institute Vision

To become a Globally Recognized Academic Institution in consonance with the social, economic and ecological environment, striving continuously for excellence in education, research and technological service to the National needs.

Institute Mission

- To educate students at Undergraduate, Post Graduate Doctoral and Post-Doctoral levels to perform challenging engineering and managerial jobs in industry.
- To provide excellent research and development facilities to take up Ph.D. programmes and research projects.
- To develop effective teaching and learning skills and state of art research potential of the faculty.
- To build national capabilities in technology, education and research in emerging areas.
- To provide excellent technological services to satisfy the requirements of the industry and overall academic needs of society.

Department Vision

To effectively integrate teaching, research and innovation for significant contribution towards National Aerospace Programmes and related activities

Department Mission

- To impart quality education and advanced research training leading to postgraduate and doctoral degree
- To generate modern infrastructure and conducive research atmosphere for carrying out innovative sponsored research projects
- To nurture spirit of excellence and professional leadership in students and faculty members through exposure to leading academic/research organisations and external experts
- To create attractive opportunities for sustained interaction and collaboration with academia and industry

Program Educational Objectives (PEO)

PEO 1 : To develop strong foundation in students to understand and analyse advance research problems in Space Engineering and Rocket Science.
PEO 2: Nurture professional graduates to develop ability in analysing real life problems of Space Technology.
PEO 3 : To foster attitude towards continuous learning for developmental activities in research, academia and industry.
PEO 4 : To improve professional skills for teamwork with ethical awareness and practice in achieving goal.

Program Outcomes (PO)

PO 1 : An ability to independently carry out research and development work to solve practical problems in Aerodynamics

PO 2 : An ability to write and present substantial technical report and research article

PO 3 : Students should be able to demonstrate a degree of mastery over and above the bachelor program in the areas of Aerodynamics.

PO 4: Ability to design, perform and interpret data from experiments and correlate them withnumerical and theoretical solutions

PO 5 : Students should be committed to professional ethics, responsibilities and norms of practices.

PO 6 : An ability to recognize the need for continuous learning throughout his professional career in the context of technological challenges and advancements

COURSE INFORMATION SHEET

Course code: SR 576
Course title: Compressible Flows
Pre-requisite(s): Engineering Mathematics, Fluid dynamics
Co- requisite(s): NA
Credits: L:3 T:0 P:0
Class schedule per week: 3 Lectures
Class: M. Tech.
Semester / Level: I/5
Branch: Space Engg. & Rocketry
Name of Teacher: Sudip Das

Course Objectives

This course enables the students to:

1.	Simplify multidimensional complex compressible flow problems to 1D counterpart and understand and solve the basic flow features.
2.	Understand one-dimensional unsteady wave motion and its characteristics and usage in shock tubes
3.	Solve problems with oblique shock, expansion waves and the combination
4.	Relate starting of flow to diffuser with several example problems of supersonic intake, wind tunnel etc.
5.	Interpret problems associated with transonic flow theories.

Course Outcomes

After the completion of this course, students should able to:

CO1	Solve high speed 1D flow situations either with isolated isentropic condition, friction, heat transfer and shock wave or the combination of them.
CO2	Compare the differences between steady and unsteady wave motions.
CO3	Solve oblique shock, expansion waves, combination of shock and expansion.
CO4	Relate the start / unstart problems at supersonic speeds for flow in diffuser ducts and intakes.
CO5	To appraise the transonic flows and its associated problems / solutions

Syllabus

One-Dimensional Flow : 1- D Flow Equations; Quasi 1- D Flow; Area- Velocity Relation; Isentropic Flow through Variable Area Ducts; Diffusers; Speed of Sound and Mach Number; Normal Shock; Pressure, Temperature, Density and Entropy Relations across a Normal Shock; Shock Strength; Rarefaction Shock an Impossibility; Hugoniot Equation; 1- D Flow with Heat Addition; 1- D Flow with Friction; Reyleigh and Fanno Lines; [8]

Unsteady 1D Flow: Unsteady Wave Motion; Moving Normal Shock Wave; Reflected Shock Wave; Physical Picture of Wave Propagation; The acoustic equations; Propagation of acoustic wave, Pressure and particle velocity in a sound wave, Linerised shock tube, Propagation of finite wave; Centered expansion wave, Incident and Reflected Expansion Waves; The Shock Tube.

[8]

Oblique Shock and Expansion Wave : Introduction and Source of Oblique Waves; Mach Wave; Mach Cone; Oblique Shock Relations for Pressure, Temperature and Mach Number; Supersonic Flow over Wedges and Cones; Weak Oblique Shock; Shock Polar; Pressure - Deflection Diagram; Reflection of Shock from a Solid Boundary; Intersection of Shocks of Opposite and Same Family; Detached Shock Wave; Physical Aspect of Conical Flow; Taylor and Maccoll Formulation; Numerical Procedure, Prandtl- Meyer Expansion Wave; Shock Expansion Theory; Laminar and Turbulent Flow Separation Caused by the Interaction of Shock Waves with the Boundary Layer.

[9]

Supersonic Flow in Diffusers and Ducts : The Problem of Starting a Supersonic Flow in Diffusers; Supersonic Inlet – Internal, External and Mixed Compression, Total Pressure Recovery, Mass Flow Characteristics and Inlet Performance; Starting of Supersonic Inlets; Shock Wave Patterns in Ducts and Shock Train Behaviour. [7]

Similarity rules and Transonic Flows : 2D linearized flow, Prandtl-Glauert and Gothert rules, von Karman's rule, Linearised axially symmetric and planar flow, Application; Physical and Theoretical Aspects of Transonic Flows; Definition of transonic range, Flow past wedge section, cone, smooth 2D shape, Example Solution of small Perturbation, full Velocity Potential Equations and Euler Equations.

[8]

Text books:

1. Modern Compressible Flow – Anderson, John D.
2. Elements of Gas Dynamics – Liepmann, H. W. and Roshko, A.
3. Dynamics and Thermodynamics of Compressible Fluid Flow - Shapiro, A. H.

Reference books:

4. Gas Dynamics - Rathakrishnan, E.

Gaps in the syllabus (to meet Industry/Profession requirements)

1) High Speed high temperature flows
2) Solution strategies through numerical techniques for steady supersonic flows

POs met through Gaps in the Syllabus

PO4, PO6

Topics beyond syllabus/Advanced topics/Design

1) Hypersonic, non-equilibrium flows
2) Compressible turbulent boundary layers

POs met through Topics beyond syllabus/Advanced topics/Design

PO5, PO6

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Industrial/guest lectures

Industrial visits/in-plant training
Self- learning such as use of NPTEL materials and internets
Simulation

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	PO1	PO2	PO3	PO4	PO5	PO6
1	3	2		2	2	-
2	3	-	2	1	-	2
3	3	3	3	2	1	2
4	1	3	2	-	1	3
5	1	2	-	1	-	3

If satisfying and < 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD6
CO2	CD1, CD6,CD7
CO3	CD1, CD2, CD3,CD6,CD7
CO4	CD1, CD3,CD6,CD7
CO5	CD1,CD2,CD3,CD4,CD5,CD7

COURSE INFORMATION SHEET

Course code: SR577
Course title: Boundary Layer Theory
Pre-requisite(s): Fundamental of Aerodynamics
Co- requisite(s):
Credits: L: 03 T:0 P:0
Class schedule per week: 3
Class: M. TECH.
Semester / Level: 02/05
Branch : Space Engg. & Rocketry
Name of Teacher: Dr. Priyank Kumar

Course Objectives

This course enables the students to:

1.	Understand the basics of the fluid flow and the governing equations
2.	Apply fluid dynamic equation for solving simple fluid dynamic problem
3.	Analyze the interaction of fluid dynamics and heat transfer in a fluid flow
4.	Understand the behaviour of time dependent boundary layer.
5.	Design the boundary layer control techniques.

Course Outcomes

After the completion of this course, students should able to:

CO1	Distinguishing the different types of fluid flows and understand the governing equations.
CO2	Solving the mathematical equation for the simple fluid dynamic problem.
CO3	Able to solve the problems of the interaction of thermal and velocity boundary layers.
CO4	Recognizing the unsteady boundary layer.
CO5	Able to devise boundary layer control techniques depending upon the fluid problems.

Syllabus

Law of Viscosity : Types of Fluids; Dependence of Boundary Layer at Different Reynolds Number, Blassius Solution and Its Series; Asymptotic Solutions; Theory of Similarity; Separation of Boundary Layer; Similar Solutions; Reduction of the Navier- Stokes Equation to the Boundary Layer Equations. [8]

Solution of Boundary Layer Equations : Exact Solutions; Flow Past a Wedge; Flow Past a Cylinder; Flow in the Wake of Flat Plate at Zero Incidence; Momentum Integral and Energy Integral Equations; Approximate Solutions; Application of Momentum Equation to the Flat Plate; Karman- Pouhlsen Method; Approximate Methods for 2D Flows; Comparison of Exact and Approximate Methods for Flat Plate at Zero Incidence, Two- dimensional Stagnation Flow and Flow Past a Circular Cylinder. Axially symmetric boundary layers, Mangler Transformations. [9]

Thermal Boundary Layer : Derivation of Energy Equation; Theory of Similarity in Heat Transfer; Non Dimensional Numbers – Grashoff's, Prandtl, Reynolds and Eckert Numbers; Analogy between Heat Transfer and Momentum Transfer; Exact Solution of Temperature Distribution in Viscous Flows; Boundary Layer Simplification; Properties of Thermal Boundary Layer; Forced and Natural Flows; Adiabatic Wall; Effect of Prandlt's Number. Relation between Velocity and Temperature Fields – Adiabatic Wall and Heat Transfer; Recovery Factor. [9]

Unsteady Boundary Layer : Introduction to Unsteady Boundary Layers; Boundary Layer Equations, Methods of approximations, Boundary layer formation in accelerated motion, Transition and Origin of Turbulence; Turbulent boundary layer over a flat plate, Boundary layer in non zero pressure gradients. [8]

Boundary Layer Control : Introduction; Fundamental Equation with Suction/ Injection; Exact and Approximate Solutions with Suction and Injection; Solution of Pressure Gradient Cases; Prevention of Separation on Aerofoil; Control and Means to Increase Lift and to Reduce Drag; Some Experimental Results.

[8]

Text books:
1. Boundary Layer Theory –H. Schlichting
2. Fundamental of Aerodynamics – John D. Anderson

Reference books:
1.. Viscous Fluid Flow – Frank M. White

Gaps in the syllabus (to meet Industry/Profession requirements)

POs met through Gaps in the Syllabus

Topics beyond syllabus/Advanced topics/Design

POs met through Topics beyond syllabus/Advanced topics/Design

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Industrial/guest lectures
Industrial visits/in-plant training
Self- learning such as use of NPTEL materials and internets
Simulation

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	PO1	PO2	PO3	PO4	PO5	PO6
1	-	-	3	-	-	2
2	2	-	3	3	1	1
3	2	1	3	2	-	1

4	-	-	3	1	-	2
5	3	2	3	3	2	2

If satisfying and < 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD6
CO2	CD1, CD6,CD7
CO3	CD1, CD2, CD3,CD6,CD7
CO4	CD1, CD3,CD6,CD7
CO5	CD1,CD2,CD3,CD4,CD5,CD7

COURSE INFORMATION SHEET

Course code: SR 579
Course title: Experimental Aerodynamics
Pre-requisite(s): Engineering Mathematics, Fluid dynamics
Co- requisite(s): Basic Physics
Credits: L:3 T:0 P:0
Class schedule per week: 3 Lectures
Class: M. Tech
Semester / Level: II/05
Branch: Space Engg. & Rocketry
Name of Teacher:

Course Objectives

This course enables the students:

1.	To understand the basics of Wind Tunnel and its components with specific orientation to its operation.
2.	To describe and implement the different wind tunnel measurement techniques adopted recently and in the past.
3.	To understand the basics of advanced flow diagnostic systems with knowledge towards its components and devices.
4.	To understand unsteady features of a flow and its associated measurement techniques.
5.	To be able to understand, use and operate advanced data acquisition system and its components.

Course Outcomes

After the completion of this course, students will be:

CO1	Describe wind tunnels and their components.
CO2	Organise in performing experiments using wind tunnel measurement techniques which are in practice.
CO3	Demonstrate the advanced measurement techniques for wind tunnel tests.
CO4	Implement the unsteady flow measurements with possible recognition to its stochastic behaviour and analysis.
CO5	Perform experiments with advanced data acquisition system with good level of confidence and minimal error.

Syllabus

Module I:

Wind Tunnel: Necessity of Wind Tunnels; Basic Principle; Types of Wind Tunnels; Components of Subsonic Tunnel, Supersonic Tunnel, Hypersonic Tunnel and Shock Tunnel; Special Purpose Wind Tunnel; Design Consideration of Subsonic Tunnel and Supersonic Tunnel; Calibration Methods of Different Wind Tunnels; [8 L]

Module II:

Flow Visualisation: Different Types of Flow Visualization Techniques for Subsonic, Supersonic and Hypersonic Tunnels; Basics of Schlieren, Shadowgraph and Interferometers; Laser Based Flow Visualization Technique.

[6 L]

Module III:

Pressure, Velocity, Force and Moment Measurement: Pitot Static Probe; Laser Doppler Velocimeter; Mechanical System for Pressure Measurement; Water and Mercury Manometers; Principle of Pressure Transducer; Different Types of Pressure Transducers; Mechanical Pressure Scanner, Electronic Pressure Scanner; Pressure Sensitive Paint; Calibration of Pressure Measuring Units, Definition of Forces and Moments on Aerospace Vehicles; Basic Principle of Mechanical Balance and Strain Gage Balance; Interaction between Different Components of Forces and Moments; Major Components for Force and Moment Measuring Systems.

[12 L]

Module IV:

Unsteady Measurement: Introduction to Unsteady data; Introduction to Turbulent measurements; Basic Principle of Hot Wire Anemometer; Constant Current and Constant Temperature Anemometer, Measurement of Unsteady Velocities Using Hot Wire Anemometers; Measurement of Turbulent Stresses; Single and Multiple Hot Wire Probes; Basic Principles of Unsteady Pressure Transducers; Calibration of Steady and Unsteady Pressure Transducers. [10 L]

Module V:

Data Acquisition System: Analog and Digital Signals; Mean and Fluctuating Signals; ADC Cards; Amplifiers; Signal Conditioners; P C Based Data Acquisition System; Data Acquisition Software; Error Analysis. [8 L]

Text books:

1. High Speed Wind Tunnel Testing, Roe, W. H. and Pope, A., Wiley, 1965. **(T1)**
2. Low Speed Wind Tunnel Testing, Pope, A. and Goin, L., Wiley, 1966. **(T2)**

Reference books:

3. Random Data: Analysis and Measurement Procedures, Bendat, J. S. and Piersol. A.G., Wiley, 2010. **(R1)**

Gaps in the syllabus (to meet Industry/Profession requirements)
Emphasis on data analysis
More elaboration on the data acquisition system and its component

POs met through Gaps in the Syllabus: PO1, PO5, PO6

Topics beyond syllabus/Advanced topics/Design
Elaborate studies on PIV instrumentation and data interpretation
Compressible boundary layer measurement techniques

POs met through Topics beyond syllabus/Advanced topics/Design: PO4, PO5, PO6

Course Delivery methods

CD	**Course Delivery methods**
CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Tutorials/Assignments
CD3	Self- learning such as use of NPTEL materials and internets

Mapping between Objectives and Outcomes

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	**Program Outcomes**					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1		2	2	1	1	
CO2	3		3	3	2	3
CO3	2	1	2			2
CO4	1	2	2	1	3	3
CO5	3		3	3	3	2

If satisfying ,< 34% = 1, 34-66% = 2, >66% = 3

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	**Course Delivery Method**
CO1	CD1
CO2	CD1
CO3	CD1, CD2
CO4	CD1, CD2, CD3
CO5	CD1,CD2,CD3

COURSE INFORMATION SHEET

Course code: SR 580
Course title: Elements of Hypersonic Flight
Pre-requisite(s): Compressible Flow
Co- requisite(s): Nil
Credits: L:3 T:0 P:0
Class schedule per week: 3 Lectures
Class: M. Tech.
Semester / Level: II/05
Branch: Space Engg. & Rocketry
Name of Teacher:

Course Objectives

This course enables the students:

1.	To know fundamental of hypersonic flow and its importance.
2.	To learn hypersonic shock, expansion-wave relations.
3.	To analyze the hypersonic inviscid flowfields using approximate and exact methods.
4.	To comprehend basic aspects boundary layer and aerodynamic heating in viscous hypersonic flow.
5.	To apply computational fluid dynamics in hypersonic viscous flow.

Course Outcomes

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

CO1	Learn the basics of hypersonic flow, high temperature and low density flows.
CO2	Understand the hypersonic shock and expansion-wave theory, Newtonian and modified Newtonian laws.
CO3	Analyze the inviscid flowfields in hypersonic flow using approximate and exact methods.
CO4	Learn the hypersonic boundary layer theory and hypersonic aerodynamic heating.
CO5	Apply the computational fluid dynamics for Navier- Stokes solutions in hypersonic flows.

Syllabus

Module I:
Introduction: Hypersonic Flow and Its Importance; Shock Layer; Entropy Layer; Viscous Interaction; High Temperature Flows; Low Density Flows; Hypersonic Flight Paths: Velocity-Altitude Map. [7 L]

Module II:
Hypersonic Shock- Expansion Theory: Shock Relation; Hypersonic Shock Relations in Terms of the Hypersonic Similarity Parameter; Expansion-Wave Relation; Newtonian Flow; Modified Newtonian Law; Centrifugal Force Corrections to Newtonian Theory; Tangent- Wedge/ Tangent- Cone Methods; Shock- Expansion Method. [10 L]

Module III:
Hypersonic Inviscid Flowfields (Approximate and Exact Methods): Introduction; The Governing Equations; Mach Number Independence; The Hypersonic Small-Disturbance Equations; Hypersonic Similarity; Hypersonic Small- Disturbance Theory; The Hypersonic Equivalence Principle and Blast Wave Theory; Thin Shock- Layer Theory; Method of Characteristics; The Hypersonic Blunt- Body Problem; Correlations for Hypersonic Shock- Wave Shapes; Modern Computational Hypersonics. [10 L]

Module IV:
Viscous Hypersonic Flow: Governing Equations for Viscous Flow; The Navier- Stokes Equations; Similarity Parameters and Boundary Conditions; The Boundary Layer Equations for Hypersonic Flow; Hypersonic Boundary Layer Theory: Self- Similar Solutions, Flat Plate Case, Stagnation Point Case; Hypersonic Transition; Hypersonic Turbulent Boundary Layer; Hypersonic Aerodynamic Heating; Entropy Layer Effects on Aerodynamic Heating. [10 L]

Module V:
Computational Fluid Dynamic Solutions of Hypersonic Viscous Flows: Introduction; Viscous Shock- Layer Technique; Parabolized Navier- Stokes Solutions; Full Navier-Stokes Solutions. [7 L]

Text books:
1. Hypersonic and High Temperature Gas Dynamics – Anderson, John D., McGraw Hill, 1989. **(T1)**

Reference books:
1. Selected Aerothermodynamic Design Problems of Hypersonic Flight Vehicles, E. Hirschel, C. Weiland., Springer-Verlag Berlin and AIAA, 2009. **(R1)**

Gaps in the syllabus (to meet Industry/Profession requirements)

Thermodynamics of Chemically Reacting Gases

POs met through Gaps in the Syllabus: PO1, PO3, PO6

Topics beyond syllabus/Advanced topics/Design

Statistical Thermodynamics

POs met through Topics beyond syllabus/Advanced topics/Design: PO1, PO3, PO5, PO6

Course Delivery methods

CD	Course Delivery methods
CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Self- learning such as use of NPTEL materials and internets
CD5	Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Mapping between Objectives and Outcomes

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes					
	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	2	1	1	2
CO2	2	2	2	1	1	2
CO3	3	2	2	2	1	3
CO4	3	2	3	2	1	3
CO5	3	2	2	2	1	3

If satisfying ,< 34% = 1, 34-66% = 2, >66% = 3

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method
CO1	CD1
CO2	CD1, CD2,CD3
CO3	CD1, CD2,CD3
CO4	CD1, CD2,CD3,CD4
CO5	CD1, CD2, CD3,CD4,CD5

COURSE INFORMATION SHEET

Course code: SR 581
Course title: Missile Aerodynamics
Pre-requisite(s): Elements of Aerodynamics
Co- requisite(s): Nil
Credits: L:3 T:0 P:0
Class schedule per week: 3 Lectures
Class: M. Tech
Semester / Level: II/05
Branch: Space Engineering & Rocketry
Name of Teacher:

Course Objectives

This course enables the students:

1.	To understand the static stability of a missile.
2.	To learn the fundamental concept of dynamic stability and its characteristics of a missile.
3.	To analyze the air loads and component load distribution of a missile.
4.	To learn aerodynamic launching problems.
5.	To understand dispersion of a missile and its design consideraoin.

Course Outcomes

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

CO1	Learn the static longitudinal, directional and lateral stability of a missile.
CO2	Apply the fundamental concept of dynamic stability for longitudinal and lateral dynamic stability analysis.
CO3	Analyze the air loads, component load distribution and aerodynamic hinge moments of a missile.
CO4	Learn the aerodynamic launching problems in air, ground and underwater launch.
CO5	Understand the free flight dispersion and its consideration in design.

Syllabus

Module I:

Introduction to Missiles and Static Stability : Introduction, Forces and Moments for Two Degree of Freedom in Static Longitudinal Stability; Derivation of Forces, Moments and Static Margin; Load Factors for Complete Missile, Canard, Wing and Tail Controls; Interference Factors; Methods to Alter the Stability of Missile; Relation between Angles in Pitch and Yaw Plane with Total Angle of Attack; Methods to Estimate the Stability of Missile in Yaw Plane; Effect of Different Control Surfaces; Induced Rolling; Roll Damping. [12L]

Module II:

Dynamic Stability : Introduction, Equation of Motion for Six Degrees of Freedom, Oscillating and Non Oscillating Motion; Short and Long Period, Phugoid Motion, Longitudinal Dynamic Stability with Two and Three Degree of Freedom, Time- to- Half and Time-to- Double, Effect due to Angular Velocity, Lateral Dynamic Stability, Response Characteristics of Missile. [8 L]

Module III:

Air Loads : Introduction, Design Criteria for Forward and Rear Control, Component Air Loads on Body and Aerodynamic Surfaces, Component Load Distribution on Body and Aerodynamic Surfaces, Aerodynamic Hinge Moments, Aerodynamic Heating. [8 L]

Module IV:

Aerodynamic Launching Problems : Introduction, Safety of Parent Aircraft in Air Launch, Launch Boundaries in Air Launch, Consideration to Parent-aircraft Performance, Problems in Ground Launch, Range Safety, Shipboard and Underwater Launches.[8 L]

Module V:

Free-flight Dispersion : Introduction, Dispersion During Launch or Boost Phase of Missiles, Dispersions During Power-off Flight of a Ballistic Missile, Dispersion-sensitivity Factors in Vacuum, Reentry-body Design Considerations. [8 L]

Text books:

1. Missile Configuration Design, Chin, S. S., McGraw-Hill, 1982. **(T1)**

Reference books:

1. Fundamental of Aerodynamics, Anderson, John D., McGraw-Hill, 2001. **(R1)**

2. Missile Aerodynamics, Jack N. Nielson, McGraw-Hill, 1960. **(R2)**

Gaps in the syllabus (to meet Industry/Profession requirements)

Structural Design Considerations

POs met through Gaps in the Syllabus: PO1, PO3, PO4, PO6

Topics beyond syllabus/Advanced topics/Design

Power Plant Design Considerations

POs met through Topics beyond syllabus/Advanced topics/Design: PO1, PO3, PO5,PO6

Course Delivery methods

CD	Course Delivery methods
CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Self- learning such as use of NPTEL materials and internets

Mapping between Objectives and Outcomes

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	Program Outcomes						
	PO1	PO2	PO3	PO4	PO5	PO6	
CO1	3	2	3	2	1	2	
CO2	2	2	3	2	1	3	
CO3	2	2	2	3	1	2	
CO4	2	2	2	2	1	2	
CO5	2	2	2	2	1	2	

If satisfying ,< 34% = 1, 34-66% = 2, >66% = 3

Mapping Between COs and Course Delivery (CD) methods

Course Outcome	Course Delivery Method
CO1	CD1,CD2,CD3
CO2	CD1, CD2,CD3,CD4
CO3	CD1, CD2,CD3
CO4	CD1, CD2
CO5	CD1, CD2

COURSE INFORMATION SHEET

Course code: SR 578
Course title: Computational Fluid Dynamics
Pre-requisite(s): Fluid Mechanics, Numerical Analysis
Co- requisite(s): Nil
Credits: L:3 T:0 P:0
Class schedule per week: 03
Class: M. Tech.
Semester / Level: II/5
Branch: Space Engg. & Rocketry
Name of Teacher: Dr. Partha Mondal

Course Objectives

This course enables the students:

1.	To know classification of partial differential equations, finite difference method, stability analysis.
2.	To learn the solution methods of finite difference equations of elliptic, parabolic and hyperbolic partial differential equations.
3.	To apply the methods to solve finite difference equations
4.	To understand the numerical techniques to solve incompressible Navier-Stokes equations.
5.	To know the finite volume method and apply it for inviscid problems.

Course Outcomes

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

1.	know the basics of CFD, classification of partial differential equations, initial and different boundary conditions.
2.	Understand finite difference methods Taylor series expansion and polynomial expansion, discrete perturbation and Von Neumann stability analysis, artificial viscosity.
3.	Apply the solution methods of finite difference equations to solve elliptic, parabolic and hyperbolic problems.
4.	Understand the different forms of incompressible Navier-Stoke equations and techniques to solve it numerically.
5.	Develop the proceddure to solve the Euler equations by finite volume method.

Syllabus

Module I:

Introduction: Computational Fluid Dynamics; Classification of Partial Differential Equations; Linear and Non- linear Partial Differential Equations – Model Equation, Elliptic Equation, Parabolic Equation and Hyperbolic Equation; System of 1st order Partial Differential Equations; System of 2nd order Partial Difference Equations; Initial Conditions; Boundary Conditions. [8L]

Module II:

Finite Difference Formulations: Introduction; Taylor Series Expansion; Finite Difference by Polynomial; Finite Difference Equations; Higher Order Derivatives; Multidimensional Finite Difference Formulas; Applications; Finite Difference Approximation of Mixed Partial Derivatives; Stability Analysis; Discrete Perturbation Stability Analysis; Von Neumann Stability Analysis; Multidimensional Problem; Error Analysis; Artificial Viscosity. [8L]

Module III:

Solution Methods of Finite Difference Equations: Elliptic Equations – Finite Difference Formulations, Jacobi Iteration Method, Point Gauss Seidel Iteration Method, Line Gauss Seidel Iteration Method, Point Successive Over Relaxation Method, Line Successive Over Relaxation Method, Alternating Direction Implicit Method, Applications; Parabolic Equations – Finite Difference Formulations, Explicit Schemes, Implicit Schemes, Alternating Direction Implicit Schemes, Parabolic Equations in Two-space Dimensions, Approximate Factorization, Fractional Step Methods; Hyperbolic Equations – Explicit and Implicit Schemes, Splitting Methods, Multistep Methods, Application to Linear and Non-linear Problems, Flux Corrected Transport, Classification of Numerical Scheme, TVD Formulations; Application – Heat conduction, Couette Flow and Wave Motion. [10L]

Module IV:

Incompressible Navier- Stokes Equations: Introduction; Primitive Variable and Vorticity Stream Function Formulations; Poisson Equations for Pressure (Primitive Variable and Vorticity Stream Function Formulation); Numerical Algorithm (Primitive Variable); Artificial Compressibility; Solution on a Regular Grid; Crank Nicolson Implicit Method; Boundary Conditions (Body Surface, Far Field, Symmetry, Inflow, Outflow); Staggered Grid; Marker and Cell Method; Implementation of Boundary Conditions; DuFort Frankel Scheme; Use of the Poisson Equation for Pressure; Unsteady Incompressible Navier- Stokes Equation. [10L]

Module V:

Euler Equations and Finite Volume Method: Explicit Formulations – Steger and Warming Flux Vector Splitting, Van Leer Flux Vector Splitting, Runge Kutta Formulation, Implicit Formulations – Steger and Warming Flux Vector Splitting; Boundary

Conditions; Global Time Step and Local Time Step; Application – Diverging Nozzle Configuration, Shock Tube or Reimann Problem, Supersonic Channel Flow; Approximation of Surface Integrals; Cell centered and Nodal Point Scheme; Interpolation and Differentiation Practices; Implementation of Boundary Conditions.

[8L]

Text books:

1. Hoffmann, K.A. and Chiang, S.T., Computational Fluid Dynamics (Vol. I & II), Engineering Education System, 2000. (**T1**)

Reference books:

1. Hirsch, C., Numerical Computation of Internal and External Flows (Vol. I & II), John Wiley and Sons, 1994. (**R1**)
2. Anderson, John D., Computational Fluid Dynamics, McGraw-Hill, 1995. (**R2**)

Gaps in the syllabus (to meet Industry/Profession requirements) : Unsteady flow simulation

POs met through Gaps in the Syllabus : PO1, PO3

Topics beyond syllabus/Advanced topics/Design : Simulation of turbulent flows

POs met through Topics beyond syllabus/Advanced topics/Design : PO1, PO2, PO3, PO6

COURSE OUTCOME (CO) ATTAINMENT ASSESSMENT TOOLS & EVALUATION PROCEDURE

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 Quizzes	30 % (3 × 10%)
Assignment (s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Course Delivery methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments/Seminars
CD3	Laboratory experiments/teaching aids
CD4	Industrial/guest lectures
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Objectives and Outcomes

Mapping of Course Outcomes onto Program Outcomes

Course Outcome #	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	2	1	1	2
CO2	2	2	2	1	1	2
CO3	2	2	3	2	1	2
CO4	3	2	2	2	2	3
CO5	3	3	2	2	2	3

If satisfying and < 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD6
CO2	CD1, CD2,CD6
CO3	CD1, CD2, CD6
CO4	CD1, CD2,CD6
CO5	CD1,CD2,CD6

COURSE INFORMATION SHEET

Course code: SR 582
Course title: Low Speed Aerodynamics Laboratory
Pre-requisite(s): NA
Co- requisite(s): NA
Credits: 2 L: T:0 P:4
Class schedule per week: 4 Lectures
Class: M. Tech.
Semester / Level: II/05
Branch: Space Engg. & Rocketry
Name of Teacher: Priyank Kumar / Sudip Das

Course Objectives

This course enables the students to:

1.	The basics of instrument calibration, handling of electronic instruments.
2.	Measure different forces and moments of the wind tunnel model
3.	Basic skills of flow visualization.
4.	Measure the steady and unsteady quantities on a wind tunnel model.
5.	Work in a group and evaluate the results to prepare the report.

Course Outcomes

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

CO1	Operate the instruments and perform the calibration independently.
CO2	Organize and perform any experiment with data acquisition system and adopt suitable precautions.
CO3	Demonstrate experimental needs to obtain meaningful and quality results.
CO4	Analyse the experimental results and write the report.
CO5	Do experimental work in the field of low speed flows in a group as well as individually.

List of the Experiments:

S. No.	Experiment	Class Hours
1	Force and Moment measurements on Delta Wing at Subsonic Speed and at different Angles of Attack.	6
2	Oil and Tuft flow visualisation over Slender Body and Delta Wing at High Angles of Attack.	6
3	Calibration of Pressure Sensors mounted in the Scanner Box for Subsonic applications.	3
4	Pressure measurements over a Delta Wing using Sensors and DAQ System.	3
5	Unsteady Pressure measurement on the Leeward side of a Delta Wing at Subsonic Speed and at different Angles of Attack.	3
6	Preparation of Hot-Wire probes for experiments with Hot-Wire Anemometer.	3
7	Boundary Layer measurement on a Flat Plate using Hot-Wire Anemometer at different Subsonic Speeds.	3
8	Measurement of Boundary Layer along the length of the Flat Plate.	3

Gaps in the syllabus (to meet Industry/Profession requirements):

Turbulence experiments
Good quality flow visualisation

POs met through Gaps in the Syllabus: PO4, PO5

Topics beyond syllabus/Advanced topics/Design:
1. Particle Image Velocimetry
2. Schlieren technique

POs met through Topics beyond syllabus/Advanced topics/Design: PO6

Mapping between CO and PO

COURSE OUTCOME	**Program Outcome**

	PO1	PO2	PO3	PO4	PO5	PO6
1	3	1	1	1	2	2
2	3	2	1	1	3	1
3	1	3	2	2	3	2
4	2	3	3	1	1	2
5	1	3	1	1	3	1

COURSE INFORMATION SHEET

Course code: SR 583

Course title: High Speed Aerodynamics Laboratory

Pre-requisite(s): NA

Co- requisite(s): NA

Credits: L: T:0 P:3

Class schedule per week: 3 Lectures

Class: M.Engg

Semester / Level: II/5

Branch: Space Engg. & Rocketry

Name of Teacher: Sudip Das / Priyank Kumar

Course Objectives

This course enables the students to:

1.	The basics of instrument calibration, handling of electronic instruments.
2.	Measure different components form the wind tunnel model.
3.	Plan an experiment with all steps, precaution and limitations.
4.	Basic skills of flow visualization.
5.	Work in a group and evaluate the results to prepare the report.

Course Outcomes

After the completion of this course, students will be able:

CO1	Operate and communicate with any instruments and calibrate them.
CO2	Organize and perform any experiment with high speed data acquisition system and adopt suitable precautions.
CO3	Demonstrate experimental needs to obtain meaningful and quality results.
CO4	Examine the experimental results and write the report.
CO5	Do experimental work in the field of compressible fluid dynamics in a group as well as individual.

List of the Experiments:

1. **<u>Experiment No. 1</u>**
   Name: Wind Tunnel Calibration
   Object : Calibration of Supersonic Wind Tunnel using the following techniques
   a) Area ratio
   b) Static Pressure Distribution
   c) Pitot Probe Measurement

2. **<u>Experiment No. 2</u>**
   Name : Study noise measurements using unsteady pressure pickups
   Object : To study the noise measurement of the tunnel and obtain the RMS pressure and overall sound pressure level.

3. **<u>Experiment No. 3</u>**
   Name: Study pressure measurements using static pressure transducers and manometer
   Object: To study pressure distribution around cylindrical protrusion placed in a supersonic flow with M=2.0

4. **<u>Experiment No. 4</u>**
   Name: Flow Visualisation Techniques at supersonic speed
   Object: To study flow visualization over a typical cylindrical protrusion and other isolated models using
   a) Oil Flow Visualisation
   b) Schlieren optical method
   c) Shadowgraph technique

5. **<u>Experiment No. 5</u>**
   Name: Cavity Pressure Fluctuation
   Object : To study the pressure fluctuations inside a generic cavity at Supersonic speed

6. **<u>Experiment No. 6</u>**
   Name: Free Jet Studies
   Object: To obtain the flow patterns at the exit of a free jet and influence of pressure ratio on the flow.

7. **<u>Experiment No. 7</u>**
   Name: Drag Measurement using single component strain gage balance
   Object: To measure drag over a blunt nose body and establish a drag reduction with adoption of spike ahead of the blunt body

References :

1. HIGH SPEED WIND TUNNEL TESTING by Alan Pope and Kennith L. Goin
2. SCHLIEREN AND SHADOWGRAPH TECHNIQUES by G.S.Settles

Gaps in the syllabus (to meet Industry/Profession requirements)

3) Boundary layer measurement technique
4) Force and moment measurements at different angles of attack

POs met through Gaps in the Syllabus

PO1, PO4, PO5

Topics beyond syllabus/Advanced topics/Design

3) Particle Image Velocimetry
4) Background Oriented Schlieren technique

POs met through Topics beyond syllabus/Advanced topics/Design

PO3, PO6

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Industrial/guest lectures
Industrial visits/in-plant training
Self- learning such as use of NPTEL materials and internets
Simulation

Mapping of Course Outcomes into Program Outcomes

Course Outcome #	PO1	PO2	PO3	PO4	PO5	PO6
1	2	1		2	2	2
2	2	-	2	2	1	-
3	2	-	2	2		2
4	1	2	2		1	-
5	2	2	2	2	-	-

If satisfying and < 34% = 1, 34-66% = 2, > 66% = 3

MAPPING BETWEEN COURSE OUTCOMES AND COURSE DELIVERY METHOD

Course Outcomes	Course Delivery Method
CO1	CD1,CD6
CO2	CD1, CD6,CD7
CO3	CD1, CD2, CD3,CD6,CD7
CO4	CD1, CD3,CD6,CD7
CO5	CD1,CD2,CD3,CD4,CD5,CD7