Department of Space Engineering and Rocketry

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

M. Tech. in Aerospace Engineering

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) - (Aerospace Engineering)

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)

Common:

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

Program Specific:

PO 4: Ability to design, perform and interpret data from experiments and correlate them with numerical 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

Department of Space Engineering and Rocketry
Birla Institute of Technology, Mesra, Ranchi - 835215 (India)

M. Tech. (Aerospace Engineering)

Semester	Course code	Courses	Mode of delivery		Total credits
			L	P	
First	SR26501	Aerospace Propulsion	3	0	3
	SR26502	Theoretical & Applied Aerodynamics	3	0	3
	SR26503	Navigation, Guidance & Control	3	0	3
	SR26514	Aerospace Structures	3	0	3
	SR26513	Applied Mathematics	3	0	3
	SR26506	Aerospace Engg. Lab	0	3	1.5
	SR26507	Aerospace Instrumentation and Simulation Lab	0	3	1.5
	SR26132	Skill Development Course – I	2	0	2
		Total			**20**
		(Specialization: Aerodynamics)			
Second		Elective I	3	0	3
		Elective II	3	0	3
		Elective III	3	0	3
		Elective IV	3	0	3
		Elective V	3	0	3
	SR26582	Low Speed Aerodynamics Lab	0	3	1.5
	SR26583	High Speed Aerodynamics Lab	0	3	1.5
	SR26133	Skill Development Course – II	2	0	2
		Total			**20**
		(Specialization: Rocket Propulsion)			
Second		Elective I	3	0	3
		Elective II	3	0	3
		Elective III	3	0	3
		Elective IV	3	0	3
		Elective V	3	0	3
	SR26556	Solid Rocket Propulsion Lab	0	3	1.5
	SR26557	Liquid and Hybrid Propulsion Lab	0	3	1.5
	SR26133	Skill Development Course – II	2	0	2
		Total			**20**
		(Specialization: Aerospace Structures)			
		Elective I	3	0	3
		Elective II	3	0	3
		Elective III	3	0	3
		Elective IV	3	0	3
		Elective V	3	0	3
	SR26597	Computational Structures Lab	0	3	1.5
	SR26598	Experimental Structures Lab	0	3	1.5
	SR26133	Skill Development Course – II	2	0	2
		Total			**20**

Third	SR26600	Thesis Part I			14
		Open Elective I/MOOC I	3	0	3
		Open Elective II/MOOC II	3	0	3
	Total				**20**
Fourth	SR26650	Thesis Part II			20
	Total				**20**
***GRAND TOTAL FOR M.TECH PROGRAMME* (20+20+20+20)**					**80**

List of Program Electives for Second Semester (Any five courses have to be selected)

(Specialization: Aerodynamics)

Course code	Courses	Mode of delivery		Total credits
		L	P	
SR26508	Aerodynamic Stability and Control	3	0	3
SR26509	Aeroacoustics	3	0	3
SR26515	Turbulent Flows	3	0	3
SR26518	Turbulence Modelling in CFD	3	0	3
SR26576	Compressible Flows	3	0	3
SR26577	Boundary Layer Theory and Applications	3	0	3
SR26578	Computational Fluid Dynamics	3	0	3
SR26579	Experimental Aerodynamics	3	0	3
SR26580	High-Speed Aerothermodynamics and Hypersonic Flows	3	0	3

List of Program Electives for Second Semester (Any five courses have to be selected)

(Specialization: Rocket Propulsion)

Course code	Courses	Mode of delivery		Total credits
		L	P	
SR26505	Flame Propagation & Stability	3	0	3
SR26519	Propellant Technology	3	0	3
SR26520	Special Topics in Chemical Propulsion	3	0	3
SR26521	Computational Combustion	3	0	3
SR26522	Cryogenic Propulsion	3	0	3
SR26523	Combustion Instabilities in Rocket Engines	3	0	3
SR26550	Liquid and Hybrid Rocket Propulsion	3	0	3
SR26551	Solid Rocket Propulsion	3	0	3
SR26552	Rocket Combustion Processes	3	0	3
SR26553	Ignition and Extinction in Chemical Rockets	3	0	3
SR26554	Advanced Propulsion Systems	3	0	3
SR26555	Heat Transfer in Space Applications	3	0	3

List of Program Electives for Second Semester (Any five courses have to be selected)

(Specialization: Aerospace Structures)

Course code	Courses	Mode of delivery		Total credits
		L	P	
SR26591	Advanced Aerospace Structure	3	0	3
SR26592	Vibrations and structural dynamics	3	0	3
SR26593	Mechanics of Composite Materials	3	0	3
SR26594	Finite Element Methods (FEM)	3	0	3
SR26595	Beam Plate and Shell	3	0	3
SR26596	Aeroelasticity	3	0	3

List of Open Electives (To be taken by other department)

Course code	Courses	Mode of delivery		Total credits
		L	**P**	
SR26504	Fundamentals of Combustion	3	0	3
SR26510	Fundamentals of Aerospace Engineering	3	0	3
SR26410	Introduction to Aerospace Engineering	3	0	3
SR26511	Fundamentals of Fuel and Combustion	3	0	3
SR26411	Introduction to Fuel and Combustion	3	0	3
SR26512	Acoustics	3	0	3
SR26578	Computational Fluid Dynamics	3	0	3
SR26579	Experimental Aerodynamics	3	0	3

Teaching and Learning Scheme

As per the new **National Credit Framework**, an account of 30 hours of learning is equivalent to 01 credit. It comprises of Classroom instructions (CI), Lab instructions (LI), Term work + Self Learning (TW + SL) in hours per semester. The division of the components mentioned will be as per the following teaching and learning schemes.

Sl. No.	Total credits	Classroom Instructions (CI) in hours per semester		Lab Instructions (LI) in hours per semester	Term work (TW)and Self Learning (SL) (TW + SL) in hours per semester	Total no. of Hours per semester
		Lectures	Tutorials			
1	**04 (Four) Theory**	42	14	0	64	120
2	**03 (Three) Theory**	28	14	0	48	90
3	**03 (Three) Theory**	42	0	0	48	90
4	**02 (Two) Theory**	28	0	0	32	60
5	**02 (Two) Lab**	0	0	56	4	60
6	**1.5 (One and half) Lab**	0	0	42	3	45
7	**01 (One) Lab**	0	0	28	2	30
8	**02 (Two) Project**	0	0	0	60	60
9	**03 (Three) Project**	0	0	0	90	90
10	**06 (Six) Project**	0	0	0	180	180
11	**03 (Three) Vocational**	14	0	56	20	90

Legend:

- CI — Classroom Instruction (includes different instructional/ implementation strategies i.e. Lecture (L), Tutorial (T), case method, Demonstrations, video demonstration, problem-based learning etc. to deliver theoretical concepts)
- LI — Laboratory Instruction (includes experiments/ practical performances, problem-based experiences in laboratory, workshop, field or other locations using different instructional/ implementation strategies)
- TW — Term Work (includes assignments, seminar micro projects, industrial visits, any other student activities etc.)
- SL — Self Learning, MOOCs, spoken tutorials, online educational resources etc. (if provided in curriculum structure)

Animesh Ghosh R.K.S.Nyk

Signed by:

Dr. Sandeep Singh Solanki
Dean (PGS)
Chairperson

Dr. Gautam Sarkhel
Dean (UGS)
Member

Dr. Raju Poddar
Dean (RIE)
Member

Dr. Praveen Srivastava
Dean (SA)
Member

Dr. Ashoke Sharon
Dean (FA)
Member

Dr. Manish Kumar
Dean (AAC)
Member

Dr. Ritesh Kumar Singh
Controller of Examination
Member

Dr. Animesh Ghosh
Director (IQAC)
Member

Dr. Rajesh Jain
Registrar
Member

Dr. Sukalyan Chakroborty
Associate Dean (UGS & PGS)
Member

Mr. Siddhi Kant Mishra
Asst. Registrar (Acad. Prog.)
Member Secretary

Department of Space Engineering and Rocketry

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

M. Tech. in Aerospace Engineering

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) - (Aerospace Engineering)

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.

Graduate Attributes (GAs)

GA1: Scholarship of Knowledge

Acquire in-depth knowledge of specific discipline or professional area, including wider and global perspective, with an ability to discriminate, evaluate, analyse and synthesise existing and new knowledge, and integration of the same for enhancement of knowledge.

GA2: Critical Thinking

Analyse complex engineering problems critically, apply independent judgement for synthesising information to make intellectual and/or creative advances for conducting research in a wider theoretical, practical and policy context.

GA3: Problem Solving

Think laterally and originally, conceptualise and solve engineering problems, evaluate a wide range of potential solutions for those problems and arrive at feasible, optimal solutions after considering public health and safety, cultural, societal and environmental factors in the core areas of expertise.

GA4: Research Skill

Extract information pertinent to unfamiliar problems through literature survey and experiments, apply appropriate research methodologies, techniques and tools, design, conduct experiments, analyse and interpret data, demonstrate higher order skill and view things in a broader perspective, contribute individually/in group(s) to the development of scientific/technological knowledge in one or more domains of engineering.

GA5: Usage of modern tools

Create, select, learn and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modelling, to complex engineering activities with an understanding of the limitations.

GA6: Collaborative and Multidisciplinary work

Possess knowledge and understanding of group dynamics, recognise opportunities and contribute positively to collaborative-multidisciplinary scientific research, demonstrate a capacity for self-management and teamwork, decision-making based on open-mindedness, objectivity and rational analysis in order to achieve common goals and further the learning of themselves as well as others.

GA7: Project Management and Finance

Demonstrate knowledge and understanding of engineering and management principles and apply the same to one’s own work, as a member and leader in a team, manage projects efficiently in respective disciplines and multidisciplinary environments after consideration of economical and financial factors.

GA8: Communication

Communicate with the engineering community, and with society at large, regarding complex engineering activities confidently and effectively, such as, being able to comprehend and write effective reports and design documentation by adhering to appropriate standards, make effective presentations, and give and receive clear instructions.

GA9: Life-long Learning

Recognise the need for, and have the preparation and ability to engage in life-long learning independently, with a high level of enthusiasm and commitment to improve knowledge and competence continuously.

GA10: Ethical Practices and Social Responsibility

Acquire professional and intellectual integrity, professional code of conduct, ethics of research and scholarship, consideration of the impact of research outcomes on professional practices and an understanding of responsibility to contribute to the community for sustainable development of society.

GA11: Independent and Reflective Learning

Observe and examine critically the outcomes of one's actions and make corrective measures subsequently, and learn from mistakes without depending on external feedback.

Program Outcomes (PO)

Common:

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

Program Specific:

PO 4: Ability to design, perform and interpret data from experiments and correlate them with numerical 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

Course code	**SR26501**
Course title	**Aerospace Propulsion**
Pre-requisite(s)	NA
Co-requisite	NA
Credits	L: 3 T:0 P:0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace Engineering
Name of Teacher	Dr. Rajiv Kumar

Course Objectives *This course aims to provide students with:*	
Sl No.	Objectives
1	Describe various types of air breathing propulsion system with their merits of challenges.
2	Classify various types of rocket propulsion and their various parameters governing it.
3	Identify the working concept of a nozzle with their applications in a propulsion system.
4	Generate sufficient information about the thrust chamber and their associated parameters along with their significance in practical applications.
5	Comprehend the basic requirements of the test facilities for rocket propulsion system.

Course Outcomes (COs) *Upon successful completion of the course, students will be able to*	
CO	Course Outcomes
1	Analyze the air breathing propulsion system along with the advanced propulsion system.
2	Understand and examine various parameters used in a chemical rockets, especially in solid rocket motor and a liquid rocket engine.
3	Explain the fundamental concept of a nozzle along with their designing challenges.
4	Comprehend and illustrate the basics of thrust chamber in terms of their designing approach.
5	Relate the significance of test facilities and their associated parameters.

Syllabus

Module No.	***Module name***	***Detailed Contents***	***No. of Lecture***
1	Introduction to Air Breathing Propulsion:	Introduction to Propulsion, Jet Propulsion; Classification of jet propulsion; Piston engine, Turbojet engine; Turboprop, Turbofan, Ramjet and Scramjet engine, Thrust equation, Thrust augmentation methods; SFC, Buzz instabilities, Challenges associated with Scramjet engine; Pulsejet, Other advanced propulsion system such as Electrical, Nuclear and IRR; Solar Cell; Application and working Principle.	8
2	Introduction to Rocket Propulsion:	Introduction; Classification of Rocket Propulsion; Application and Classification of Solid Propellant Rocket; Propellants and their Characteristics; Ingredients and Processing; Propellant Burning Rate; Propellant Grains and Grain Configurations, Grain Design. Liquid Propellant and their Properties; Liquid Propellant Feed Systems; Injectors; Thrust Chamber Shapes and Characteristic Length, Design of liquid rocket; Hybrid Propellant Rocket; Gaseous Propellant Rocket and Reaction Control Systems, Design of Hybrid Rocket; Nozzleless Rocket.	8
3	Nozzle Theory:	Ideal Rocket; Isentropic Flow through Nozzles; Exhaust Velocity; Choking; Nozzle Types; Critical ratio for choking; Divergence loss; Nozzle Shape; Nozzle Area Expansion Ratio; Under-expansion and Overexpansion; Nozzle Configurations; Real Nozzles; Unconventional and Conventional Nozzle; Multiphase Flow.	8
4	Thrust and Thrust Chambers:	Thrust Equation; Specific Impulse, Thrust Coefficient, Characteristic Velocity and other Performance Parameters; Thrust Chambers; Methods of Cooling of Thrust Chambers; Steady State and Transient Heat Transfer; Heat Transfer Distribution; Steady State Heat Transfer to Liquids in Cooling Jackets; Uncooled Thrust Chambers.	8
5	Rocket Testing:	Types of Tests; Test Facilities and Safeguards; Safety and Environmental Concerns; Monitoring and Control of Toxic Materials and Exhaust Gases; Instrumentation and Data Management; Reliability and Quality Control; Flight Testing, Post-Accident Procedures; Safety Requirements for test firings.	8

Learning Resources	
Text Books	***Reference Books***
1. Rocket Propulsion Elements, Sutton, G.P., Biblarz, O., 7thEd. John Wiley & Sons, Inc., New York, 2001. (T1) 2. Understanding Chemical Rocket Propulsion, Mukunda, H.S., I K International Publishing House, 2017. (T2)	1. Rocket Propulsion, Barrere, M., Jaumotte, A., Fraeijs de Veubeke, B.,Vandenkerckhove J., Elsevier Publishing Company, 1960.(R1) 2. Rocket and Spacecraft Propulsion: Principle, Practice and New Developments, Turner, M. J. L., Springer Verlag. 2000.(R2) 3. Rocket Propulsion, Ramamurthi, K., 2nd Edition, Trinity Press of Laxmi Publications Private Limited, India, 2016. (R3)

Gaps in the Syllabus (to meet Industry/Profession requirements)	Detailed studies on the choice of neutral and other configurations in the grain design.
Pos met through Gaps in the Syllabus	PO1, PO2, PO3, PO5, PO6
Topics beyond syllabus/Advanced topics/Design	Integral Ram Rocket Types of Error in the Measurements
Pos met through Topics beyond syllabus/Advanced topics/Design	PO4, PO6

Course Outcome (Co) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	Assignment(s)	10%				
	Seminar before a Committee	10%				
	Assessment Components	***CO1***	***CO2***	***CO3***	***CO4***	***CO5***
	Continuous Internal Assessment					
	Semester End Examination					

Indirect Assessment	Student Feedback on Faculty
	Student Feedback on Course Outcome

Mapping Between Course Outcomes and Program Outcomes

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	2	3	1	1	3
CO2	1	1	2	1	-	3
CO3	1	1	1	1	1	3
CO4	3	2	2	1	-	2
CO5	1	1	2	1	2	2

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 Course Outcomes and Course Delivery Method	
Course Outcomes	**Course Delivery Method**
CO1	CD1,CD2,CD3, CD6
CO2	CD1, CD3, CD6
CO3	CD1, CD6
CO4	CD1, CD2, CD3, CD6
CO5	CD1,CD3, CD6

Course Designers		
Experts from Industry	*Experts from Higher Technical Institutions*	*Internal Experts*

COURSE INFORMATION

Course code	**SR26502**
Course title	**Theoretical & Applied Aerodynamics**
Pre-requisite(s)	**Engineering Mathematics, Fluid dynamics**
Co-requisite	Basic Physics
Credits	L: 3 T:0 P:0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace Engineering
Name of Teacher	Dr. Sudip Das/Dr. Priyank Kumar

Course Objectives *This course aims to provide students with:*	
Sl No.	Objectives
1	Understand the basics of fluid flow, its model and tool to solve the fluid flow problems.
2	Describe and implement the elementary flows to combine and form realistic flows with assumptions.
3	Apply the basics of low speed flow over two-dimensional aerofoils and three dimensional wing structures
4	Implement basics of isolated high speed flows with shock waves
5	Implementation of viscous flows, boundary layers and their equations extending even to hypersonic flows

Course Outcomes (COs)

Upon successful completion of the course, students will be able to

CO	Course Outcomes
1	Describe fundamental principles of the fluid flow
2	Solve Inviscid, incompressible and irrotational flows.
3	Theoretically evaluate and relate flows over 2D aerofoils and 3D wings.
4	Solve basic flow across one-dimensional and two-dimensional shock waves.
5	Use the viscous consideration in a flow, leading to corelate different boundary layer thickness and boundary layer equations.

Syllabus

Module No.	*Module name*	*Detailed Contents*	*No. of Lecture*
1	Fundamental Principles	Continuity and Momentum Equations; Application of Momentum Equation for the Estimation of Drag of a Two- dimensional Body; Energy Equation, Substantial Derivatives; Pathlines and Streamlines of a Flow; Angular Velocity, Vorticity and Strain; Circulation; Stream Function; Velocity Potential.	8
2	Inviscid Flows	Flow Measuring Device – Pitot Tube; Laplace's Equation; Source Flow, Source- Sink Flows, Doublet Flow, Non- lifting Flow over a Circular Cylinder; Vortex Flow; Lifting Flow over a Cylinder; Kutta – Joukowski Theorem and the Generation of Lift; Numerical Source Panel Method, Vortex Panel Method; Kutta- Joukowski Transformation.	8
3	Incompressible Flows (Aerofoils and Wings)	Aerofoil Nomenclature and Aerofoil Characteristics; Vortex Sheet Method; Kutta's Conditions; Kelvin`s Circulation Theorem and Starting Vortex; Classical Thin Aerofoil Theory; Downwash and Induced Drag; The Vortex Filament, Biot- Savart Law, Helmholtz`s Vortex Theorem; Prandtl's Classical Lifting Line Theory;	8
4	Compressible Flows	Normal Shock; Pressure, Temperature, Density and Entropy Relations across a Normal Shock; Shock Strength; Rarefaction Shock an Impossibility; Hugoniot Equation; Source of Oblique Shock Waves; Mach Wave; Mach Cone; Oblique Shock Relations for Pressure, Temperature and Mach Number.	8
5	Viscous Flows	Boundary Layer and its characteristics; Displacement Thickness; Momentum Thickness and Energy Thickness; Skin friction; Hypersonic flow and its limits; Newton Sine square law; Interaction of thermal and velocity boundary layer in hypersonic flow	8

Learning Resources	
Text Books	***Reference Books***
3. Fundamentals of Aerodynamics – Anderson, J. D. (T1) 4. Aerodynamics for Engineering Students – Houghton, E. L. and Carpenter, P. W. (T2)	4. Boundary Layer Theory – Schlichting, H. **(R1)**

Gaps in the Syllabus (to meet Industry/Profession requirements)	1) Unsteady flows 2) Numerical solutions of viscous flows
Pos met through Gaps in the Syllabus	PO3, PO5, PO6
Topics beyond syllabus/Advanced topics/Design	1) Transonic flows
Pos met through Topics beyond syllabus/Advanced topics/Design	PO6

Course Outcome (Co) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	Assignment(s)	10%				
	Seminar before a Committee	10%				
	Assessment Components	***CO1***	***CO2***	***CO3***	***CO4***	***CO5***
	Continuous Internal Assessment					
	Semester End Examination					

Indirect Assessment	Student Feedback on Faculty
	Student Feedback on Course Outcome

Mapping Between Course Outcomes and Program Outcomes						
CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	-	-	1	2	2	-
CO2	3	-	2	1	1	-
CO3	2	3	-	3	3	2
CO4	3	2	3	1	2	3

CO5	1	3	3	1	2	3

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 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 Designers		
Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

COURSE INFORMATION

Course code	**SR 513**
Course title	**Applied Mathematics**
Pre-requisite(s)	
Co-requisite	
Credits	L: 3 T:0 P:0 SL: 0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace
Name of Teacher	Dr. Partha Mondal

Course Objectives

This course aims to provide students with:

Sl No.	Objectives
1.	To know the basic concepts of solving algebraic and transcendental equations, solution methods of linear systems.
2.	To learn the numerical techniques of interpolation in various intervals and lesat squares curve fitting procedures.
3.	To apply the numerical techniques for differentiation and integration.
4.	To know the various techniques and methods of solving ordinary differential equations.
5.	To apply the various techniques and methods of solving various types of partial differential equations.

Course Outcomes (COs) *Upon successful completion of the course, students will be able to*	
CO	Course Outcomes
1.	know the basic concepts and techniques of solving algebraic and transcendental equations, solution of linear systems of equations.
2.	Understand the numerical techniques of interpolation in various intervals and least squares curve fitting procedures in real life situations.
3.	Apply the numerical techniques of differentiation and integration for engineering problems.
4.	Know the various numerical techniques and methods for solving first and second order ordinary differential equations.
5.	Apply the various numerical techniques and methods for solving partial differential equations with engineering applications.

Syllabus

Module No.	*Module name*	*Detailed Contents*	*No. of Lecture*
1	**Solution of Equations and Eigenvalue Problem**	Solution of Algebraic and Transcendental Equations - Bisection Method, Method of False Position, Iteration Method, Newton-Raphson Method, Secant Method, Direct Methods for Solution of Linear Systems - Gauss Elimination, Gauss–Jordan Method, LU Decomposition Method, Iterative Methods for Solution of Linear Systems - Jacobi Method, Gauss-Seidel Method; Solution of Non-Linear Simultaneous Equations; Matrix Eigenvalue Problem.	8
2	**Interpolation and Curve Fitting**	Finite Differences, Newton's Formulae for Interpolation, Central Difference Interpolation Formulae, Gauss's Forward and Backward Interpolation Formulae, Stirling's Formula, Bessel's Formula, Interpolation with Unevenly Spaced Points - Lagrange's Interpolation Formula; Divided Differences and Their Properties; Cubic Splines, Least Squares Curve Fitting Procedures.	8
3	**Numerical Differentiation and Integration**	Numerical Differentiation, Numerical Integration - Trapezoidal Rule, Simpson's 1/3-Rule, Simpson's 3/8-Rule, Boole's rule, Weddle's rule, Newton-Cotes Integration Formulae, Gaussian Integration, Numerical Double Integration.	8
4	**Numerical Solution of Ordinary Differential Equations**	Taylor's Series Method, Picard's Method, Euler's Method, Modified Euler's Method, Runge-Kutta Methods, Adams-Moulton and Milne's Predictor-Corrector Methods, Simultaneous First Order Differential Equations, Second Order Differential Equations, Boundary-value Problems, Finite-Difference Method.	8
5	**Numerical Solution of Partial Differential Equations and Linear Programming**	Classification of Second Order Equations, Finite Difference Approximations to Derivatives, Solution of Laplace's Equation, Solution of Poisson's Equation, Solution of One Dimensional Heat Equation, Solution of Wave Equation, Linear Programming.	8

Learning Resources	
Text Books	**_Reference Books_**
1. S. S. Sastry, "Introductory Methods of Numerical Analysis", 5 th Edition, PHI Learning Pvt. Ltd, 2015.	1. B. S. Grewal, and J. S. Grewal, "Numerical Methods in Engineering and Science", Khanna Publishers, 10 th Edition, New Delhi, 2015.
2. S. D. Conte and Carl de Boor, "Elementary Numerical Analysis - An Algorithmic Approach", 3rd edition, McGraw-Hill, 1981.	2. K. E. Atkinson, "An Introduction to Numerical Analysis", 2nd edition, Wiley-India, 1989.

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 and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	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

Mapping Between Course Outcomes and Program Outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	2	1	1	3
CO2	3	2	3	2	2	3
CO3	3	3	3	2	2	3
CO4	2	1	2	1	1	3

CO5	3	2	3	2	-	3

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 (SL) such as use of NPTEL materials and internets
CD7	Simulation

Mapping Between Course Outcomes and Course Delivery Method	
Course Outcomes	**Course Delivery Method**
CO1	CD1,CD2,CD6
CO2	CD1,CD2,CD6
CO3	CD1,CD2,CD6
CO4	CD1,CD2,CD6
CO5	CD1,CD2,CD6

Course Designers

Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

COURSE INFORMATION

Course code	**SR 26527**
Course title	**Aerospace Structures**
Pre-requisite(s)	**Solid Materials**
Co-requisite	Physics & Mathematics
Credits	L: 3 T:0 P:0 SL: 0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace Engineering
Name of Teacher	

Course Objectives *This course aims to provide students with:*	
Sl No.	Objectives
1.	Introduce the fundamentals of aircraft structural components, materials, loads, and area properties necessary for basic structural analysis.
2.	Analyse the stress–strain behaviour, deformation, and elastic response of materials in 2D and 3D under various loading conditions.
3.	Interpret energy methods, virtual work principles, and variational approaches for evaluating structural response under different loading conditions.
4.	To understand airframe loads, bending behavior, shear stress, and structural response of aircraft components.
5.	To introduce vibration and aeroelastic phenomena in aerospace structural systems.

Course Outcomes (COs) *Upon successful completion of the course, students will be able to*	
CO	Course Outcomes
1.	To identify aircraft structural components, material types, and basic sectional properties relevant to structural analysis.
2.	To analyse stress, strain, deformation, and elastic behaviour of materials under various loading conditions.
3.	To determine structural displacements and responses using strain energy, virtual work, and variational principles.
4.	Explain airframe loads, beam bending, shear force, bending moment, and structural deflection concepts.
5.	Analyze vibration characteristics and aeroelastic phenomena such as divergence and flutter in aerospace structures.

Syllabus

Module No.	*Module name*	*Detailed Contents*	*No. of Lecture*
1	**Introduction to Aerospace Structures and Materials:**	Introduction to aircraft structures; Basic structural components - wing, fuselage, fins, shell, motor casing, missile body etc; Aircraft material – Wood, Steel, Aluminum alloy, Titanium alloy, Composite materials; Loads on structural components; V-n diagrams; Area properties – Center of gravity, First moment of area, Second moment of area; Calculation of sectional properties	6
2	**Elasticity:**	Stress, St. Venant's Principle, Equation of equilibrium, Determination of stresses on inclined planes, principal stress, principal strain, Mohr's circle of stress, Plane stress, Plane strain; Concept of deformation and displacement, Strain, Compatibility equations, Determination of strains on inclined planes, principal strain; 3D Stress-Strain relationship for linear elastic material - Anisotropic, Orthotropic, specially orthotropic, isotropic material; Temperature effects. Stress-strain relationship for 2D problems; Temperature effects. Stress-strain relationship for 2D problems.	10
3	**Energy Approach:**	Strain energy, Strain energy due to axial bending and torsional loads, Castigliano's theorem, Work, Potential energy, Principle of minimization of total potential energy, Principle of superposition, Maxwell reciprocal theorem, Virtual work, Internal and external virtual work, Principle of virtual work. Variational method.	8
4	**Airframe Loads, Bending and Flexural Shear:**	Airworthiness, Factor of safety, Flight envelope. Aircraft inertia loads, symmetric maneuver loads; Derivation of Simple Beam Equation, Unsymmetric Bending. Load intensity, shear force and bending moment relationships. Bending moment and shear force diagram.; Deflection due to bending; Transverse shear stress due to transverse force in symmetric section.	8
5	**Introduction to Vibration and Aeroelasticity**	Introduction, Degrees of freedom, Elements of vibratory system – Mass, Spring, Damper, Equation of motion for single-degree of freedom (SDOF), Viscous damping, Critical damping, Over damping, Under damping, equivalent systems; Static and dynamic aero elastic phenomenon, Critical speeds, Divergence and reversal of aileron control, flutter and buffeting.	8

Learning Resources	
Text Books	***Reference Books***
1. Aircraft Structures for Engineering Students, T.H.G. Megson, 4th Ed., Elsevier Ltd, 2012	Aircraft structures, D.J.Peery, McGraw Hill, 1950
2. Mechanics of aircraft structures: C.T.Sun, 3rd Ed , John Wiley publishers, 1998	Vibration Engineering by G. K. Grover, Nem Chand & Bros., Roorkee, 8th Edition, 2019.

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 and Evaluation Procedure

Direct Assessment

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

Continuous Internal Assessment	***% Distribution***
Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%
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

Mapping Between Course Outcomes and Program Outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	2	1	1	2
CO2	1	1	3	1	2	2
CO3	3	2	3	2	2	3
CO4	3	2	3	2	2	3

CO5	2	1	2	2	1	2

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 (SL) such as use of NPTEL materials and internets
CD7	Simulation

Mapping Between Course Outcomes and Course Delivery Method	
Course Outcomes	**Course Delivery Method**
CO1	CD1,CD2,CD6
CO2	CD1,CD2,CD6
CO3	CD1,CD2,CD6
CO4	CD1,CD2,CD6

CO5	CD1,CD2,CD6

Course Designers		
Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

COURSE INFORMATION

Course code	**SR26503**
Course title	**Guidance, Navigation and Control**
Pre-requisite(s)	**Control Systems**
Co-requisite	Physics and Mathematics
Credits	L: 3 T:0 P:0 SL: 0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace
Name of Teacher	Dr. Priyank Kumar

Course Objectives *This course aims to provide students with:*	
Sl No.	Objectives
	To introduce the fundamental concepts and architecture of guidance, navigation, and control systems used in aerospace vehicles.
	To develop the ability to model and analyze dynamic systems relevant to aerospace applications.
	To provide knowledge of stability and control characteristics of flight systems.
	To familiarize students with classical control techniques and their application in aerospace systems.
	To expose students to basic principles of guidance laws and navigation systems.

Course Outcomes (COs) *Upon successful completion of the course, students will be able to*	
CO	Course Outcomes
	Model dynamic systems using state-space and transfer function approaches.
	Analyze stability and dynamic response characteristics of aerospace systems.
	Design basic feedback controllers (e.g., PID) for aerospace applications.
	Interpret fundamental guidance laws and navigation system principles.
	Implement simple control and guidance simulations using computational tools.

Syllabus

Module No.	*Module name*	*Detailed Contents*	*No. of Lecture*
1	Introduction to orbital Mechanics	Orbits, trajectories, Kepler's laws of motion orbital velocities, escape velocity, staging of rockets, atmosphere, interplanetary missions,	6
2	**Introduction to GNC & System Modeling**	Overview of guidance, navigation and control functions in aerospace systems, system architecture including sensors, actuators and feedback loops, classification of open- and closed-loop systems, linearization of nonlinear systems and state-space representation, fundamentals of guidance and navigation with distinction from control, basic guidance laws including pursuit and proportional navigation, concepts of trajectory tracking, overview of navigation systems such as IMU and GPS, sensor errors, drift and basic state estimation concepts.	10
3	**Flight Dynamics & Stability**	Equations of motion for aerospace vehicles with longitudinal and lateral-directional dynamics, development of simplified dynamic models, concepts of static and dynamic stability, modes of motion including phugoid and short-period, interpretation of stability derivatives and flight stability characteristics.	8
4	**Control System Fundamentals**	Fundamentals of feedback control systems, block diagram representation and transfer function modeling, analysis of time response characteristics, concepts of stability, application of Routh-Hurwitz criterion and basic interpretation of root locus.	8
5	**Control Design & Implementation**	Design of feedback controllers including P, PI, PD and PID control, tuning methods and steady-state error analysis, introduction to compensators, evaluation of closed-loop performance and techniques for response improvement.	8

Learning Resources

Text Books	*Reference Books*
1. Modern Control Engineering Author: Katsuhiko Ogata Edition: 5th Edition Publisher: Prentice Hall Year: 2010	Missile Configuration Design Author: Shyh S. Chin Publisher: McGraw-Hill Year: 1961

ISBN: 978-0136156734	
2. Flight Stability and Automatic Control Author: Robert C. Nelson Edition: 2nd Edition Publisher: McGraw-Hill Year: 1998 ISBN: 978-0070462731	Modern Inertial Technology Navigation, Guidance, and Control Anthony Lawrence Mechanical Engineering Series eBook ISBN 978-1-4612-1734-3, 2012

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 and Evaluation Procedure

<table>
<tr><td rowspan="12">Direct Assessment</td><td>Assessment Tool</td><td colspan="5">% Contribution during CO Assessment</td></tr>
<tr><td>Continuous Internal Assessment</td><td colspan="5">50%</td></tr>
<tr><td>Semester End Examination</td><td colspan="5">50%</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td>Continuous Internal Assessment</td><td colspan="5">% Distribution</td></tr>
<tr><td>Best 2 Quiz marks out of 3 Quizzes of 15 marks each.</td><td colspan="5">30%</td></tr>
<tr><td>Assignment(s)</td><td colspan="5">10%</td></tr>
<tr><td>Seminar before a Committee</td><td colspan="5">10%</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td>Assessment Components</td><td>CO1</td><td>CO2</td><td>CO3</td><td>CO4</td><td>CO5</td></tr>
<tr><td>Continuous Internal Assessment</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Semester End Examination</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Indirect Assessment</td><td colspan="6"></td></tr>
<tr><td colspan="6"></td></tr>
</table>

<table>
<tr><td colspan="7">Mapping Between Course Outcomes and Program Outcomes</td></tr>
<tr><td>CO</td><td>PO1</td><td>PO2</td><td>PO3</td><td>PO4</td><td>PO5</td><td>PO6</td></tr>
<tr><td>CO1</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>CO2</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>CO3</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>CO4</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>CO5</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="7"></td></tr>
</table>

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 (SL) such as use of NPTEL materials and internets
CD7	Simulation

Mapping Between Course Outcomes and Course Delivery Method	
Course Outcomes	**Course Delivery Method**
CO1	
CO2	
CO3	
CO4	
CO5	

Course Designers		
Experts from Industry	*Experts from Higher Technical Institutions*	*Internal Experts*

COURSE INFORMATION SHEET

Course code: SR 26506

Course title: Aerospace Engineering Laboratory

Pre-requisite(s): NA

Co- requisite(s): NA

Credits: L: T:0 P:3

Class schedule per week: 3

Lectures **Class:** M.Tech

Semester / Level: II/ 5

Branch: Aerospace

Name of Teacher: Sudip Das / Rajiv Kumar / Shelly Biswas / Pawan Ojha

Course Objectives

This course enables the students to:

1.	Understand the significance of the experiments to compliment theoretical information.
2.	Collect and interpret data obtained from various experiments.
3.	Examine the results individually or in a group and evaluate it to prepare the report.
4.	Have hands down experience of processing, assembly and use of instrumentation
5.	Recognize and follow various safety precautions required during the experimentations

Course Outcomes

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

CO1	Operate the wind tunnel and estimate basic parameters from the subsonic and supersonic wind tunnel.
CO2	Do work pertaining to calibration and setup of electronic balance, pressure sensor and free jets.
CO3	Carry out the solid propellant processing with different ingredients and evaluate burn rates.
CO4	Explain the significance of ignition delay and determine it using experimental techniques.
CO5	Perform hardness and impact testing of engineering materials for mechanical properties and evaluate the effect of bending moment and shear force

List of the Experiments

Experiment No. 1

Name: Introduction to Subsonic Wind Tunnel

Objective: Emphasis on the following techniques

a) Contraction ratio estimate and use of Bernoulli's equation
b) Static Pressure measurement using manometer
c) Velocity Measurement using pitot probe
d) Flow visualization concept

Experiment No. 2

Name : Introduction to Supersonic Wind Tunnel

Objective: a) Convergent Divergent nozzle concept
b) Flow visualization concept
c) Pitot pressure measurement and use of Rayleigh pitot tube formulae
d) Estimation of Mach number at the test section

Experiment No. 3

Name: Calibration of pressure transducers

Objective: a) Low range sensors used for subsonic tunnel use
b) High range sensors used for supersonic tunnel use

Experiment No. 4

Name: Supersonic Free Jet

Objective: a) Running of free jet at various Nozzle Pressure Ratios
b) Streamwise pressure distribution along centerline of jet
c) Jet flow characteristics through flow visualisation

Experiment No. 5

Name: Preparation of Composite Solid Propellant with and without Burn Rate Modifiers

Objective: To prepare composite solid propellants with and without additives at given oxidizer/fuel ratio.

Experiment No. 6

Name: Ignition delay of Liquid Bipropellant Systems

Objective: To determine the ignition delay of the conventional liquid bi-propellant system with and without Catalyst

Experiment No. 7

Name: Effect of Additives on Burn Rate of Solid propellants

Objective: To determine the burn rates of composite solid propellant prepared with and without additives at a given oxidizer/fuel ratio.

Experiment No. 8

Name: Flame Propagation and Burning Velocity measurement

Objective: To study the burning velocity of premixed flames at various air/fuel ratio using
Hilton's Flame Stability Unit.

Experiment No. 9

Name: Tensile Testing of a Given Specimen using Universal Testing Machine (UTM)

Objective: To determine the mechanical properties of the material, including Young's modulus, ultimate tensile strength, breaking stress, percentage elongation, and toughness, through tensile testing.

Experiment No. 10

Name: Preparation of Natural Fiber Reinforced Polymer Composite using Jute Fibers and Polyester Resin

Objective: a) Introduction to natural fiber reinforced polymer composite materials and their aerospace applications

b) Fabrication of jute fiber reinforced polyester resin composite using hand lay-up technique

c) Study of fiber–matrix interaction and curing characteristics of the composite material

d) Understanding the mechanical behavior and applications of natural fiber composites in lightweight structural components

Experiment No. 11

Name: Find Bending moment and shear force at the cut-section

Objective: Determine the bending moment and shear force at the cut-section by applying various load

Experiment No. 12

Name: Flutter and Divergence Demonstration using a Flexible Wing Spar Model

Objective: a) Introduction to aeroelastic phenomena such as flutter and structural divergence

b) Experimental demonstration of flutter and divergence behavior using a flexible wing spar model

c) Observation of the effect of airflow velocity on structural stability and vibration response

d) Identification of critical flutter/divergence conditions through experimental measurements

e) Understanding the importance of aeroelastic stability in aerospace structural design

References :

1. High Speed Wind Tunnel Testing By Alan Pope And Kennith L. Goin
2. Schlieren And Shadowgraph Techniques By G.S.Settles
3. G. P. Sutton and O. Biblarz, Rocket Propulsion Elements, 7thEd. John Wiley & Sons, Inc., New York, 2001.
4. K. Ramamurthy, Rocket Propulsion, 2nd Edition, Trinity Press of Laxmi Publications Private Limited, India, 2016.
5. Aircraft Structures for Engineering Students, T.H.G. Megson, 4th Ed., Elsevier Ltd, 2012.
6. Aero-Elasticity. Raymond L. Bisplinghoff, Holt Ashley and Robert L. Halfman. Addison Wesley Publishing Co. Inc., Cambridge,

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

POs met through Gaps in the Syllabus

PO1, PO4, PO5

Topics beyond syllabus/Advanced topics/Design

POs met through Topics beyond syllabus/Advanced topics/Design

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

If satisfying and < 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, CD3, CD6
CO3	CD1, CD2, CD3
CO4	CD1, CD3, CD4, CD6
CO5	CD3, CD5

COURSE INFORMATION SHEET

Course code: SR 26507

Course title: Aerospace Instrumentation and Simulation Lab

Pre-requisite(s): NA

Co- requisite(s): NA

Credits: L:2 T:0 P:0

Class schedule per week: 02 Class: M.Tech

Semester / Level: I/05 Branch: SER

Name of Teacher:

Course Objectives: This course enables the students to:

1.	To provide knowledge of modern manufacturing and additive manufacturing techniques for aerospace applications.
2.	To develop understanding of sensors, data acquisition, and signal analysis methods.
3.	To study flow visualization, diagnostics, and experimental techniques in aerospace engineering.
4.	To introduce computational methods for grid generation and CFD-based flow simulation.
5.	To develop practical understanding of embedded systems, motor control, and shock wave analysis.

Course Outcomes

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

1.	Carry out fabrication of components using CNC, laser machining, and additive manufacturing techniques.
2.	Perform sensor interfacing, data acquisition, and signal analysis using modern instrumentation systems.
3.	Explain flow visualization, flow diagnostics, and experimental fluid analysis techniques.
4.	Generate computational grids and perform CFD simulations using commercial software.
5.	Carry out experiments on motor control systems and shock wave propagation analysis.

List of Experiments

1. Experiment No. 1

Name:

Design and Fabrication of 2D/3D Components using CNC and Laser Engraving Systems

Object:
a) Creation of 2D and 3D component geometry using software
b) Generation of tool path and machining parameters for CNC and laser systems
c) Fabrication and engraving of components using CNC machining and laser cutting/engraving machines
d) Study of machining accuracy, surface finish, and dimensional inspection of fabricated components

2. Experiment No. 2

Name:
Additive Manufacturing of Components using FDM and SLA Based 3D Printing Technologies

Object:
a) Preparation of CAD models and slicing for additive manufacturing processes
b) Study and Fabrication of components using FDM and SLA based 3D printing systems
d) Comparison of surface finish, dimensional accuracy, and build quality of printed components

3. Experiment No. 3

Name:
Data Acquisition and Sensor Interfacing using NI DAQ and Arduino Board

Object:
a) Introduction to NI DAQ and Arduino-based data acquisition systems
b) Interfacing of sensors and transducers with NI DAQ and Arduino boards
c) Measurement and acquisition of real-time sensor data using data acquisition software
d) Signal conditioning, analog-to-digital conversion, and data visualization techniques

4. Experiment No. 4

Name:
Study of Various Sensors, Data Acquisition and Signal Analysis Techniques

Object:
a) Introduction to various sensors and transducers used in aerospace applications
b) Interfacing of sensors with data acquisition systems for real-time measurements
c) Measurement and acquisition of parameters such as temperature, pressure, displacement, and vibration
d) Understanding the applications of sensors and data acquisition systems in aerospace instrumentation and monitoring

5. Experiment No. 5

Name:
High-Speed Camera Based Flame Visualization and Flow Analysis

Object:
a) Introduction to high-speed imaging techniques for combustion and flow visualization
b) Application of high-speed camera systems for flame visualization experiments
c) Recording and analysis of transient flame propagation and flow behavior
d) Image acquisition, frame analysis, and visualization of combustion phenomena

6. Experiment No. 6

Name:
Flow Diagnostics and Visualization Techniques for Aerospace Applications

Object:
a) Introduction to flow diagnostic methods used in aerodynamic and propulsion studies
b) Application of flow visualization techniques for identification of flow patterns and characteristics
c) Measurement and analysis of flow parameters using diagnostic instruments and sensors
d) Visualization of laminar, turbulent, and separated flow phenomena

7. Experiment No. 7

Name:
Computational Grid Generation and Mesh Development for Aerospace Applications

Object:
a) Introduction to computational grid generation techniques used in numerical simulations
b) Creation of structured and unstructured meshes for aerospace geometries
c) Study of mesh quality parameters and grid refinement techniques
d) Generation and visualization of computational domains for CFD analysis
e) Understanding the importance of computational grids in aerospace flow and structural simulations

8. Experiment No. 8

Name: Flow Simulation and Analysis using Commercial CFD Software

Objective:
a) Introduction to computational fluid dynamics (CFD) and commercial simulation software
b) Pre-processing of aerospace geometries and definition of flow boundary conditions
c) Simulation of fluid flow behavior around aerospace configurations using CFD tools
d) Post-processing and analysis of flow parameters such as pressure, velocity, and streamlines
e) Understanding the applications of CFD simulation techniques in aerospace design and analysis

9. Experiment No. 9

Name:
Measurement of Fluid Viscosity using Viscometer

Object:
a) Introduction to viscosity measurement techniques and viscometer operation
b) Measurement of dynamic and kinematic viscosity of fluids using a viscometer
c) Study of the effect of temperature on fluid viscosity characteristics

10. Experiment No. 10

Name:
Thermal and Rheological Analysis of Engineering Materials

Object:
a) Introduction to thermal and rheological characterization techniques for engineering materials
b) Study of rheological behavior and flow characteristics of materials
c) Data acquisition and interpretation of thermal and rheological response parameters

11. Experiment No. 11

Name:
Develop a stepper motor drive and servo mechanism

Object:
a) To understand the operation and control of stepper motor drive and servo mechanisms using embedded systems.
b) To develop and analyze motion control techniques for precision positioning and actuation applications.

12. Experiment No. 12

Name:
Estimation of shock speed using shock tube

Object:
a) To study the generation and propagation of shock waves in a shock tube.
b) To estimate the shock wave speed using experimental measurements and pressure data analysis.

Reference books:

1. Computational Fluid Dynamics: The Basics with Applications by John D. Anderson Jr.
2. Theory and Design for Mechanical Measurements by Richard S. Figliola and Donald E. Beasley
3. Mechanical Measurement and Instrumentation by R. K. Rajput

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

POs met through Gaps in the Syllabus

PO1, PO4, PO5

Topics beyond syllabus/Advanced topics/Design

POs met through Topics beyond syllabus/Advanced topics/Design

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

If satisfying and < 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, CD3, CD6
CO3	CD1, CD2, CD3
CO4	CD1, CD3, CD4, CD6
CO5	CD3, CD5

Department of Space Engineering and Rocketry
Birla Institute of Technology, Mesra, Ranchi - 835215 (India)

M. Tech. in Aerospace Engineering

Second Semester

Specialization: Aerodynamics

COURSE INFORMATION

Course code	**SR 26508**
Course title	**Aerodynamic Stability and Control**
Pre-requisite(s)	**Fundamentals of Aerodynamics**
Co-requisite	
Credits	L: 3 T:0 P:0 SL: 0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace
Name of Teacher	Dr. Partha Mondal

Course Objectives *This course aims to provide students with:*	
Sl No.	Objectives
1.	Understand the basics of flight dynamics and classifications.
2.	Understand and apply the concept of static stability on the aerospace vehicles.
3.	Recognize the behaviour of aerospace vehicle in a flow with respect to time.
4.	Comprehend the basics of the control systems related to the flight control
5.	The understand the reliability and failure concepts pertaining to the aerospace vehicles

Course Outcomes (COs) *Upon successful completion of the course, students will be able to*	
CO	Course Outcomes
CO1.	Describe the forces and moments over an aerospace vehicle.
CO2.	Analyzing the static stability on an aerospace vehicle.
CO3.	Examining the behaviour of disturbed flight w.r.t. time.
CO4.	Realizing and applying the concept of control system to aerospace vehicles.
CO5.	Apply the concept of reliability engineering to aerospace vehicles.

Syllabus

Module No.	***Module name***	***Detailed Contents***	***No. of Lecture***
1	**Introduction**	Missile Aerodynamics Versus Airplane Aerodynamics; Classification of missiles, Axes and angles, Aerodynamic characteristics of rectangular and triangular lifting surfaces on the basis of supersonic wing theory, Types of missile design and control, Aerodynamic characteristics of airframe components.	8
2	**Static Stability**	Introduction to Six Degrees of Freedom; Forces and Moments for Two Degrees of Freedom; Longitudinal Stability, Stick-fixed and Stick-free Static Stability, Contribution of Different Components in Longitudinal Stability, Neutral Point and Static Margin; Load factor, Maneuvering flight, Directional stability, Contribution of Different Components in Directional Stability, Lateral stability, Contribution of Different Components in Lateral Stability.	8
3	**Dynamic Stability**	Basic Concept, Fundamental of Dynamics: Eigen Problems, Oscillatory and Non-Oscillatory Motion; Short-Period Oscillation and Phugoid Motion, Damping in Yaw, Damping in Roll, Strip Theory, Directional and Spiral Divergences, Dutch Roll, Autorotation, The Spin, Effect of Various Control Surfaces.	8
4	**Controls**	Different Types of Disturbances, Time- to- Half; Time- to- Double; Active and Passive Controls; Open Loop and Closed Loop Controls; Feed back, Types of Feed back, Time Domain Analysis, Frequency Domain Analysis, Nyquist criterion, Response, Staging of Missile and rockets, it's advantages and disadvantages.	8
5	**Performance**	Introduction to Reliability; Theories of Reliability, Estimation of reliability and it's importance, Accuracy; Safety of Aircraft, Missiles, Rockets, Description and necessity of Launcher & launch complex, Safety aspects for different launchers and Associated Problems.	8

Learning Resources	
Text Books	***Reference Books***
1. Aerodynamics for Engineering Students – Houghton, E. L. and Carruthers, N. B.	1. Fundamentals of Aerodynamics – Anderson, J. D.
2. Airplane Performance, Stability & Control – Perkins, C. D. and Hege, R. E.	
3. Aerodynamics – Clancy, L. J., Sterling Book House, 2006.	
4. Missile Aerodynamics – Chin, S. S.	
5. Automatic Control system – B. C. Kuo	
6. Reliability Engineering - Alessandro Birolini	

Gaps in the Syllabus (to meet Industry/Profession requirements)	1. Design of aerospace vehicles **2.** Failure analysis
Pos met through Gaps in the Syllabus	PO1, PO4
Topics beyond syllabus/Advanced topics/Design	**1.** Design of control system in stability of aerospace vehicles
Pos met through Topics beyond syllabus/Advanced topics/Design	PO1, PO3

Course Outcome (Co) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	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

Mapping Between Course Outcomes and Program Outcomes

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	-	-	3	1	-	2
CO2	2	-	3	2	-	2
CO3	1	1	3	2	1	1
CO4	1	1	3	2	1	2

CO5	3	1	3	2	3	2

Mapping Between Course Outcomes and Course Delivery Method

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 (SL) such as use of NPTEL materials and internets
CD7	Simulation

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 Designers

Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

COURSE INFORMATION

Course code	**SR 26579**
Course title	**Experimental Aerodynamics**
Pre-requisite(s)	**Engineering Mathematics, Fluid dynamics**
Co-requisite	NA
Credits	L: 3 T: 0 P: 0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace
Name of Teacher	Dr. Sudip Das

Course Objectives
This course aims to provide students with:

Sl No.	Objectives
1	To understand the basics of Wind Tunnel and its components with specific
2	orientation to its operation.
3	To describe and implement the different wind tunnel measurement techniques
4	adopted recently and in the past.
5	To understand the basics of advanced flow diagnostic systems with knowledge

Course Outcomes (COs)
Upon successful completion of the course, students will be able to

CO	Course Outcomes
1	Describe wind tunnels and their components.
2	Organise in performing experiments using wind tunnel measurement techniques which are in practice.
3	Demonstrate the advanced measurement techniques for wind tunnel tests.
4	Implement the unsteady flow measurements with possible recognition to its stochastic behaviour and analysis.
5	Perform experiments with advanced data acquisition system with good level of confidence and minimal error.

Syllabus

Module No.	***Module name***	***Detailed Contents***	***No. of Lecture***
1	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
2	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
3	Pressure, Velocity, Force and Moment Measurement	Pitot Static Probe; Laser Doppler Velocimeter; Water and Mercury Manometers; Principle of Pressure Transducer; Different Types of Pressure Transducers; Electronic Pressure Scanner; Pressure Sensitive Paint; Definition of Forces and Moments on Aerospace Vehicles; Major Components for Force and Moment Measuring Systems.	8
4	Unsteady Measurement	Introduction to Unsteady data and turbulence; Basic Principle of Hot Wire Anemometer; Measurement of Unsteady parameters Using Hot Wire Anemometers, calibration; Single and Multiple Hot Wire Probes, directional aspects of hot wire; Basic Principles of Unsteady Pressure Transducers; Calibration of Steady and Unsteady Pressure Transducers.	8
5	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

Learning Resources	
Text Books	***Reference 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)	1. 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)	1) Emphasis on data analysis 2) 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	1) Elaborate studies on PIV instrumentation and data interpretation 2) Compressible boundary layer measurement techniques
Pos met through Topics beyond syllabus/Advanced topics/Design	PO4, PO5, PO6

Course Outcome (Co) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	Assignment(s)	10%				
	Seminar before a Committee	10%				
	Assessment Components	***CO1***	***CO2***	***CO3***	***CO4***	***CO5***
	Continuous Internal Assessment					
	Semester End Examination					

Indirect Assessment	Student Feedback on Faculty
	Student Feedback on Course Outcome

Mapping Between Course Outcomes and Program Outcomes						
CO	**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

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 Course Outcomes and Course Delivery Method

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

Course Designers

Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

COURSE INFORMATION

Course code	**SR 26578**
Course title	**Computational Fluid Dynamics**
Pre-requisite(s)	**Fluid Mechanics, Numerical Analysis**
Co-requisite	Nil
Credits	L: 3 T:0 P:0 SL: 0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace
Name of Teacher	Dr. Partha Mondal

Course Objectives

This course aims to provide students with:

Sl No.	Objectives
1.	Know classification of partial differential equations, finite difference method, stability analysis.
2.	Learn the solution methods of finite difference equations of elliptic, parabolic and hyperbolic partial differential equations.
3.	Apply the methods to solve finite difference equations
4.	Understand the numerical techniques to solve incompressible Navier-Stokes equations.
5.	Know the finite volume method and apply it for inviscid problems.

Course Outcomes (COs)

Upon successful completion of the course, students will be able to

CO	Course Outcomes
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 procedure to solve the Euler equations by finite volume method.

Syllabus

Module No.	*Module name*	*Detailed Contents*	*No. of Lecture*
1	**Introduction**	Computational Fluid Dynamics; Conservation Laws of Fluid Motion, Linear and Non-linear Partial Differential Equations, Classification of Partial Differential Equations; 2^{nd} order Partial Difference Equations, Model Equations: Elliptic Equation, Parabolic Equation and Hyperbolic Equation; System of 1^{st} order Partial Differential Equations; System of 2^{nd} order Partial Difference Equations; Initial and Boundary Conditions.	8
2	**Finite Difference Formulations**	Introduction; Taylor Series Expansion; Finite Difference by Polynomial; Finite Difference Equations; Higher Order Derivatives; Multidimensional Finite Difference Formulas; Finite Difference Approximation of Mixed Partial Derivatives; Stability Analysis; Von Neumann Stability Analysis; Modified Partial Differential Equations, Artificial Viscosity, Numerical Dissipation and Dispersion.	8
3	**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, Parabolic Equations – Finite Difference Formulations, Explicit Schemes, Implicit Schemes, Alternating Direction Implicit Schemes, Parabolic Equations in Two-space Dimensions, Fractional Step Methods; Hyperbolic Equations – Explicit and Implicit Schemes, Multistep Methods, Runge-Kutta Method, Modified Runge-Kutta Method, Flux Corrected Transport, Classification of Numerical Schemes (Monotone, TVD and ENO Schemes).	10
4	**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; Crank Nicolson Implicit Method; Staggered Grid; Marker and Cell Method; Use of the Poisson Equation for Pressure; The SIMPLE Algorithm.	10
5	**Euler Equations and Finite Volume Method**	Euler Equations, Finite Volume Method, Explicit and Implicit Procedures, Flux Vector Splitting, Flux Difference Splitting, Steger and Warming Flux Vector	8

		Splitting, Van Leer Flux Vector Splitting, Roe's Flux Difference Splitting, Runge-Kutta Formulation, Boundary Conditions; Global Time Step and Local Time Steps; Cell-centered and Vertex-Centered Schemes, Application – Diverging Nozzle Configuration, Shock Tube or Reimann Problem, Supersonic Channel Flow.	

Learning Resources	
Text Books	***Reference Books***
1. Hoffmann, K.A. and Chiang, S.T., Computational Fluid Dynamics (Vol. I & II), Engineering Education System, 2000.	1. Hirsch, C., Numerical Computation of Internal and External Flows (Vol. I & II), John Wiley and Sons, 1994.
2. Versteeg, H. K. and Malalasekera, W., An Introduction to Computational Fluid Dynamics: The Finite Volume Method, Pearson Education Limited, 2007	2. Anderson, John D., Computational Fluid Dynamics, McGraw-Hill, 1995.

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 and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	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

Mapping Between Course Outcomes and Program Outcomes

CO	**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

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 (SL) such as use of NPTEL materials and internets
CD7	Simulation

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 Designers

Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

COURSE INFORMATION

Course code	**SR 26576**
Course title	**Compressible Flows**
Pre-requisite(s)	**Engineering Mathematics, Fluid dynamics**
Co-requisite	NA
Credits	L: 3 T:0 P:0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace
Name of Teacher	Dr. Sudip Das

Course Objectives *This course aims to provide students with:*	
Sl No.	Objectives
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 (COs) *Upon successful completion of the course, students will be able to*	
CO	Course Outcomes
1	Solve high speed 1D flow situations either with isolated isentropic condition, friction, heat transfer and shock wave or the combination of them.
2	Compare the differences between steady and unsteady wave motions.
3	Solve oblique shock, expansion waves, combination of shock and expansion.
4	Relate the start / unstart problems at supersonic speeds for flow in diffuser ducts and intakes.
5	To appraise the transonic flows and its associated problems / solutions

Syllabus

Module No.	***Module name***	***Detailed Contents***	***No. of Lecture***
1	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; Shock waves, Rarefaction Shock an Impossibility; 1- D Flow with Heat Addition; 1- D Flow with Friction; Reyleigh and Fanno Lines.	8
2	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
3	Oblique Shock and Expansion Wave	Oblique shock waves; 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.	8
4	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.	8
5	Similarity rules and Transonic Flows	2D linearized flow(Velocity Potential equations, Pressure coefficient, subsonic flows), Prandtl-Glauert and Gothert rules, von Karman's rule; Physical and Theoretical Aspects of Transonic Flows; Example Solution of small Perturbation, full Velocity Potential Equations and Euler Equations	8

Learning Resources	
Text Books	***Reference Books***
3. Modern Compressible Flow – Anderson, John D. 4. Elements of Gas Dynamics – Liepmann, H. W. and Roshko, A. 5. Dynamics and Thermodynamics of Compressible Fluid Flow - Shapiro, A. H.	1. 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 and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	Assignment(s)	10%				
	Seminar before a Committee	10%				
	Assessment Components	***CO1***	***CO2***	***CO3***	***CO4***	***CO5***
	Continuous Internal Assessment					
	Semester End Examination					

Indirect Assessment	Student Feedback on Faculty
	Student Feedback on Course Outcome

Mapping Between Course Outcomes and Program Outcomes						
CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	2		2	2	-
CO2	3	-	2	1	-	2
CO3	3	3	3	2	1	2
CO4	1	3	2	-	1	3
CO5	1	2	-	1	-	3

Course Delivery Methods	
CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Tutorials/Assignments
CD3	Seminars
CD4	Mini projects/Projects
CD5	Laboratory experiments/teaching aids
CD6	Industrial/guest lectures
CD7	Industrial visits/in-plant training
CD8	Self- learning such as use of NPTEL materials and internets
CD9	Simulation

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 Designers		
Experts from Industry	*Experts from Higher Technical Institutions*	*Internal Experts*

COURSE INFORMATION

Course code	**SR 26581**
Course title	**Missile Aerodynamics**
Pre-requisite(s)	**Elements of Aerodynamics**
Co-requisite	Nil
Credits	L: 3 T:0 P:0 SL: 0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace
Name of Teacher	Dr. Partha Mondal

Course Objectives *This course aims to provide students with:*	
Sl No.	Objectives
1.	Understand the static stability of a missile.
2.	Learn the fundamental concept of dynamic stability and its characteristics of a missile.
3.	Analyze the air loads and component load distribution of a missile.
4.	Learn aerodynamic launching problems.
5.	Understand dispersion of a missile and its design consideration.

Course Outcomes (COs) *Upon successful completion of the course, students will be able to*	
CO	Course Outcomes
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 No.	***Module name***	***Detailed Contents***	***No. of Lecture***
1	**Introduction to Missiles and Static Stability**	Introduction, Classes of Missiles, Types of Design and Control, Aerodynamic Characteristics of Airframe Components, 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.	12
2	**Dynamic Stability**	Introduction, Fundamental of Dynamics: Eigen Problems, Oscillatory and Non-Oscillatory Motion, Equation of Motion for Six Degrees of Freedom, 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.	8
3	**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
4	**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
5	**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

Learning Resources	
Text Books	***Reference Books***

1. Missile Configuration Design, Chin, S. S., McGraw-Hill, 1982.	1. Fundamental of Aerodynamics, Anderson, John D., McGraw-Hill, 2001.
	2. Missile Aerodynamics, Jack N. Nielson, McGraw-Hill, 1960
	3. Aerodynamics – Clancy, L. J., Sterling Book House, 2006.

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 Outcome (Co) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	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

Mapping Between Course Outcomes and Program Outcomes						
CO	**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

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 (SL) such as use of NPTEL materials and internets
CD7	Simulation

Mapping Between Course Outcomes and Course Delivery Method	
Course Outcomes	**Course Delivery Method**
CO1	CD1,CD2,CD3
CO2	CD1, CD2,CD3,CD4
CO3	CD1, CD2,CD3
CO4	CD1, CD2
CO5	CD1, CD2

Course Designers		
Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

COURSE INFORMATION

Course code	**SR 26577**
Course title	**Boundary Layer Theory and Applications**
Pre-requisite(s)	**Aerodynamics**
Co-requisite	Physics and Mathematics
Credits	L: 3 T:0 P:0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace
Name of Teacher	Dr. Priyank Kumar

Course Objectives

This course aims to provide students with:

Sl No.	Objectives
1	To develop a fundamental understanding of boundary layer theory and the governing equations associated with viscous fluid flows over solid surfaces.
2	To analyze laminar boundary layer behavior using similarity solutions, integral methods, and thermal boundary layer concepts relevant to aerodynamic and heat transfer applications.
3	To understand the physics of turbulent boundary layers, transition mechanisms, separation phenomena, and the fundamentals of turbulence modeling used in engineering analysis and CFD.
4	To study compressible and high-speed boundary layer flows including aerodynamic heating, shock-boundary layer interaction, and hypersonic flow effects relevant to aerospace systems.
5	To introduce computational and experimental techniques for boundary layer analysis, enabling students to apply CFD tools and modern diagnostic methods for practical engineering and research problems.

Course Outcomes (COs) *Upon successful completion of the course, students will be able to*	
CO	Course Outcomes
1	Derive and apply boundary layer equations to analyze viscous flow behavior, skin friction, and drag characteristics over engineering surfaces.
2	Evaluate laminar boundary layer flows and heat transfer characteristics using analytical, similarity, and approximate solution methods.
3	Analyze turbulent boundary layer structures, transition processes, and separation phenomena using empirical relations and turbulence modeling approaches.
4	Investigate compressible and high-speed boundary layer effects including aerodynamic heating and shock-boundary layer interactions in aerospace applications.
5	Apply computational and experimental methods for boundary layer studies, including CFD-based near-wall analysis and flow diagnostic techniques for aerodynamic and propulsion systems.

Syllabus

Module No.	*Module name*	*Detailed Contents*	*No. of Lecture*
1	Fundamentals and Governing Framework	Concept of boundary layer, physical significance and historical development, scaling analysis and order-of-magnitude arguments, derivation of boundary layer equations from Navier–Stokes equations, boundary layer assumptions and simplifications, definitions of boundary layer thickness, displacement thickness and momentum thickness, skin friction coefficient and drag, von Kármán momentum integral equation, flow over flat plate and basic velocity profile characteristics.	8
2	**Laminar Boundary Layers and Similarity Solutions**	Blasius solution for laminar flow over flat plate, similarity transformation and similarity variables, Falkner–Skan solutions for pressure gradient flows, boundary layer behavior over wedges and curved surfaces, thermal boundary layer and energy equation, Pohlhausen method for approximate solutions, Reynolds analogy between momentum and heat transfer, effect of Prandtl number, laminar flow heat transfer correlations.	8
3	**Turbulent Boundary Layers and Modeling**	Transition from laminar to turbulent flow, structure of turbulent boundary layer, viscous sublayer, buffer layer and logarithmic region, law of the wall and velocity distribution, empirical correlations for skin friction coefficient, mixing length theory and eddy viscosity concept, introduction to turbulence modeling, basics of RANS equations, k–ε and k–ω models overview, boundary layer separation and reattachment, adverse pressure gradient effects.	8
4	**Compressible and High-Speed Boundary Layers**	Compressibility effects on boundary layer, transformation methods for compressible flows, Crocco–Busemann relation, recovery factor and adiabatic wall temperature, compressible laminar and turbulent boundary layers, heat transfer in high-speed flows, shock-boundary layer interaction, separation in supersonic flows, introductory concepts of hypersonic boundary layers and aerodynamic heating.	8
5	**Computational and Experimental Methods in Boundary Layers**	Numerical solution of boundary layer equations, discretization approaches and solution techniques, introduction to CFD for boundary layer flows, near-wall treatment and y-plus concept, wall functions and low Reynolds number models, grid generation for boundary layer resolution, experimental techniques including	8

		hot-wire anemometry and Pitot probes, particle image velocimetry basics, flow visualization methods such as Schlieren and smoke techniques, case studies involving airfoils, jets and turbomachinery flows	

Learning Resources	
Text Books	***Reference Books***
6. Boundary-Layer Theory by Hermann Schlichting and Klaus Gersten, Springer 7. Viscous Fluid Flow by Frank M. White, McGraw-Hill 8. Fundamentals of Aerodynamics by John D. Anderson Jr., McGraw-Hill 9.	2. Turbulent Flows by Stephen B. Pope, Cambridge University Press 3. Computational Fluid Dynamics: The Basics with Applications by John D. Anderson Jr., McGraw-Hill 4. Hypersonic and High-Temperature Gas Dynamics by John D. Anderson Jr., AIAA 5. Theoretical and Computational Aerodynamics by Tapan K. Sengupta, Universities Press

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 and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	Assignment(s)	10%				
	Seminar before a Committee	10%				
	Assessment Components	***CO1***	***CO2***	***CO3***	***CO4***	***CO5***
	Continuous Internal Assessment					
	Semester End Examination					
Indirect Assessment						

Mapping Between Course Outcomes and Program Outcomes						
CO	**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

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 (SL) such as use of NPTEL materials and internets
CD7	Simulation

Mapping Between Course Outcomes and Course Delivery Method	
Course Outcomes	**Course Delivery Method**
CO1	CD1,CD2,CD3
CO2	CD1, CD2,CD3,CD4
CO3	CD1, CD2,CD3
CO4	CD1, CD2
CO5	CD1, CD2

Course Designers		
Experts from Industry	*Experts from Higher Technical Institutions*	*Internal Experts*

COURSE INFORMATION

Course code	**SR 26580**
Course title	**High-Speed Aerothermodynamics and Hypersonic Flows**
Pre-requisite(s)	**Aerodynamics**
Co-requisite	Physics and Mathematics
Credits	L: 3 T:0 P:0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace
Name of Teacher	Dr. Priyank Kumar

Course Objectives

This course aims to provide students with:

Sl No.	Objectives
1	To develop a comprehensive understanding of the physics and governing principles of compressible and hypersonic flows relevant to aerospace applications.
2	To introduce hypersonic flow theories and approximation techniques used in the analysis of high-speed external aerodynamic configurations.
3	To study high-temperature gas dynamics, real gas effects, chemical reactions and non-equilibrium phenomena encountered in hypersonic flight regimes.
4	To understand aerodynamic heating mechanisms, viscous interactions, shock-boundary layer interactions and thermal protection concepts associated with re-entry and hypersonic vehicles.
5	To familiarize students with hypersonic vehicle configurations, propulsion systems, computational techniques and experimental facilities used in modern high-speed aerospace research and design.

Course Outcomes (COs) _Upon successful completion of the course, students will be able to_	
CO	Course Outcomes
1	Analyze compressible flow behavior involving nozzles, shock waves, expansion waves and high-speed aerodynamic phenomena using fundamental governing equations.
2	Apply hypersonic flow theories and approximation methods for predicting aerodynamic characteristics of slender and blunt body configurations.
3	Evaluate the influence of high-temperature gas effects, chemical reactions and thermodynamic property variations in hypersonic flow environments.
4	Investigate aerodynamic heating, viscous interaction and shock-boundary layer interaction effects relevant to thermal protection and re-entry vehicle design.
5	Utilize computational and experimental approaches for the analysis of hypersonic vehicles and propulsion systems, including CFD methods and high-enthalpy testing techniques.

Syllabus

Module No.	***Module name***	***Detailed Contents***	***No. of Lecture***
1	Fundamentals of High-Speed Flows	Classification of high-speed regimes, Mach number and flow characteristics, compressibility effects, governing equations for compressible flow, speed of sound and Mach waves, isentropic flow relations, stagnation properties, area–velocity relation, flow through nozzles, normal and oblique shock waves, expansion waves and Prandtl–Meyer theory.	8
2	Hypersonic Flow Theory and Approximations	Definition and characteristics of hypersonic flows, hypersonic similarity parameters, thin shock layer theory, Newtonian and modified Newtonian theory, hypersonic small disturbance theory, shock-expansion methods, pressure distribution over blunt and slender bodies, hypersonic flow over wedges and cones.	8
3	High-Temperature Gas Dynamics	Thermal and caloric imperfections, real gas effects, chemical reactions in high-speed flows, dissociation and ionization, equilibrium and non-equilibrium flows, thermodynamic and transport properties variation, introduction to reacting gas dynamics, shock layer chemistry basics.	8
4	Aerodynamic Heating and Boundary Layer Effects	Viscous interaction in hypersonic flows, compressible boundary layers, shock-boundary layer interaction, aerodynamic heating mechanisms, recovery temperature and heat transfer correlations, stagnation point heating, thermal protection systems, ablative and reusable materials, surface catalysis effects.	8
5	Hypersonic Vehicles, Propulsion and Computational Methods	Introduction to hypersonic vehicle configurations, re-entry physics and trajectory considerations, wave drag and lift generation, scramjet propulsion basics, air-breathing hypersonic engines, CFD approaches for hypersonic flows, grid generation and numerical challenges, experimental techniques including shock tunnels and high-enthalpy facilities, case studies of re-entry vehicles and hypersonic cruise systems	8

Learning Resources	
Text Books	***Reference Books***
10. Hypersonic and High-Temperature Gas Dynamics by John D. Anderson Jr., AIAA Education Series 11. Modern Compressible Flow with Historical Perspective by John D. Anderson Jr., McGraw-Hill 12. Fundamentals of Aerodynamics by John D. Anderson Jr., McGraw-Hill 13. Elements of Gasdynamics by Hans Wolfgang Liepmann and Anatol Roshko, Dover Publications	6. Aerothermodynamics of Gas Turbine and Rocket Propulsion by Gordon C. Oates, AIAA 7. High Temperature Gas Dynamics by Tarit K. Bose, Springer 8. Hypersonic Aerothermodynamics by John J. Bertin, AIAA Education Series 9. Computational Fluid Dynamics: The Basics with Applications by John D. Anderson Jr., McGraw-Hill

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 and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	Assignment(s)	10%				
	Seminar before a Committee	10%				
	Assessment Components	***CO1***	***CO2***	***CO3***	***CO4***	***CO5***
	Continuous Internal Assessment					
	Semester End Examination					
Indirect Assessment						

Mapping Between Course Outcomes and Program Outcomes						
CO	**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

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 (SL) such as use of NPTEL materials and internets
CD7	Simulation

Mapping Between Course Outcomes and Course Delivery Method

Course Outcomes	**Course Delivery Method**
CO1	
CO2	
CO3	
CO4	
CO5	

Course Designers

Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

COURSE INFORMATION

Course code	**SR 26518**
Course title	**Turbulence Modeling in CFD**
Pre-requisite(s)	**Fluid Mechanics, Numerical Analysis, Computational Fluid Dynamics**
Co-requisite	Nil
Credits	L: 3 T:0 P:0 SL: 0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace
Name of Teacher	Dr. Partha Mondal

Course Objectives

This course aims to provide students with:

Sl No.	Objectives
1.	Know basics of turbulence and numerical techniques to solve the governing equations.
2.	Understand the averating techniques and RANS equations.
3.	Learn the algebraic models and their application in different flows.
4.	Understand the one and two equation turbulence models and numerical implementation.
5.	Know the Large Eddy Simulation and Direct Numerical Simulation and their advantages and disadvantages.

Course Outcomes (COs) *Upon successful completion of the course, students will be able to*	
CO	Course Outcomes
CO1	Know the fundamental concepts of turbulence and numerical techniques to solve pdes in fluid flows.
CO2	Understand different averaging techniques and RANS equations.
CO3	Apply the algebraic turbulence models to solve problems like wall bounded and separated flows.
CO4	Learn and implement the one and two equation turbulence models and compare the different models.
CO5	Understand the Large Eddy Simulation, Detached Eddy Simulation, Direct Numerical Simulations and their limitations.

Syllabus

Module No.	*Module name*	*Detailed Contents*	*No. of Lecture*
1	**Introduction to Turbulence and CFD**	Fundamental Concepts of Turbulence, Transition from Laminar to Turbulent Flows, Descriptors of Turbulent Flows, Characteristics of Simple Turbulent Flows, Conservation Laws of Fluid Motion, Numerical Techniques to Solve Governing Equations in Fluid Flows, Inviscid Flux Schemes, Boundary Conditions.	10
2	**Basic Equations of Turbulence**	Reynolds Averaging, Favre (Mass) Averaging, The Navier-Stokes Equations, Reynolds-Averaged Navier-Stokes (RANS) Equations, Favre- and Reynolds-Averaged Navier-Stokes Equations, Closure Problem, Eddy Viscosity Hypothesis, Numerical Implementation of Euler / Navier-Stokes Equations.	10
3	**Algebraic Models**	Molecular Transport of Momentum, The Mixing-Length Hypothesis, Application to Free Shear Flows, Modern Variants of Mixing-Length Model: Cebeci-Smith Model, Baldwin-Lomax Model, Application to Wall-Bounded Flows, Separated Flows, The ½ Equation Model, Range of Applicability.	8
4	**One and Two Equations Models**	The Turbulence Energy Equation, Baldwin-Barth One-Equation Turbulence Model, Spalart-Allmaras One-Equation Turbulence Model, K- ε Two-Equation Tubulence Model, RNG K- ε Model, k-ω Two-Equation Turbulence Model, SST k-ω Model, Wall Functions, Comparison of Various Turbulence Models, Closing Remarks on RANS turbulence Models.	8
5	**Large Eddy Simulation and Direct Numerical Simulation**	Background Information, Large Eddy Simulation (LES), Spatial Filtering, Filtered Governing Equations, Subgrid-Scale Modeling: Eddy Viscosity Models, Smagorinsky SGS Model, Dynamic SGS Models, Detached Eddy Simulation (DES), Direct Numerical Simulation (DNS), Advantages and Limitations of LES, DES and DNS.	8

Learning Resources	
Text Books	***Reference Books***
1. Wilcox, D. C., Turbulence Modeling for CFD, DCW Industries, 1994.	1. Blazek, J., Computational Fluid Dynamics: Principles and Applications, Elsevier, 2001.
2. Versteeg, H. K., and Malalasekera, W., An Introduction to Computational Fluid Dynamics, Pearson Education Limited, 2007.	2. Hoffmann, K. A. and Chiang, S. T., Computational Fluid Dynamics (Vol. III), Engineering Education System, 2000.

Gaps in the Syllabus (to meet Industry/Profession requirements)	Developing a RANS code
Pos met through Gaps in the Syllabus	PO1, PO2, PO3, PO4, PO5, PO6
Topics beyond syllabus/Advanced topics/Design	Developing a LES code
Pos met through Topics beyond syllabus/Advanced topics/Design	PO1, PO2, PO3, PO4, PO5, PO6

Course Outcome (Co) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	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					

Mapping Between Course Outcomes and Program Outcomes						
CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	1	1	2	1	1	1
CO2	2	1	3	1	1	2
CO3	2	2	2	2	1	3
CO4	3	2	3	2	2	3
CO5	3	2	3	2	2	3

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 (SL) such as use of NPTEL materials and internets
CD7	Simulation

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 Designers

Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

COURSE INFORMATION

Course code	**SR 26515**
Course title	**Turbulence Flows**
Pre-requisite(s)	**Fundamentals of Aerodynamics**
Co-requisite	Nil
Credits	L: 3 T:0 P:0 SL: 0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace
Name of Teacher	Dr. Priyank Kumar

Course Objectives

This course aims to provide students with:

Sl No.	Objectives
1.	Understand the origin of turbulence in fluids.
2.	Recognize the turbulence transport equations.
3.	Examine the effect of parametric variation in turbulence.
4.	Understand the flow with and without wall boundaries.
5.	Analyze turbulence using statistics.

Course Outcomes (COs) _Upon successful completion of the course, students will be able to_	
CO	Course Outcomes
CO1	Illustrating the growth of turbulence in a fluid flow.
CO2	Able to describe transport equations related to fluid flow.
CO3	Explaining the variation in turbulence due to various factors.
CO4	Able to demonstrate the turbulence in free shear and wall bounded flows.
CO5	Applying the statistical approach for turbulence realization in a fluid flow.

Syllabus

Module No.	***Module name***	***Detailed Contents***	***No. of Lecture***
1	Turbulence :	Introduction, Nature of Turbulence, Methods of Analysis- Dimensional, Asymptotic and local invariance, Origin, Diffusivity with length and time scale, Eddy Diffusivity.	7
2	Turbulent Transport :	Reynolds equation, decomposition, mean flow, Reynolds Stress, Introduction to kinetic theory of gases, Estimates of Reynolds stresses, Reynolds stress and vortex stretching, Mixing length model, heat transfer.	7
3	Dynamics of turbulence:	Kinetic energy of the mean flow, Effect of viscosity, Production and dissipation, Taylor microscale, Spectral energy, Wind tunnel turbulence, Pure Shear Flows, Vorticity dynamics, vector and tensor, Reynolds Stress and vorticity equations, Two dimensional mean flows, Multiple length scales.	9
4	Free Shear and wall bounded Flows :	Two dimensional flows, plane flows, Cross stream momentum equation, wakes, mixing, Multiple scales- sublayer, velocity defect law, Channel flows, Logarithmic friction law, Effect of pressure gradient.	8
5	Statistical description, Turbulent Transport, Spectral Dynamics :	Probability density, Effect of spikes and discontinuities, Correlations, Transport in stationary, homogenous turbulence, Diffusion equation, Uniform shear flow, Grid turbulence, one and three dimensional spectra, Three dimensional spectrum, Isotropic relations, effect of production and dissipation.	9

Learning Resources	
Text Books	***Reference Books***
1. A first course in Turbulence – Tennekes and Lumley	1. Turbulence – J. O. Hinze

2. Turbulent Flow – Steven B. Pope	2. Basics of Engineering Turbulence – S. David, K. Ting

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 and Evaluation Procedure

<table>
<tr><td rowspan="11">Direct Assessment</td><td>Assessment Tool</td><td colspan="5">% Contribution during CO Assessment</td></tr>
<tr><td>Continuous Internal Assessment</td><td colspan="5">50%</td></tr>
<tr><td>Semester End Examination</td><td colspan="5">50%</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td>Continuous Internal Assessment</td><td colspan="5">% Distribution</td></tr>
<tr><td>Best 2 Quiz marks out of 3 Quizzes of 15 marks each.</td><td colspan="5">30%</td></tr>
<tr><td>Assignment(s)</td><td colspan="5">10%</td></tr>
<tr><td>Seminar before a Committee</td><td colspan="5">10%</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td>Assessment Components</td><td>CO1</td><td>CO2</td><td>CO3</td><td>CO4</td><td>CO5</td></tr>
<tr><td>Continuous Internal Assessment</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Semester End Examination</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Indirect Assessment</td><td colspan="6">1. Student Feedback on Faculty</td></tr>
<tr><td colspan="6">2. Student Feedback on Course Outcome</td></tr>
</table>

Mapping Between Course Outcomes and Program Outcomes						
CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	-	-	3	1	-	-
CO2	2	-	3	2	-	1
CO3	3	1	3	3	2	2
CO4	3	2	3	3	2	2
CO5	3	2	3	3	2	3

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 (SL) such as use of NPTEL materials and internets
CD7	Simulation

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 Designers		
Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

COURSE INFORMATION SHEET

Course code: SR 26582

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: Dr. Priyank Kumar/ Dr. 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 26583

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.Tech

Semester / Level: II/5

Branch: Aerospace

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. **Experiment No. 1**
   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. **Experiment No. 2**
   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. **Experiment No. 3**
   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. **Experiment No. 4**
   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. **Experiment No. 5**
   Name: Cavity Pressure Fluctuation
   Object: To study the pressure fluctuations inside a generic cavity at Supersonic speed

6. **Experiment No. 6**
   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. **Experiment No. 7**
   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

Department of Space Engineering and Rocketry
Birla Institute of Technology, Mesra, Ranchi - 835215 (India)

M. Tech. in Aerospace Engineering

Second Semester
Specialization: Rocket Propulsion

COURSE INFORMATION

Course code	**SR 26550**
Course title	**Liquid & Hybrid Rocket Propulsion**
Pre-requisite(s)	NA
Co-requisite	NA
Credits	L: 3 T:0 P:0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace Engineering
Name of Teacher	Dr. Rajiv Kumar

Course Objectives
This course aims to provide students with:

Sl No.	Objectives
1	Explain the working theory of liquid rocket engine, cryogenic engine and hybrid rocket propulsion system.
2	Identify the fundamental concept of the feed systems of the liquid rocket propulsion system in terms of designing in a practical application.
3	Identify the concept of thrust chamber and other combustion devices of liquid rocket engine in the design approach.
4	Generate sufficient information on the precautions and designing challenges of a cryogenic propulsion system.
5	Create a basic platform for designing a hybrid rocket propulsion system.

Course Outcomes (COs) *Upon successful completion of the course, students will be able to*	
CO	Course Outcomes
1	To get the knowledge on the various basic terms and performance parameters used in a liquid rocket engine.
2	To analyze and investigate various types of feed system used in a liquid rocket engine and later utilize it in the designing process.
3	To comprehend the concept of thrust chamber and other combustion devices of liquid rocket engine in the design approach.
4	To describe the basic information related to the designing challenges of the cryogenic propulsion system.
5	To explain the limitations and designing challenges of the hybrid rocket motor.

Syllabus

Module No.	*Module name*	*Detailed Contents*	*No. of Lecture*
1	**Liquid Propellants and LPR Engine:**	Basic Elements of an LPR Engine; Performance Parameters of selected existing Liquid Rocket Engines.	6
2	**Feed Systems:**	Types of feed system in liquid rocket engine, Purpose; Types of Pressure Feed Systems; Methods of Tank- pressure Control; Types of Pressurization Systems; Desirable Characteristics of Pressurants; Tank Pressurant requirements and its Determination; Pressurized Gas Systems, Elements of Pump Feed Systems; Centrifugal Pumps and Axial Flow Pumps; Turbines; Design Layout of Turbo-pump Assemblies; Control Valves and their selection; Transient Pressures due to Valve Closure and Valve Opening; Design of the Wall Thickness of Propellant Line; Frictional Losses in Propellant Feed Lines, Overall design of feed systems both pressure fed and turbo pump fed systems.	10
3	**Thrust Chambers and Auxiliary Combustion Devices:**	Basic Thrust Chamber Elements; Combustion Chamber Design and Characteristic Length; Combustion Process; Performance Parameters; Engine Design and Control; Configuration Layout; Materials and Selection; Types of Injectors; Injector Design and Performance; Ignition Devices; Heat Transfer; Regenerative Cooling; design of regenerative cooled engines, Uncooled Chambers; Combustion Instability; Nozzle Flow; Nozzle Design; Thrust Vector Control. Design of liquid rockets with sub system design.	9
4	**Cryogenic Propulsion:**	Cryogenic Loading Problems; Temperature and Pressure Effects on Loading; Tank Collapse; Phenomenon of Thermal Stratification; Effect of Thermal Stratification on Rocket Engine Performance; Prediction and Methods of Elimination of Thermal Stratification.	7
5	**Hybrid Rocket Propulsion:**	Introduction; Classification; System Arrangement and Components; Typical Fuels and Oxidizers; Advantages and Disadvantages; Application Areas; Performance and Limitations; Performance Parameters of selected existing Hybrid Rocket Engines; System Integration; Manufacturing Methods for Low- and High- Thrust Engines. Design of hybrid rockets with sub system design including grain design.	8

Learning Resources	
Text Books	***Reference Books***
1. Design of Liquid Propellant Rocket Engine – Huzel, D. K. & Huang, D. H., NASA SP-125 2. Fundamental of Hybrid Rocket Combustion and Propulsion, Martin J. Chiaverini and Kennith K. Kuo, Progress in Aeronautics & Astronautics, Vol. 218, AIAA. 3. Safety in the Handling of Cryogenic Fluids, Frederick J. Edeskuty and Walter F. Stewart. The International Cryogenic Monograph Series, Springer Science + Business Media New York.	1. Rocket Propellant and Pressurization Systems – Ring, E. 2. Heterogeneous Combustion – Wolfhard,H. G., Progress in Aeronautics & Astronautics, Vol. 15, AIAA. 3. Liquid Rocket and Propellants – Bollinger, L. E., Progress in Aeronautics & Astronautics, Vol. AIAA. 4. Cryogenic Systems – Barron, R. 5. Thermodynamic Properties of Cryogenic Fluids, Richard T Jacobsen, Steven G Penoncello and Eric W. Lemmon, The International Cryogenic Monograph Series, Springer Science + Business Media New York.

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 and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	Assignment(s)	10%				
	Seminar before a Committee	10%				
	Assessment Components	***CO1***	***CO2***	***CO3***	***CO4***	***CO5***
	Continuous Internal Assessment					
	Semester End Examination					

Indirect Assessment	Student Feedback on Faculty
	Student Feedback on Course Outcome

Mapping Between Course Outcomes and Program Outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	2	1	1	3
CO2	3	2	3	2	2	3
CO3	3	3	3	2	2	3
CO4	2	1	2	1	1	2
CO5	3	2	3	2	-	2

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 Course Outcomes and Course Delivery Method

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

Course Designers

Experts from Industry	*Experts from Higher Technical Institutions*	*Internal Experts*

COURSE INFORMATION

Course code	**SR 26551**
Course title	**Solid Rocket Propulsion**
Pre-requisite(s)	NA
Co-requisite	NA
Credits	L: 3 T:0 P:0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace Engineering
Name of Teacher	Dr. Rajiv Kumar

Course Objectives *This course aims to provide students with:*	
Sl No.	Objectives
1	Demonstrate the information and implications of the types of grain suitable for a particular solid rocket motor.
2	Examine the importance on the types of the nozzle and performance parameters utilization in practical applications.
3	Apply the concept of metal combustion and identify the changes in energetics and combustion behaviour due to erosive burning.
4	Apply the basic knowledge of an igniters in the designing process of a solid rocket motor.
5	Examine the various types of instabilities occurring in solid rocket motor along with their remedies.

Course Outcomes (COs) *Upon successful completion of the course, students will be able to*	
CO	Course Outcomes
1	To interpret different types of propellant grain and its significance in the designing of solid rocket motor.
2	To analyze the various performance parameters and application of different types of nozzle used in solid rocket motor.
3	Identify and analyze the effect of metal addition on the combustion energetics and interpret the instabilities associated with erosive burning, their remedial methods.
4	To describe the concept of ignition system in designing the igniters for a solid rocket motor.
5	To predict the various types of instabilities occurring in solid rocket motor along with their remedies.

Syllabus

Module No.	***Module name***	***Detailed Contents***	***No. of Lecture***
1	**Solid Rocket Motor:**	Introduction to Solid Rocket, Classification, Types of Grain and its importance, Propellant Characteristics, Star Configuration; Design Criteria; Segmented Grains; Burning Surface Area Evaluation; Dual Thrust Grains. Structural Analysis of Propellant Grain, Types of Mechanical Load, Structure Failure of Grains.	9
2	**Nozzle and Performance prediction methods:**	Nozzle Configuration; Annular Nozzles, Adopted Nozzles, Submerged Nozzles; Nozzle Construction; Prediction and Measurements of Specific Impulse, Computation of Adiabatic Flame Temperature; Theoretical Performance Evaluation of Solid Rocket Propellants; Equilibrium and Frozen Flow; Experimental Determination of Rocket Performance.	8
3	**Metals and Erosive Burning:**	Description and Classification of Various Burning Metals; Theories of Combustion of Metal Powders; Effect of Aluminum on Propellant Burning Rate; Erosive burning; Laboratory Methods for Determination of the Erosion Function; Theories of Erosive Burning, Effect of Erosion on various parameters, Negative Erosion Phenomenon.	8
4	**Associated Systems :**	Ignition and Ignition Delay; Selection Criteria of Igniter Composition, Quantity and Location; Design of Igniters; Sample Calculation; Igniters for Solid Rocket Motor; Igniter Hardware; Igniter Pellets; Pyrogen Igniters; Extinction of Solid Rocket Motors; Restart of Solid Rocket Motors; Inhibition and Inhibitors; Insulation and Liners; Thrust Vector Control; Mechanism and Methods of TVC; Testing and Integration with Vehicle.	9
5	**Combustion Instability:**	Types of Instability – Bulk Mode, Transverse Mode and Axial Mode Instabilities; Causes of Instability in Solid Rocket Motors; Analysis of Instability in Solid Rocket Motors; Remedial Methods.	6

Learning Resources	
Text Books	***Reference Books***
1. Solid Rocket Propulsion – Barrere, M., et. Al 2. Rocket Propulsion Elements – Sutton, G. P. and Biblarz, O., 7th Ed.	1. Solid Rocket Technology – Shorr, M. and Zaehringer, A. J. 2. Understanding Aerospace Chemical Propulsion, H S Mukunda 3. Rocket Propulsion, K Ramamurthi. 4. Introduction to Rocket Technology, V. I. Feodosiev and G. B. Siniarev 5. Materials for Missiles and Spacecraft, E. R. Parker

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 and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	Assignment(s)	10%				
	Seminar before a Committee	10%				
	Assessment Components	***CO1***	***CO2***	***CO3***	***CO4***	***CO5***
	Continuous Internal Assessment					
	Semester End Examination					

Indirect Assessment	Student Feedback on Faculty
	Student Feedback on Course Outcome

Mapping Between Course Outcomes and Program Outcomes

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	2	3	2	1	3
CO2	3	2	3	2	2	3
CO3	1	1	2	1	1	3
CO4	3	1	3	1	1	2
CO5	3	1	3	1	1	2

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 Course Outcomes and Course Delivery Method

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

Course Designers

Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

COURSE INFORMATION

Course code	**SR 26552**
Course title	**Rocket Combustion Process**
Pre-requisite(s)	NA
Co-requisite	NA
Credits	L: 3 T:0 P:0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace Engineering
Name of Teacher	Dr. Shelly Biswas

Course Objectives

This course aims to provide students with:

Sl No.	Objectives
1	Understand the concept of enthalpy, adiabatic flame temperature, chemical kinetics and their application to combustion related problems.
2	Comprehend the various types of flames, along with detonation waves observed in rocket motors.
3	Understand details of combustion process associated with double base and composite propellants and compare the condensed and gas phase theories related to them.
4	Understand combustion of liquid propellants in rocket motor with emphasis on atomization and related combustion models.
5	Comprehend combustion model of hybrid propellants in view of existing theories of hybrid combustion and related operating parameters in a hybrid rocket motor.

Course Outcomes (COs) *Upon successful completion of the course, students will be able to*	
CO	Course Outcomes
1	Apply the basic concept of thermochemistry and chemical kinetics to combustion related problems.
2	Distinguish between premixed, diffusion flames, deflagration and detonation process and their use in combustion devices and rockets.
3	Comprehend principal concepts and predict the related theory for a typical case of solid propellant combustion.
4	Summarize the effect of atomization and droplet size distribution in the combustion of liquid propellant and evaluate the effect of different parameters in the combustion process.
5	Comprehend the theories of hybrid combustion and evaluate the effect of related operating parameters in a hybrid rocket motor.

Syllabus

Module No.	***Module name***	***Detailed Contents***	***No. of Lecture***
1	**Basics to Combustion:**	Stoichiometry, Adiabatic Flame Temperature and its Application in Rocket combustion; Enthalpy of Formation; Enthalpy of Combustion; Rate and Order of Different Reactions; Arrhenius Equation; Chain Reaction, Explosion Limits; Combustion Products in Equilibrium, Ionization in Rocket Exhaust.	7
2	**Flames and Detonation:**	Concept of Flame; Properties of Premixed Flames; Properties of Diffusion Flames; Burning Velocity; Flame Stabilization; Flame Quenching; Detonation Wave and their Characteristics; Deflagration to Detonation Transition; Chapman-Jouguet States and their Properties; Computation of Detonation Velocity.	8
3	**Solid Propellant Combustion :**	Combustion of Double Base Propellants; Theories of Combustion of D. B. Propellants – Boys & Corner Theory, Two- temperature Postulate of composite propellant; Guirao-Williams Model for Combustion of Ammonium Perchlorate; Combustion Mechanism of Composite Propellants; Theories of Combustion – Outline of Thermal Theory, GDF Model and Multiple Flame (BDP) Combustion Model.	10
4	**Liquid Propellant Combustion:**	Physico- Chemical Description of Combustion in a Liquid Propellant Rocket Engine; Atomization and Droplet Size Distribution in Injection Sprays; Spherico-symmetric Model of Fuel Burning in Oxidizing Atmosphere; Correlation for Non-spherical Model; Effect of Drag on Combustion; Effect of Pressure on Combustion; Droplet Burning Rate Measurement; Combustion Models for Monopropellants.	7
5	**Hybrid Propellant Combustion :**	Introduction; Combustion Model for a Hybrid Fuel Burning in an Oxidizer Stream; Theories of Hybrid Combustion, Effect of Pressure and Mass Flow Rate on Combustion; Transient Behaviour of Hybrid Regression Rate; Temperature Profile inside the Regressing Solid Fuel; Combustion of Metallized Hybrid Fuel; Effect of Radiation, Burning Time, Length and Port Size on Fuel Regression Rate.	8

Learning Resources	
Text Books	***Reference Books***
1. S. R. Turn, An Introduction to Combustion - Concepts and Applications, 3rd Edition, McGraw-Hill, India, 2012.(T1) 2. Fundamentals of Solid Propellant Combustion, Kuo, K. K., Summerfield, M., Progress in Astronautics & Aeronautics, Vol. 90, AIAA. 1984. 3. Liquid Propellant Rockets, Altman, D., Carter, J. M., Penner, S.S., Summerfield, M., Princeton University Press, 1960.	1. B. Lewis and G. von Elbe, Combustion, Flames and Explosions of Gases, 3rd Edition, Academic Press, Orlando, 1987. (R1) 2. A. G. Gaydon and H. D. Wolfhard, Flames: Their Structure, Radiation and Temperature, 3rd Edition, Springer NY, USA, 1970. (R2) 3. Solid Rocket Propulaion Technology, Ed. Alain Davenas, Elsevier, 1992. (ISBN 978-0-08-040999-3 (R3) 4. Fundamental of Hybrid Rocket Combustion and Propulsion, Chiaverini, M.J., Kuo, K.K., Progress in Astronautics & Aeronautics, Vol. 218, AIAA. 2007. (R4) 5. Heterogeneous Combustion, Wolfhard, H.G., Glassman, I., Green, L., Progress in Astronautics & Aeronautics, Vol. 15, AIAA. 1964.

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 and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	Assignment(s)	10%				
	Seminar before a Committee	10%				
	Assessment Components	***CO1***	***CO2***	***CO3***	***CO4***	***CO5***
	Continuous Internal Assessment					
	Semester End Examination					

Indirect Assessment	Student Feedback on Faculty
	Student Feedback on Course Outcome

Mapping Between Course Outcomes and Program Outcomes

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	1	2	1		3
CO2	2	1	2	1		3
CO3	3	2	3	2	3	3
CO4	2	1	3	2		1
CO5	3	3	3	2	2	3

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 Course Outcomes and Course Delivery Method

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

Course Designers

Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

COURSE INFORMATION

Course code	**SR 26553**
Course title	**Ignition and Extinction in Chemical Rocket**
Pre-requisite(s)	NA
Co-requisite	NA
Credits	L: 3 T:0 P:0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace Engineering
Name of Teacher	Dr. Shelly Biswas

Course Objectives

This course aims to provide students with:

Sl No.	Objectives
1	Identify and interpret the factors affecting the ignition energy release and its mechanism for any given ignition source.
2	Examine the suitability of ignitions for any chemical rocket based on its merits and demerits.
3	Judge the type of igniters to be designed for any chemical rocket propulsion system.
4	Generate the sufficient information about the flame spreading and its mechanism in solid rocket motor.
5	Assess the knowledge of solid propellant extinction in the designing process of a solid rocket motor.

Course Outcomes (COs) *Upon successful completion of the course, students will be able to*	
CO	Course Outcomes
1	Interpret different types of igniters and its applications in the propulsion system.
2	Analyze the ignition mechanism and its sequence mainly for solid rocket applications.
3	Design an igniter for the given chemical rocket propulsion system for the given thrust range.
4	Describe the concept of flame spreading and ignition transient in a solid rocket motor.
5	Predict the various mechanism of extinction utilized in the solid rocket motor along with their advantages and disadvantages.

Syllabus

Module No.	*Module name*	*Detailed Contents*	*No. of Lecture*
1	**Ignition & Factors affecting Ignition Energy:**	Introduction; Process of Self- ignition; Induction Period; Limits of Self-ignition; Forced ignition; Basic Idea of Ignition by Spark; Pilot Flames; Hot Gases and Shock Waves; Effect of Composition, Type of Electrode, Spark Duration, Pressure, Temperature, Diluents, Effect of Mixture Velocity and Turbulence on Ignition Energy.	8
2	**Ignition Mechanism:**	Sequence of Ignition; Theories of Ignition – Thermal Ignition Theory, Gas-Phase Theory and Heterogeneous Theory; Pre- ignition Reactions; Effect of Catalyst on Ignition Process; Shock Tube and Ignition Experiments.	7
3	**Igniters for Chemical Rocket :**	Igniters for Solid Rocket Motors – Role and Requirements; Classification of Igniters based on Mounting Locations and Energy Release Systems; Construction and Initiation Systems; Hardware Components; Design of Pyrotechnic and Pyrogen Igniters; Testing and Evaluation; Igniters for Liquid Propellant Engines, Hypergolic Ignition and Ignition Delay; Catalyst Induced Ignition; Igniters for Cryogenic Engines – Spark Torch, Pyrotechnic, Pyrogen and Plasma Igniters; Igniters for Hybrid Motors and Air Breathing Engines; Laser Induced Ignition and its Applications.	11
4	**Flame Spreading and Ignition Transient:**	Physical Processes during Ignition Transient; Ignition Transient Models and Experiments; Flame Spreading over Solid Propellants, Fuels, Defects and Cracks.	7
5	**Extinction:**	Controlled Termination of Thrust – Approaches; Energy Balance at Burning Surface; Dynamic Extinction by Fast Depressurization, Fast Deradiation and other Quenching Techniques, like Injection of Flame Inhibitors, Heat Sink, etc.; Theories and Experiments of Extinction.	8

Learning Resources	
Text Books	***Reference Books***
1. Fuels & Combustion – Sharma, S.P. & Mohan, C., Tata-McGraw Hill, 1984 (T1) 2. Fundamental Aspects of Solid Propellant Rockets, Williams, F.A., Barrère, M., Huang, N.C., The Advisory Group for Aerospace Research and Development of N.A.T.O. [by] Technivision Services, 1969.(T2)	1. Advanced Chemical Rocket Propulsion Elements – Timnat, Y.M., Academic Press, 1987.(R1) 2. Fundamentals of Solid Propellant Combustion – Kuo, K.K., Summerfield, M., Progress in Astronautics & Aeronautics, Vol. 90, AIAA. 1984.(R2) 3. Solid Rocket Technology – Shorr, M. and Zaehringer, A. J.(R3) 4. Understanding Aerospace Chemical Propulsion, H S Mukunda(R4) 5. Rocket Propulsion, K Ramamurthi.(R5)

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 and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	Assignment(s)	10%				
	Seminar before a Committee	10%				
	Assessment Components	***CO1***	***CO2***	***CO3***	***CO4***	***CO5***
	Continuous Internal Assessment					
	Semester End Examination					
Indirect Assessment	Student Feedback on Faculty					
	Student Feedback on Course Outcome					

Mapping Between Course Outcomes and Program Outcomes						
CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	1	2	1	1	3
CO2	2	2	3	2	1	3
CO3	3	3	3	2	2	3
CO4	2	2	3	1	2	3
CO5	1	1	2	2	1	3

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 Course Outcomes and Course Delivery Method

Course Outcomes	**Course Delivery Method**
CO1	CD1,CD2,CD3, CD6
CO2	CD1, CD2, CD3, CD6
CO3	CD1, CD6
CO4	CD1, CD2, CD3, CD6
CO5	CD1,CD2, CD3, CD6

Course Designers

Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

COURSE INFORMATION

Course code	**SR 26554**
Course title	**Advanced Propulsion Systems**
Pre-requisite(s)	**Elements of Rocket Propulsion**
Co-requisite	NA
Credits	L: 3 T:0 P:0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace Engineering
Name of Teacher	Dr. Shelly Biswas/Dr. Rajiv Kumar

Course Objectives

This course aims to provide students with:

Sl No.	Objectives
1	Understand the concept of various types of advanced propulsion system
2	Apply the concept of the different combustion systems used in scramjet, ramjet propulsion and hypersonic propulsion
3	Analyse the characteristics of nuclear propulsion and the hazards associated with it
4	Interpret the various electric propulsion system and the ways power generation in space
5	Interpret the various micro-propulsion systems developed and emerging technologies involved

Course Outcomes (COs) *Upon successful completion of the course, students will be able to*	
CO	Course Outcomes
1	To understand the concept of various types of advanced chemical propulsion system and its application to real systems.
2	To demonstrate the utilization of combustion systems in scramjet, ramjet propulsion and hypersonic propulsion.
3	To infer the concept of nuclear rockets and evaluate the performance, operation parameters and handling hazard involved
4	To differentiate between electro-thermal and pure electric thrusters and interpret the concept for power generation in space.
5	To appraise the various micro-propulsion systems developed and emerging technologies involved.

Syllabus

Module No.	***Module name***	***Detailed Contents***	***No. of Lecture***
1	**Advanced Chemical Propulsion System:**	High Performance Chemical Propulsion Systems, Tripropellants; Metalized Propellants; Free Radical Propulsion; Flight Hybrid Rocket Propulsion Systems.	8
2	**Scramjet and Hypersonic Propulsion:**	Scramjet and Ram Rocket Propulsion System; Scramjet Inlets; Scramjet Performance, Introduction to Hypersonic Propulsion; Developments in High Speed Vehicle Propulsion System; Aerodynamic Shape of a Hypersonic Vehicle with an Air Breathing Engine; Engine Cycle; Diffusion Flame Combustion and Supersonic Combustion; Supersonic Flow Combustors; Dual-mode Combustion System.	10
3	**Nuclear Propulsion System :**	Types of Nuclear Propulsion Systems; Heat Transfer in Nuclear Rockets; Gaseous Core Nuclear Rockets; Pure Nuclear Propulsion System; Operation, Performance and Application Areas; Nuclear Hazards; Nuclear Power Generation in Space.	7
4	**Electric Propulsion System :**	Overview of Application Areas; Ideal Flight Performance; Electro-thermal Thrusters – Resistojets and Arcjets. Pure Electric Thrusters – Electrostatic, Electro Magnetic and Hall- effect Thrusters; Optimum Flight Performance; Electric Power Generation in Space.	7
5	**Micropropulsion System :**	Recent Micro Spacecraft Developments; Micro-propulsion Options; Primary Set of Micropropulsion Requirements; Chemical Propulsion Options; Review of Electric Propulsion Technologies for Micro and Nano- satellites; Emerging Technologies: MEMS and MEMS- Hybrid Propulsion System.	8

Learning Resources	
Text Books	***Reference Books***
1. Developments in High Speed- Vehicle Propulsion System, Murthy, S.N.B, Curran, E.T., Progress in Astronautics & Aeronautics, Vol.165, AIAA, 1996. 2. Scramjet Propulsion, Curran, E.T., Murthy, S.N.B., Progress in Astronautics & Aeronautics, Vol. 189, AIAA,2001. 3. Micropropulsion for Small Spacecraft, Paul, Z., Progress in Astronautics &Aeronautics, Vol. 187, AIAA,2000.	1. Rocket Propulsion Elements, Sutton, G.P., Biblarz, O., 7th Ed. John Wiley & Sons, Inc., New York, 2001.

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 and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	Assignment(s)	10%				
	Seminar before a Committee	10%				
	Assessment Components	***CO1***	***CO2***	***CO3***	***CO4***	***CO5***
	Continuous Internal Assessment					
	Semester End Examination					
Indirect Assessment	Student Feedback on Faculty					
	Student Feedback on Course Outcome					

Mapping Between Course Outcomes and Program Outcomes

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	2	3	1	2	3
CO2	3	2	3	3	1	3
CO3	3	3	3	3	2	3
CO4	3	2	3	3	1	3
CO5	3	3	3	3	2	3

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 Course Outcomes and Course Delivery Method

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

Course Designers

Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

COURSE INFORMATION

Course code	**SR 26555**
Course title	**Heat Transfer in Space Applications**
Pre-requisite(s)	NA
Co-requisite	NA
Credits	L: 3 T:0 P:0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace Engineering
Name of Teacher	Dr. Pawan Kumar Ojha

Course Objectives
This course aims to provide students with:

Sl No.	Objectives
1	Identify various heat transfer mechanism and its utilities in the spacecraft applications.
2	Select and examine the suitability of material at higher temperature of the spacecraft.
3	Assess various equation for the analysis of heat transfer problem in the spacecraft.
4	Analyze the thermal environmental effect on the spacecraft structure during launch and ascent phases.
5	Interpret the heat transfer process and its controlling mechanisms of the various devices used in spacecraft.

Course Outcomes (COs) *Upon successful completion of the course, students will be able to*	
CO	Course Outcomes
1	Distinguish different modes of heat transfer and utilize effectively in space application.
2	Apply the knowledge of the heat transfer mechanism in the design of spacecraft thermal system.
3	Analyze the heat transfer equation for the spacecraft applications.
4	Examine the influence of thermal environment on the spacecraft during its various phases of launch.
5	Interpret the working principles of various high temperature resistive devices and hardware of the spacecraft.

Syllabus

Module No.	***Module name***	***Detailed Contents***	***No. of Lecture***
1	**Introduction to heat transfer:**	Heat Transfer Mechanisms, Conduction, Convection and Radiation, Basic equations governing these Heat Transfer, Simultaneous Heat Transfer Mechanism.	8
2	**Spacecraft Thermal Design:**	Fundamental of Thermal Radiation, Spacecraft Surface Material, Thermal Blanket, Diurnal and Annual Variations of Solar Heating, Need of Spacecraft Thermal Control – Temperature Specification – Energy Balance in a Spacecraft, Factors that influence Energy Balance in a spacecraft – Principles of Spacecraft Thermal Control.	10
3	**Spacecraft Thermal Analysis:**	Formulation of Energy, Momentum and Continuity Equations for problems in Spacecraft Heat Transfer – Development of Discretized Equation – Treatment of Radiative Heat Exchange (for non-participative media based on radiosity and Gebhart method) – incorporation of Environmental Heat Flux in energy equation – Numerical Solution Methods – input parameters required for analysis.	10
4	**Spacecraft Thermal Environments:**	Launch and Ascent – Earth Bound Orbits – Interplanetary Mission and Re-entry Mission.	5
5	**Devices and Hardware for Spacecraft TCS:**	Passive Thermal Control - mechanical joints – heat sinks and doublers – phase change materials – thermal louvers and switches – heat pipes Thermal Coating Materials – thermal insulation – Ablative Heat Transfer – Active Thermal Control Techniques: electrical heaters, HPR fluid systems, space borne cooling systems. Application of principles for the Development of Spacecraft TCS.	8

Learning Resources	
Text Books	***Reference Books***
1. Fundamentals of Heat and Mass Transfer, Incropera, F.P., DeWitt, D.P., 7th ed., John Wiley, 2011(T1). 2. Spacecraft Thermal Control Handbook, Volume I: Fundamental Technologies, Gilmore, D.G., 2nd ed., The Aerospace Press, AIAA, 2002(T2).	1. Elements of Space Technology, Meyer, R.X., Academic Press, 1999 (R1). 2. Numerical Methods for Engineers, Chapra, S.C., Canale, R.P., 7th ed., McGraw-Hill 2014(R2).

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 and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	Assignment(s)	10%				
	Seminar before a Committee	10%				
	Assessment Components	***CO1***	***CO2***	***CO3***	***CO4***	***CO5***
	Continuous Internal Assessment					
	Semester End Examination					

Indirect Assessment	Student Feedback on Faculty
	Student Feedback on Course Outcome

Mapping Between Course Outcomes and Program Outcomes

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	1	1	2	1	2	3
CO2	3	2	3	2	3	3
CO3	2	2	3	2	2	3
CO4	1	1	2	1	1	3
CO5	2	1	2	1	2	3

Mapping Between Course Outcomes and Course Delivery Method	
Course Outcomes	**Course Delivery Method**
CO1	CD1,CD2,CD3, CD6
CO2	CD1, CD2, CD3, CD6
CO3	CD1, CD6
CO4	CD1, CD2, CD3, CD6
CO5	CD1,CD2, CD3, CD6

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

Course Designers		
Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

COURSE INFORMATION

Course code	**SR 26519**
Course title	**Propellant Technology**
Pre-requisite(s)	NA
Co-requisite	NA
Credits	L: 3 T:0 P:0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace Engineering
Name of Teacher	Dr. Rajiv Kumar /Dr. Shelly Biswas

Course Objectives

This course aims to provide students with:

Sl No.	Objectives
1	Comprehend the knowledge about constituents of different types of solid propellant systems in processing of each category and determining key properties.
2	Understand the fundamentals of solid propellant grain design
3	Use grain design fundamentals in design of grains for static and flight rockets.
4	Differentiate between various types of liquid propellants and to analyse the related aspects of ignition, combustion and performance evaluation.
5	Analyze the concept of propellant loading in liquid rocket tanks, and their effective utilization including specific technical issues related to cryogenic propellants.

Course Outcomes (COs) _Upon successful completion of the course, students will be able to_	
CO	Course Outcomes
1	Demonstrate the processing of different types of solid propellants and effect of processing on the vital properties of solid propellants.
2	To comprehend the fundamentals of solid propellant grain design.
3	Design solid propellant grain for static and flight rocket motors.
4	Evaluate the ignition delay and combustion parameters of a liquid rocket engine for different combustion chamber configurations.
5	Evaluate the technical problems associated with propellant loading and other design issues associated with a liquid rockets engine.

Syllabus

Module No.	***Module name***	***Detailed Contents***	***No. of Lecture***
1	**Solid Propellant:**	Classification – Double Base, Composite, Composite Modified Double Base, Fuel-rich and Metallized Propellants; Ingredients; Composition and Processing; Mechanical and Ballistic Properties; Ageing Characteristics.	8
2	**Grain Design Fundamentals:**	Classification of Solid Propellant Grains; End Burning, Radial Burning and Non-cylindrical Burning Grains; Fundamental Characteristics; Various Configurations; Internal Burning Star Configuration; Segmented Grains; Grain Clustering; Burning Surface Area Evaluation; Design Criteria; Dual Thrust Grains; Free- standing and Case- bonded Grains; Inhibitors and Insulators.	8
3	**Grain Design:**	Design Parameters; Performance Parameters; End Burning and Radial Burning Grain Design as applicable to Static Motors and Flight Rockets; Sample Calculations; Stress Analysis in Solid Propellant Grains.	6
4	**Liquid Propellant:**	Classification – Mono-; Bi- and Tri- Propellants; Non Hypergolic and Hypergolic Systems; Gel Propellant Systems; Essential Characteristics of Liquid Propellants; Physical Properties; Ignition Characteristics; Ignition Delay; Ignition and Combustion Properties; Performance of Selected Bipropellant Systems; Factors affecting the Performance.	8
5	**Propellant Loading:**	Cryogenic Propellants, Performance Considerations; Loading Concepts; Outage–Prediction and Control; Calibrated and Propellant Utilization Systems; Tank Ullage; Propellant Slosh; Estimation of Sloshing Mass; Frequency and Stiffness of an Equivalent System; Cavitation Drop- out and Vortexing; Design of Tank Outlet.	10

Learning Resources	
Text Books	***Reference Books***
1. Fundamental Aspects of Solid Propellant Rockets, Williams, F.A., Barrère, M., Huang, N.C., The Advisory Group for Aerospace Research and Development of N.A.T.O. [by] Technivision Services, 1969. 2. Solid Rocket Technology – Shorr, M.,Zaehringer, A.J., John Wiley New York, 1967.	1. Rocket Propulsion, Barrere, M., Jaumotte, A., Fraeijs de Veubeke, B., Vandenkerckhove, J., Elsevier Publishing Company, 1960 2. Internal Ballistics of Solid-Fuel Rockets: Military Rockets Using Dry-Processed Double-Base Propellant as Fuel, Wimpress, R.N., Sage, B.H.,ReInk Books, 2017.

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 and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	Assignment(s)	10%				
	Seminar before a Committee	10%				
	Assessment Components	***CO1***	***CO2***	***CO3***	***CO4***	***CO5***
	Continuous Internal Assessment					
	Semester End Examination					

Indirect Assessment	Student Feedback on Faculty
	Student Feedback on Course Outcome

Mapping Between Course Outcomes and Program Outcomes

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	2	2	1	1	3
CO2	2		3	1	1	3
CO3	3	2	3	2	3	3
CO4	3	1	3	1	1	3
CO5	3		3	2	2	3

Mapping Between Course Outcomes and Course Delivery Method	
Course Outcomes	**Course Delivery Method**
CO1	CD1,CD2,CD3, CD6
CO2	CD1, CD2, CD3, CD6
CO3	CD1, CD6
CO4	CD1, CD2, CD3, CD6
CO5	CD1,CD2, CD3, CD6

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

Course Designers		
Experts from Industry	*Experts from Higher Technical Institutions*	*Internal Experts*

COURSE INFORMATION

Course code	**SR 26520**
Course title	**Special Topics in Chemical Propulsion**
Pre-requisite(s)	NA
Co-requisite	NA
Credits	L: 3 T:0 P:0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace Engineering
Name of Teacher	Dr. Rajiv Kumar/Dr. Shelly Biswas

Course Objectives

This course aims to provide students with:

Sl No.	Objectives
1	Analyze the combustion mechanism involved in chemical propulsion.
2	Interpret the significance of green propellant
3	Analyze two-phase flow on the performance of solid rocket motor.
4	Examine the effect of various parameters on the combustion and performance in a liquid rocket engine.
5	Demonstrate the significance of the studying about rocket plume and its real applications.

Course Outcomes (COs) *Upon successful completion of the course, students will be able to*	
CO	Course Outcomes
1	To analyze the importance of combustion modeling in solid rocket propulsion system.
2	To assess the significance of green propellant and its effective utilization in practical applications.
3	To interpret the influence of two-phase flow in the performance of solid rocket motor.
4	To demonstrate the effect of various parameters on the performance of a liquid rocket engine.
5	To examine the rocket plume and identify their control methods to qualify the propulsion system for a real time applications.

Syllabus

Module No.	*Module name*	*Detailed Contents*	*No. of Lecture*
1	**Combustion Modeling:**	Introduction; Theoretical Formulation – Solid Phase Region; Subsurface Multiphase Region and Gas Phase Region; Boundary Conditions; Numerical Methods; Effect of Chemical Additives on Burn Rate of Solid Propellants; Modeling of Liquid Propellant Combustion Phenomena – Basic Idea of Droplet and Spray Combustion Modeling.	10
2	**Green Propellants & Their Applications:**	Introduction; Advantages of Green Propellants; Physico-chemical Properties; Performance, Design and Operational Requirements.	6
3	**Two- Phase Flow in Solid Rocket Motors:**	Introduction; Aluminium Oxide Formation; Interactions between Droplet and Gas Flow fields; Slag Accumulation; Two- phase Flow fields; Effect of Droplet Coalescence; Effect of Vortices.	7
4	**Jet Atomization & Spray Characterization:**	Jet Atomization & Spray Characterization: Introduction; General Characteristics of Impinging Liquid Jets; Theoretical Models of Impinging Jet Atomization; Effect of Flow Conditions; Droplet Size Distribution; Orifice L/ D Ratio and Impingement Length Effects; Primary Atomization Mechanisms. Introduction to Spray; Confined and Unconfined Sprays; Experimental Methods for Spray Characterization; Effect of Gas Velocity; Orifice Diameter; Flow Rate; Chamber Pressure on Spray Characteristics; Composite Mean Droplet Sizes.	10
5	**Rocket Plume:**	Rocket Plume: Introduction; Chemical Origin of Smoke; Homogeneous and Heterogeneous Nucleation of Smoke; Plume Visibility; Ionization in Rocket Exhaust Plume; Smoke Measurements; Methods for Reducing Smoke.	7

Learning Resources	
Text Books	***Reference Books***
1. Solid Propellant Chemistry, Combustion and Motor Interior Ballistics – Yang, V., Brill, T.B. and Ren, W., Progress in Astronautics & Aeronautics, Vol. 185, AIAA, 2000. 2. Advanced Propulsion Systems and Technologies, Today to 2020, Bruno, C., Accettura, A.G., Progress in Astronautics & Aeronautics, Vol. 223, AIAA, 2009.	1. Liquid Rocket Engine Combustion Instability – Yang, V., Anderson, W., Progress in Astronautics & Aeronautics, Vol. 169, AIAA, 1995. 2. Fundamentals of Solid Propellant Combustion – Kuo, K.K., Summerfield, M., Progress in Astronautics & Aeronautics, Vol. 90, AIAA, 1984. 3. Rocket Propulsion Elements, Sutton, G.P., Biblarz, O., 7th Ed. John Wiley & Sons, Inc., New York, 2001

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 and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	Assignment(s)	10%				
	Seminar before a Committee	10%				
	Assessment Components	***CO1***	***CO2***	***CO3***	***CO4***	***CO5***
	Continuous Internal Assessment					
	Semester End Examination					
Indirect Assessment	Student Feedback on Faculty					
	Student Feedback on Course Outcome					

Mapping Between Course Outcomes and Program Outcomes

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	2	3	2	2	3
CO2	2	1	2	1	2	3
CO3	2	1	2	1	2	2
CO4	3	2	3	2	2	3
CO5	3	2	3	2	2	3

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 Course Outcomes and Course Delivery Method	
Course Outcomes	**Course Delivery Method**
CO1	CD1,CD2,CD3, CD6
CO2	CD1, CD3, CD6
CO3	CD1, CD6
CO4	CD1, CD2, CD3, CD6
CO5	CD1,CD3, CD6

Course Designers		
Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

COURSE INFORMATION

Course code	**SR 26521**
Course title	**Computational Combustion**
Pre-requisite(s)	NA
Co-requisite	NA
Credits	L: 3 T:0 P:0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace Engineering
Name of Teacher	Dr. Pawan Kumar Ojha

Course Objectives
This course aims to provide students with:

Sl No.	Objectives
1	Introduce the governing equations of chemical kinetics, mass, momentum, and heat transfer
2	Introduce advanced mathematical modeling of laminar and turbulent flames
3	Employ methods of computational fluid dynamics for numerical solution of models developed for complex flow and combustion problems
4	Understand the best practices for reliable predictions from complex computational models of combustion problems

Course Outcomes (COs) *Upon successful completion of the course, students will be able to*	
CO	Course Outcomes
1	Demonstrate capability to analyze governing equations and coupling among them
2	Be able to solve ignition problems
3	Be able to solve laminar flame propagation problems using multistep kinetics
4	Be able to apply the concepts used in the modeling of turbulent flames for selecting appropriate models during calculations
5	Be able to comprehensively analyze complex combustion problems using specialized software

Syllabus

Module No.	***Module name***	***Detailed Contents***	***No. of Lecture***
1	**Governing Equations for Reacting Flows and Solution Methods:**	Governing equations for mass, energy, momentum, and species transport; constitutive relations; chemical kinetics models; boundary and initial conditions; solution methods and algorithms; solution strategies for reacting flows.	6
2	**Laminar Reacting Flows:**	Solution of ignition and flame propagation problems; premixed combustion, non-premixed combustion, partially premixed combustion; wall-stabilized laminar flames; laminar flame dynamics.	7
3	**Turbulent Reacting Flows:**	Description of turbulence, scales of turbulence, turbulence models; turbulence-flame interactions; premixed combustion; progress variable, turbulent flame speed, EBU/ED and BML models; nonpremixed combustion; mixture fraction, PDF methods; partially premixed combustion; explicit accounting of chemical kinetics in turbulence.	12
4	**Liquid-Gas Reacting Flows:**	Simplified models of droplet combustion; detailed multiphase flow models; atomizer modeling; ignition and stabilization of spray flame.	6
5	**Advanced Topics:**	Solid propellant combustion; compressible flow equations; low Mach number approximation; supersonic combustion; convergence and error analysis.	9

<table>
<tr><th colspan="2">Learning Resources</th></tr>
<tr><th>Text Books</th><th>Reference Books</th></tr>
<tr><td>1. T. Poinsot and D. Veynante. Theoretical and Numerical Combustion. 2nd Edition. R. T. Edwards Inc., USA (2005).</td><td>1. J. Warnatz, U. Mass, and R. W. Dibble. Combustion: Physical and Chemical Fundamentals, Modeling and Simulation, Experiments, Pollutant Formation. 3rd Edition. Springer-Verlag, Germany (2001).
2. R. Fox. Computational Models for Turbulent Reacting Flows. Cambridge University Press, UK (2003).
3. E. S. Oran and J. P. Boris. Numerical Simulation of Reactive Flow. 2nd Edition. Cambridge University Press, UK (2001).</td></tr>
</table>

<table>
<tr><td>Gaps in the Syllabus (to meet Industry/Profession requirements)</td><td>• Computational modeling of solid propellant combustion
• Different approaches in computations of nonpremixed flames</td></tr>
<tr><td>Pos met through Gaps in the Syllabus</td><td><table>
<tr><th>Gaps in Syllabus</th><th>POs</th></tr>
<tr><td>Computational modeling of solid propellant combustion</td><td>PO1</td></tr>
<tr><td>Different approaches in computations of nonpremixed flames</td><td>PO1, PO6</td></tr>
</table></td></tr>
<tr><td>Topics beyond syllabus/Advanced topics/Design</td><td>Large eddy simulation of reacting flows</td></tr>
<tr><td>Pos met through Topics beyond syllabus/Advanced topics/Design</td><td><table>
<tr><th>Topic beyond Syllabus</th><th>POs</th></tr>
<tr><td>Large eddy simulation of reacting flows</td><td>PO6</td></tr>
</table></td></tr>
</table>

Course Outcome (Co) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	Assignment(s)	10%				
	Seminar before a Committee	10%				
	Assessment Components	***CO1***	***CO2***	***CO3***	***CO4***	***CO5***
	Continuous Internal Assessment					
	Semester End Examination					
Indirect Assessment	Student Feedback on Faculty					
	Student Feedback on Course Outcome					

Mapping Between Course Outcomes and Program Outcomes

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	1	-	2	-	-	3
CO2	1	-	3	3	-	3
CO3	3	-	3	3	-	3
CO4	3	-	2	2	-	3
CO5	3	3	3	3	2	3

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 Course Outcomes and Course Delivery Method

Course Outcomes	**Course Delivery Method**
CO1	CD1,CD2,CD3, CD6
CO2	CD1, CD2, CD3, CD6
CO3	CD1, CD6
CO4	CD1, CD2, CD3, CD6
CO5	CD1,CD2, CD3, CD6

Course Designers

Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

COURSE INFORMATION

Course code	**SR 26522**
Course title	Cryogenic Propulsion
Pre-requisite(s)	NA
Co-requisite	NA
Credits	L: 3 T:0 P:0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace Engineering
Name of Teacher	Dr. Rajiv Kumar

Course Objectives
This course aims to provide students with:

Sl No.	Objectives
1	Identify cryogenic substance and examine its characteristics in cryogenic environments.
2	Analyze the storage and transfer vessel arrangements for the suitability of cryogenic propulsion system.
3	Explain the working concept of the turbo-pump feed system designed for cryogenic fluids.
4	Analyze the various challenges associated with cryogenic propulsion systems
5	Design cryogenic propulsion system for the given operating conditions

Course Outcomes (COs) *Upon successful completion of the course, students will be able to*	
CO	Course Outcomes
1	To demonstrate the characteristics of the cryogenic fluid and the challenges acquired in achieving it.
2	To design and demonstrate the storage vessels used for the practical application of cryogenic propulsion system.
3	To analyse the turbo-pump feed system utilized for injecting cryogenic fluid and various challenges associated with it.
4	To examine cryogenic propulsion system and their various challenges associated during practical operating conditions.
5	To interpret the various testing process to be conducted prior to the actual launch of the cryogenic propulsion system.

Syllabus

Module No.	*Module name*	*Detailed Contents*	*No. of Lecture*
1	**Introduction to Cryogenics:**	Cryogenic fluid, Materials at low temperature mainly for cryogenic propulsion, Thermo physical and fluid dynamic properties of liquid and gas hydrogen and oxygen, Liquefaction systems of hydrogen and oxygen gases, Joule Thomson effect and inversion curve; Adiabatic and isenthalpic expansion with their comparison. Cryogenic heat exchangers.	8
2	**Storage and Loading of Cryogenic Liquids:**	Design considerations of storage vessel; Dewar vessels; Storage of cryogenic fluids in space; Transfer systems and Lines for cryogenic liquids; Cryogenic valves in transfer lines; Two phase flow in Transfer system; Cool-down of storage and transfer systems, Measurement of strain, pressure, flow, liquid level and Temperature in cryogenic environment.	8
3	**Turbo-Pump Feed System:**	GG cycle, Expander cycle and SSC and their performance comparison. Various types of turbine and pumps and their arrangements in turbo-pump feed system. Prevention of pump cavitation-NPSH, Starting of the turbo-pump system at time t=0. Bearing and Sealants. Design of injectors-various types and injection pattern, fluid flow circuits of various rockets such as SSME, SPACEX, Ariane etc.	8
4	**Cryogenic Propulsion System:**	Cryogenic propellants, fuels and oxidizers – properties, performance comparison, evaporation system for cryogenic propellants, Geysering Phenomenon and its prevention, Zero –'g' problem, Effects and prevention of Thermal Stratification; Methods of Elimination of Thermal Stratification. On-board storage of cryogenic propellants and insulation, LOX-Methane propulsion system, Semi-cryo system using LOX and Kerosene and tri-propellant system using kerosene+LOX+LH2.	8
5	**Cryogenic Engine Testing:**	Test Configuration and Test Readiness, Hot Run, Hot run Preparation, Start up Transient, Control and Regulation, Monitoring of Engine parameters, Shut-down and Transient, Engine Performance Map, Principles of Erection of Test facilities, Fuel and Oxidizer supply, Measurement, Control and Command System, Detection system.	8

Learning Resources	
Text Books	***Reference Books***
1. Cryogenic Process Engineering, Timmerhaus, K.D, Flynn, T.M, Plenum Press, USA, 2009. 2. Operation of a Cryogenic Rocket Engine, Wolfgaug K., Springer-Verlag Berlin Heidelberg 2011.	1. Rocket Propellant and Pressurization Systems, Ring, E, Prentice Hall Inc, N.J., 1964. 2. Cryogenic Engineering, Flynn, T.M, Dekker, M., Plenum Press, USA, 2009. 3. Design of Liquid Propellant Rocket Engine, Huzel, D.K., Huang, D.H., NASA SP-125, Scientific and Technical Information Division, NASA, Washington, 1971.

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 and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	Assignment(s)	10%				
	Seminar before a Committee	10%				
	Assessment Components	***CO1***	***CO2***	***CO3***	***CO4***	***CO5***
	Continuous Internal Assessment					
	Semester End Examination					
Indirect Assessment	Student Feedback on Faculty					
	Student Feedback on Course Outcome					

Mapping Between Course Outcomes and Program Outcomes

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	2	1	1	2	3
CO2	3	2	2	2	3	3
CO3	3	2	3	3	2	3
CO4	2	2	2	2	2	3
CO5	1	1	1	1	2	3

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 Course Outcomes and Course Delivery Method

Course Outcomes	**Course Delivery Method**
CO1	CD1,CD2,CD3, CD6
CO2	CD1, CD3, CD6
CO3	CD1, CD6
CO4	CD1, CD2, CD3, CD6
CO5	CD1,CD3, CD6

Course Designers

Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

COURSE INFORMATION

Course code	**SR 26523**
Course title	**Combustion Instability in Rocket Engines**
Pre-requisite(s)	NA
Co-requisite	NA
Credits	L: 3 T:0 P:0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace Engineering
Name of Teacher	Dr. Pawan Kumar Ojha

Course Objectives *This course aims to provide students with:*	
Sl No.	Objectives
1	To introduce concepts useful for understanding combustion instability
2	To introduce measurement methods for combustion instability
3	To introduce methods for analysis of combustion instability using linear theory
4	To introduce methods for mitigation and stabilization of combustion instability
5	To introduce the effects of instability in the design of rocket motors

Course Outcomes (COs) *Upon successful completion of the course, students will be able to*	
CO	Course Outcomes
1	Identify the type of combustion instability in different types of rocket motors
2	Analyze experimental data on combustion instability
3	Identify measures to be taken for stabilizing unstable combustion
4	Carry out linear instability analysis
5	Design rocket motors with consideration to the effects of instabilities

Syllabus

Module No.	*Module name*	*Detailed Contents*	*No. of Lecture*
1	**Introduction to Combustion Instability:**	Steady and unsteady combustion; origins of combustion instability; types of combustion instability; effects of combustion instability; factors affecting combustion instability.	4
2	**Instabilities in Solid Rocket Propulsion :**	Introduction; general features; bulk, transverse, and axial mode instabilities; aerodynamic instabilities; processes contributing to stability; measurement methods for stability testing; particulate damping; effect of propellant characteristics; control of combustion instability.	9
3	**Instabilities in Liquid Rocket Propulsion :**	Overview; classification of instabilities; initiation of instabilities; dynamic stability; dynamics of processes in liquid rocket engines; wave propagation; effects of design factors on excitation and damping; effects of atomization and droplet combustion; experimental evaluation of instability; control of combustion instability.	10
4	**Analysis of Combustion Instability:**	Introduction; thermal lags in solid phase; linear analysis of instability in solid rocket motors; analysis of low, intermediate, and high-frequency instability in liquid rocket engines using time lag models.	8
5	**Instabilities in Hybrid Rocket Propulsion :**	Introduction; subsystems of hybrid rocket motors; transient events in hybrid rocket propulsion; hybrid rocket instabilities; feed system coupled instabilities; chuffing; low-frequency instabilities; comparison among solid, liquid, and hybrid low-frequency instabilities; experimental evaluation of instability; driving mechanisms for instabilities; control of combustion instability; analysis of instability in hybrid rocket motors.	9

Learning Resources	
Text Books	***Reference Books***
1. M. Barrere, A. Jaumotte, B.F. DeVeubeke and J. Vandenkerchove, Rocket Propulsion, Elsevier (Latest Edition) (T1) 2. M.S. Natanzon and F.E.C. Culick, Combustion Instability, Progress in Astronautics and Aeronautics, 2008, ISBN: 978-1-56347-928-1, eISBN: 978-1-60086-691-3 (T2)	1. E.W. Price. Experimental observations of combustion instability (Chapter 13); J.S. T'ien. Theoretical analysis of combustion instability (Chapter 14). In K. Kuo and M. Summerfield (Eds.). Fundamentals of Solid-Propellant Combustion. Progress in Astronautics and Aeronautics Vol. 90, AIAA, New York, 1984. (R1) 2. V. Yang and W. Anderson (Eds.). Liquid Rocket Engine Combustion Instability. Progress in Astronautics and Aeronautics Vol. 169, AIAA, Washington DC, 1995. (R2) 3. A. Karabeyoglu. Combustion instability and transient behavior in hybrid rocket motors (Chapter 9). In M.J. Chiaverini and K.K. Kuo (Eds.) Fundamentals of Hybrid Rocket Combustion and Propulsion. Progress in Astronautics and Aeronautics Vol. 218, AIAA, Reston, Virginia, 2007. (R3)

Gaps in the Syllabus (to meet Industry/Profession requirements)	stability rating
Pos met through Gaps in the Syllabus	PO1
Topics beyond syllabus/Advanced topics/Design	nonlinear analysis of instability
Pos met through Topics beyond syllabus/Advanced topics/Design	PO1, PO4

Course Outcome (Co) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	Assignment(s)	10%				
	Seminar before a Committee	10%				
	Assessment Components	***CO1***	***CO2***	***CO3***	***CO4***	***CO5***
	Continuous Internal Assessment					
	Semester End Examination					
Indirect Assessment	Student Feedback on Faculty					
	Student Feedback on Course Outcome					

Mapping Between Course Outcomes and Program Outcomes

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	1	3	2	1	3
CO2	2	3	3	3	1	3
CO3	3	3	3	2	2	3
CO4	2	3	3	3	2	3
CO5	3	1	3	3	2	3

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 Course Outcomes and Course Delivery Method	
Course Outcomes	**Course Delivery Method**
CO1	CD1
CO2	CD1, CD2, CD4
CO3	CD3
CO4	CD4
CO5	CD5

Course Designers		
Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

COURSE INFORMATION

Course code	**SR 26505**
Course title	**Flame Propagation & Stability**
Pre-requisite(s)	NA
Co-requisite	NA
Credits	L: 3 T:0 P:0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace Engineering
Name of Teacher	Dr. Shelly Biswas

Course Objectives

This course aims to provide students with:

Sl No.	Objectives
1	Understand the structure of laminar flames and the theories associated with flame propagation.
2	Perceive the structure of turbulent flames and comprehend theories associated with flame propagation.
3	Relate the concepts of flame noise and flame oscillation and the instabilities associated with it.
4	Interpret the concept of flame spreading and the mechanism involved.
5	Realize concept of stabilisation of flames and the methods involved therein.

Course Outcomes (COs) _Upon successful completion of the course, students will be able to_	
CO	Course Outcomes
1	Comprehend the structure of laminar flame and apply related theories of flame propagation for various types of laminar flames.
2	Apply the knowledge of structure of turbulent flames in predicting the factors affecting burning velocity.
3	Distinguish between flame noise and oscillation and mitigate their effect in combustion devices and rockets.
4	Analyse the concept of flame spreading and its mechanism on propellant grain surface and cracks.
5	Evaluate the methods of stabilisation of flames and their application in burners.

Syllabus

Module No.	*Module name*	*Detailed Contents*	*No. of Lecture*
1	**Laminar Flame Propagation:**	Structure of Laminar Flame; Temperature Profile; Concentration Profile; Adiabatic Plane Combustion Wave; General Description of Heat Sink and Flow Effects; Laminar Flame Propagation in Tubes; Theories of Laminar Flame Propagation - Thermal Theories, Semenov Equation, Diffusion Theories, Comprehensive Theories; Limits of Flammability	8
2	**Turbulent Flame Propagation:**	Description of Turbulent Flames; Concept of Turbulent Flow; Turbulent Burning Velocity; Factors affecting Turbulent Burning Velocity; Structure of a Turbulent Flame; Turbulent Flame Theories.	8
3	**Flame Noise and Flame Oscillations:**	Jet Noise; Singing Flames; Combustion Chamber Oscillations; Flame Flicker and other Instabilities; Sensitive Flames.	8
4	**Ignition Transient and Flame Spreading:**	Ignition and Thrust Transient in Solid Rocket Motors; Flame Spreading over Solid Propellants and Fuels; Flame Spreading Mechanism; Theories and Experiments; Flame Spreading into Solid Propellant Cracks and Flaws; Theories and Experiments of Flame Spreading in Propellant Cracks.	8
5	**Flame Stability:**	Flame stabilization; Characteristic Stability Diagram; Mechanism of Flame Stabilization; Flame Stretch Theory; Flames Supported by Inserting a Solid Object in a Gas Stream; Flame Stabilization by Eddies; Quenching Distance; Penetration Distance and Dual Space.	8

Learning Resources	
Text Books	***Reference Books***
1. S. R. Turn, An Introduction to Combustion-Concepts and Applications, 3rd Edition, Tata McGraw-Hill, India, 2012. (T1) 2. K. K. Kuo, Principles of Combustion, John Wiley and Sons, New York, 1986. (T2)	1. B. Lewis and G. von Elbe, Combustion, Flames and Explosions of Gases, 3rd Edition, Academic Press, Orlando, 1987. (R1) 2. A. G. Gaydon and H. D. Wolfhard, Flames: Their Structure, Radiation and Temperature, 3rd Edition, Springer USA, 1970.(R2)

Gaps in the Syllabus (to meet Industry/Profession requirements)	Hand down practical training on turbulent flame propagation
Pos met through Gaps in the Syllabus	PO5 will be met through virtual lab/presentation/assignment.
Topics beyond syllabus/Advanced topics/Design	Flame propagation in mines/closed spaces and design of burners
Pos met through Topics beyond syllabus/Advanced topics/Design	PO6

Course Outcome (Co) Attainment Assessment Tools and Evaluation Procedure

<table>
<tr><td rowspan="11">Direct Assessment</td><td>Assessment Tool</td><td colspan="5">% Contribution during CO Assessment</td></tr>
<tr><td>Continuous Internal Assessment</td><td colspan="5">50%</td></tr>
<tr><td>Semester End Examination</td><td colspan="5">50%</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td>Continuous Internal Assessment</td><td colspan="5">% Distribution</td></tr>
<tr><td>Best 2 Quiz marks out of 3 Quizzes of 15 marks each.</td><td colspan="5">30%</td></tr>
<tr><td>Assignment(s)</td><td colspan="5">10%</td></tr>
<tr><td>Seminar before a Committee</td><td colspan="5">10%</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td>Assessment Components</td><td>CO1</td><td>CO2</td><td>CO3</td><td>CO4</td><td>CO5</td></tr>
<tr><td>Continuous Internal Assessment</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>Semester End Examination</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Indirect Assessment</td><td colspan="6">Student Feedback on Faculty</td></tr>
<tr><td colspan="6">Student Feedback on Course Outcome</td></tr>
</table>

Mapping Between Course Outcomes and Program Outcomes

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	2	3	1	1	2
CO2	2	2	3	1	1	2
CO3	3	3	3	3	1	3
CO4	3	2	3	2	1	3
CO5	3	3	3	3	2	3

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 Course Outcomes and Course Delivery Method

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

Course Designers

Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

COURSE INFORMATION SHEET

Course code: SR 26556
Course title: Solid Rocket Propulsion lab
Pre-requisite(s): NA
Co- requisite(s): NA
Credits: 2 L:0 T:0 P:3
Class schedule per week: 4
Class: M.Tech
Semester / Level: II/05
Branch: SER
Name of Teacher: Dr. Rajiv Kumar/Dr. Shelly Biswas

Course Objectives: This course enables the students to:

1.	Understand the significance of the experiment with respect to theoretical information.
2.	Collect and interpret data obtained from experiments.
3.	Examine the results in a group of team and evaluate it to utilize in preparing the report.
4.	Explain the working and designing procedure of the solid rocket motor.
5.	Follow and utilize all the safety features required during the experimentations

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

CO1	To analyze the types of error observed during the experiments.
CO2	To explain the significance of the processing of the propellants in correlation with practical applications.
CO3	To comprehend and illustrate various methods of improving the burn rate in a solid rocket motor
CO4	To operate the solid rocket experimental setup and generate results for the meaning analysis as an individual and as in a group.
CO5	To identify the equipments used in the experiment along with their significance of using them.

List of the Experiments:

1. **<u>Experiment No. 1</u>**
   Name : Introduction to solid rocket and its processing lab
   Objective : To introduce and give brief information about the equipments used in solid rocket propulsion lab.

2. **<u>Experiment No. 2</u>**
   Name : Preparation of fuel grain

Objective : Processing of solid composite propellant grain with different perforations having compositions as PVC-DBP and AP.

3. **Experiment No. 3**

Name : Rheological study

Objective : To study the rheological properties of the freshly prepared solid propellant mix.

4. **Experiment No. 4**

Name : Heat of Combustion

Objective : To determine the heat of combustion of solid propellant sample at least at two different inert gas pressures.

5. **Experiment No. 5**

Name : Study of mechanical properties

Objective : To evaluate the mechanical properties of composite solid propellant.

6. **Experiment No. 6**

Name SEM Analysis

Objective : To study the surface morphology of solid propellant with the help of Scanning Electron Microscope.

7. **Experiment No. 7**

Name : Experiments on STA

Objective : Thermal decomposition study of solid propellant with the help of Simultaneous Thermal Analyzer.

Experiment No. 8

Name : Burn rate measurement at higher pressure

Objective : To measure the burn rate of solid propellant strands at various pressures by using Crawford Bomb set-up.

Experiment No. 9

Name : Burn rate measurement at sub-atmospheric pressure

Objective : To measure the burn rate of solid propellant strands at sub-atmospheric pressures.

8. **Experiment No. 10**

Name : Preparation of igniter

Objective : To prepare pyrotechnic igniters and determine its ignition delay.

9. **Experiment No. 11**

Name : Solid Rocket Static Firing

Objective : To perform static solid rocket firing and determine its performance parameters such as thrust and Specific impulse.

Reference books:

1. Rocket Propulsion Elements – Sutton, G. P. and Biblarz, O., 7th Ed.
2. Understanding Aerospace Chemical Propulsion, H S Mukunda.
3. Rocket Propulsion, K Ramamurthi.

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 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 Program Outcome and Course Outcomes

Mapping of Course Outcomes onto Program Outcomes

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

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

Mapping between COs and Course Delivery (CD) methods

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

COURSE INFORMATION SHEET

Course code: SR 26557
Course title: Liquid and Hybrid Propulsion Lab
Pre-requisite(s): NA
Co- requisite(s):NA
Credits: 2 L:0 T:0 P:3
Class schedule per week: 4
Class: M.Tech
Semester / Level: II/05
Branch: SER
Name of Teacher: Dr. Rajiv Kumar/ Dr. Shelly Biswas

Course Objectives : This course enables the students to:

1.	Understand the significance of the experiment with respect to theoretical information.
2.	Collect and interpret data obtained from experiments.
3.	Examine the results in a group of team and evaluate it to utilize in preparing the report.
4.	Explain the working and designing procedure of the liquid and hybrid rocket motor.
5.	Follow and utilize all the safety features required during the experimentations

Course Outcomes

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

CO1	To analyze the types of error observed during the experiments.
CO2	To explain the various methods of improving the burn rate in a hybrid rocket motor
CO3	To operate the experimental setup and collect data as an individual and as in a group.
CO4	To demonstrate the output of the results for the meaningful analysis.
CO5	To identify the equipments used in the experiment with their significance of using them.

List of the Experiments:

1. **<u>Experiment No. 1</u>**
   Name : Introduction to liquid and hybrid lab
   Objective : To introduce and give brief information about the equipments used in liquid and hybrid lab
2. **<u>Experiment No. 2</u>**
   Name : Preparation of fuel grain
   Objective : Processing of PVC-Plastisol based hybrid fuel grain with tubular perforation of two different compositions.

3. **Experiment No. 3**
   Name : Effect of solid loading on regression rate
   Objective : To study the effect of solid loading on the regression rate of PVC based fuel in a hybrid rocket motor.
4. **Experiment No. 4**
   Name : Pressure Effect on Regression Rate
   Objective : To Study the effect of chamber pressure on regression rate in a hybrid rocket motor.

5. **Experiment No. 5**
   Name : Processing of paraffin based fuel
   Objective : To measure regression rate of paraffin based fuel and compare with the PVC based fuel in a hybrid rocket.

6. **Experiment No. 6**
   Name : Effect of injectors
   Objective : To study the effect of varying oxidizer injectors on the regression rate of hybrid fuel.

7. **Experiment No. 7**
   Name : Performance Evaluation through CEA Software
   Objective : To Evaluate the theoretical performace parameters of the given fuel and oxidizer combinations at various O/F ratios.
8. **Experiment No. 8**
   Name : Effect of protrusion on efficiencies
   Objective : To study the effect of protrusion on the efficiencies of hybrid rocket motor.
9. **Experiment No. 9**
   Name : Synthesis of energetic fuel
   Objective : Synthesis of the Aniline-Furfuryldehyde condensate as hybrid fuel.

10. **Experiment No. 10**
    Name : Ignition delay test
    Objective : To conduct hypergolic ignition delay test for the Aniline-Furfuryldehyde hybrid fuel with red fuming nitric acid.

11. **Experiment No. 11**
    Name : Effect of burn duration on regression rate
    Objective : To study the effect of burn duration on the regression rate using PVC-DBP as a hybrid fuel.
12. **Experiment No. 12**
    Name : Liquid rocket firing
    Objective : To conduct experiment on a liquid rocket firing set-up to understand the operation of liquid rocket engine.

Reference books:

1. Design of Liquid Propellant Rocket Engine – Huzel, D. K. & Huang, D. H., NASA SP-125.
2. Fundamental of Hybrid Rocket Combustion and Propulsion, Martin J. Chiaverini and Kennith K. Kuo, Progress in Aeronautics & Astronautics, Vol. 218, AIAA.
3. Rocket Propulsion Elements – Sutton, G. P. and Biblarz, O., 7th Ed.
4. Understanding Aerospace Chemical Propulsion, H S Mukunda

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 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

<u>Mapping between Program Outcome and Course Outcomes</u>

Mapping of Course Outcomes onto Program Outcomes

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

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

Mapping between COs and Course Delivery (CD) methods

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

Department of Space Engineering and Rocketry
Birla Institute of Technology, Mesra, Ranchi - 835215 (India)

M. Tech. (Aerospace Engineering)-Structures
SEMESTER-II

COURSE INFORMATION

Course code	**SR 26591**
Course title	**Advanced Aerospace Structures**
Pre-requisite(s)	**Aerospace Structures**
Co-requisite	Physics and Mathematics
Credits	L:3 T:0 P:0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace Engineering
Name of Teacher	Dr. Abha Gupta

Course Objectives
This course aims to provide students with:

Sl No.	Objectives
1.	Develop a clear understanding of shear behavior in structural members, with emphasis on both open- and closed-section beams.
2.	Analyse the torsional behavior of solid bar, single-cell and multi-cell thin-walled section
3.	Apply the structural idealization approach for the analysis of Aircraft Wing and Fuselage.
4.	Explain the buckling characteristics in the column with different boundary condition.
5.	Analyse the elastic buckling of thin plates though different Governing equations.

Course Outcomes (COs) *Upon successful completion of the course, students will be able to*	
CO	Course Outcomes
CO1.	To explain the fundamentals of transverse shear stress, in-plane shear stress, shear flow, and their significance in structural elements.
CO2.	To analyse torsional behavior of wing structures through modeling it as single-cell and multi-cell thin-walled section.
CO3.	To determine structural behavior like shear and torsional properties of Aircraft Wing and Fuselage.
CO4.	To evaluate the critical buckling load for column under different boundary conditions.
CO5.	To calculate the critical buckling load in thin plates for different boundary conditions.

Syllabus

Module No.	*Module name*	*Detailed Contents*	*No. of Lecture*
1	**Shear of Thin-walled Beams**	Transverse shear stress and in-plane shear stress in thin-walled structural members; concept and evaluation of shear flow and its distribution in open and closed cross-sections; Determination of shear center; Analysis of shear behavior in thin-walled open and closed section beams.	10
2	**Torsion of solid and thin-walled beam**	Torsional behavior of solid and thin-walled structural members subjected to twisting moments; Torsion of uniform bars, analysis of closed single-cell and multicell thin-walled sections, determination of torsional stiffness and shear flow distribution, and application to aerospace structures.	10
3	**Aerospace Structural Design and Analysis**	Structural Idealization- Idealization of panel, Effect of idealization on the analysis of open and closed section beams, Shear loading of closed section beams; Stress Analysis of Aircraft Components- Wing spars and box beams, Fuselages.	8
4	**Buckling of Columns**	Buckling behavior of slender structural members under compressive loading, including determination of critical buckling loads using Euler's theory for columns with different end conditions. Effect of load eccentricity on buckling response, stability, and load-carrying capacity, with applications to aerospace structural components subjected to compressive loads.	4
5	**Elastic buckling of thin plates**	Elastic buckling behavior of thin plates subjected to in-plane compressive loading, including formulation of governing equations and boundary conditions using the equilibrium approach. Energy-based methods for plate buckling analysis, derivation of governing equations through variational principles, and evaluation of critical buckling loads for different plate geometries and support conditions.	8

Learning Resources

Text Books	*Reference Books*
1. Mechanics of aircraft structures: C.T.Sun, 3rd Ed , John Wiley	1. Aircraft structures" : D.J.Peery, McGraw Hill, 1950

publishers	
2. Structural stability of Columns and Plates : N G R Iyengar, John Wiley & sons	2. Aircraft Structures for Engineering Students, T.H.G. Megson, 4th Ed., Elsevier Ltd
3. Structural and Stress Analysis. Book, Third Edition, 2014. Author: T.H.G. Megson	

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 and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	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

Mapping Between Course Outcomes and Program Outcomes

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	2	3	1	1	2
CO2	2	2	3	1	2	2
CO3	3	2	3	2	2	3
CO4	2	1	2	2	1	2
CO5	3	2	3	2	2	3

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 (SL) such as use of NPTEL materials and internets
CD7	Simulation

Mapping Between Course Outcomes and Course Delivery Method	
Course Outcomes	**Course Delivery Method**
CO1	CD1,CD2, CD6
CO2	CD1, CD2, CD6
CO3	CD1, CD2, CD6
CO4	CD1, CD2, CD6
CO5	CD1, CD6

Course Designers		
Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

COURSE INFORMATION

Course code	**SR 26592**
Course title	Vibration and Structural Dynamics
Pre-requisite(s)	**Theory of Machines**
Co-requisite	Physics and Mathematics
Credits	L: 3 T:0 P:0 SL: 0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace Engineering
Name of Teacher	Dr Sudip Das

Course Objectives

This course aims to provide students with:

Sl No.	Objectives
1.	Introduce the fundamentals of vibration which includes single- and multi-degree of freedom system with damping.
2.	To familiarize students with classical and energy-based solution methods for free vibration analysis.
3.	To derive the equation of motion for forced vibration of SDOF systems and interpret the resulting dynamic behavior.
4.	To formulate mass, stiffness, and damping matrices for 2DOF and MDOF mechanical systems.
5.	To analyze multi-degree-of-freedom and continuous vibratory systems and understand their physical and mathematical differences.

Course Outcomes (COs)

Upon successful completion of the course, students will be able to

CO	Course Outcomes
CO1.	To develop the ability to formulate equations of motion for single-degree-of-freedom (SDOF) systems using Newton's law, energy method, and D'Alembert's principle.
CO2.	Apply the classical and energy methods to obtain solutions for undamped free vibration.
CO3.	To determine structural forced vibration responses using strain energy, virtual work, and variational principles.
CO4.	To compute natural frequencies and mode shapes for undamped and damped 2DOF systems and interpret modal behavior.
CO5.	To apply modal decomposition to decouple equations of motion and obtain independent modal responses.

Syllabus

Module No.	***Module name***	***Detailed Contents***	***No. of Lecture***
1	**Free Vibration of SDOF**	Free vibration of an undamped SDOF system, differential equation of motion, classical solution, energy solution, simple harmonic motion, combinations of two simple harmonic motions, determining natural frequency and mode shapes. Free vibration of a viscously damped SDOF system, differential equation of motion, solution of a damped spring-mass system for underdamped	6
2	**Forced Vibration of SDOF**	Forced vibration- equation of motion, Steady-state response. Amplitude vs frequency response of undamped and damped SDOF systems to a constant force. Force transmissibility. Forced vibration, transient response, time-history response of SDOF systems, solution procedure. Response of a SDOF to a periodic force, Periodic function, and its Fourier series expansion	10
3	**Two Degree of Freedom**	**System** Vibration of two-degree-of-freedom systems, Mass, stiffness, and Damping Matrices, Natural frequencies, and mode shapes, Free vibration response of undamped and damped 2DOF systems	8
4	**Coordinate Coupling and Principal coordinates in 2DOF system**	Forced vibration analysis. Self excitation and stability analysis, Transfer function approach, Solution using Laplace transform and frequency transfer functions	8
5	**Multi-Degree of Freedom System**	Multi-degree-of-freedom system and its natural frequencies and mode shapes. Multi-degree-of-freedom system vs Continuous systems, Eigen value problem and its solution, Modal decomposition, Transverse vibration of strings	8

Learning Resources

Text Books	***Reference Books***
Mechanical Vibrations by Singiresu S. Rao, Pearson Education, 2017.	Vibration Engineering by G. K. Grover, Nem Chand & Bros., Roorkee, 8th Edition, 2019.

Engineering Vibration by Daniel J. Inman, Fourth Edition.	Vibration of Mechanical Systems by Alok Sinha, Cambridge University Press, 2010.

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 and Evaluation Procedure

<table>
<tr><td rowspan="13">Direct Assessment</td><td>Assessment Tool</td><td colspan="5">% Contribution during CO Assessment</td></tr>
<tr><td>Continuous Internal Assessment</td><td colspan="5">50%</td></tr>
<tr><td>Semester End Examination</td><td colspan="5">50%</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td>Continuous Internal Assessment</td><td colspan="5">% Distribution</td></tr>
<tr><td>Best 2 Quiz marks out of 3 Quizzes of 15 marks each.</td><td colspan="5">30%</td></tr>
<tr><td>Assignment(s)</td><td colspan="5">10%</td></tr>
<tr><td>Seminar before a Committee</td><td colspan="5">10%</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td>Assessment Components</td><td>CO1</td><td>CO2</td><td>CO3</td><td>CO4</td><td>CO5</td></tr>
<tr><td>Continuous Internal Assessment</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Semester End Examination</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

<table>
<tr><td rowspan="2">Indirect Assessment</td><td>1. Student Feedback on Faculty</td></tr>
<tr><td>2. Student Feedback on Course Outcome</td></tr>
</table>

<table>
<tr><td colspan="7">Mapping Between Course Outcomes and Program Outcomes</td></tr>
<tr><td>CO</td><td>PO1</td><td>PO2</td><td>PO3</td><td>PO4</td><td>PO5</td><td>PO6</td></tr>
<tr><td>CO1</td><td>2</td><td>2</td><td>2</td><td>1</td><td>2</td><td>2</td></tr>
<tr><td>CO2</td><td>1</td><td>1</td><td>2</td><td>1</td><td>2</td><td>2</td></tr>
<tr><td>CO3</td><td>3</td><td>2</td><td>3</td><td>2</td><td>2</td><td>3</td></tr>
<tr><td>CO4</td><td>3</td><td>2</td><td>3</td><td>2</td><td>2</td><td>3</td></tr>
<tr><td>CO5</td><td>2</td><td>3</td><td>2</td><td>2</td><td>2</td><td>2</td></tr>
<tr><td colspan="7"></td></tr>
</table>

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 (SL) such as use of NPTEL materials and internets
CD7	Simulation

Mapping Between Course Outcomes and Course Delivery Method	
Course Outcomes	**Course Delivery Method**
CO1	CD1,CD2, CD6
CO2	CD1, CD2, CD6
CO3	CD1, CD2, CD6
CO4	CD1, CD2, CD6
CO5	CD1, CD6

Course Designers		
Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

COURSE INFORMATION

Course code	**SR 26593**
Course title	**Mechanics of Composite Materials**
Pre-requisite(s)	**Strength of Materials**
Co-requisite	**Aerospace Structures**
Credits	L: 3 T:0 P:0 SL: 0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace Engineering
Name of Teacher	Dr. Abha Gupta

Course Objectives *This course aims to provide students with:*	
Sl No.	Objectives
1.	Introduce the fundamentals, types, design, and aerospace applications of composite materials
2.	To understand the elastic behavior, stress–strain relations, and failure mechanisms of composite lamina
3.	Analyse the elastic behavior of composite lamina using micromechanics and constitutive stress-strain relationships
4.	To understand composite manufacturing, testing, recycling, and repair techniques
5.	To understand the analytical methods and classical laminate theory for laminated composites.

Course Outcomes (COs) *Upon successful completion of the course, students will be able to*	
CO	Course Outcomes
CO1.	To Identify different types of composite materials, their constituents, and aerospace applications.
CO2.	To interpret the mechanical behavior and failure modes of unidirectional composites.
CO3.	Explain longitudinal and transverse behavior, shear modulus, and Poisson’s ratio of unidirectional composites.
CO4.	To analyse composite manufacturing processes, defect evaluation, repair methods, and recycling techniques.
CO5.	To apply laminate theories to determine stresses, and strains in laminated composite structures.

Syllabus

Module No.	*Module name*	*Detailed Contents*	*No. of Lecture*
1	**Introduction to composites**	Definition of composite materials, different types of composite materials- based on fibers and based on matrix, and behaviors of matrixes/reinforcements/interface; Applications of composites in Aerospace Industry	6
2	**Elastic Behavior of Composite Lamina**	Stress- Strain Relation, Transformation of Engineering Constants, Hooke's Law and Stiffness and Compliance Matrices, Failure Theories, Modes, Types of Failures.	10
3	**Behavior of Unidirectional Composites**	Introduction, Longitudinal Behavior of Unidirectional Composites, Transverse Stiffness and Strength, Prediction of Shear Modulus, Prediction of Poisson's Ratio	8
4	**Manufacturing, Testing, Recycling and Repairing of Advanced Composite Materials**	Manufacturing of composites & Recycling of Composites; Mechanical Testing & Destructive testing Method; Repair of Composites: Defects in composites, Non-destructive inspection techniques, Damage assessment, evaluation and classification	8
5	**Analysis of Laminated Composites**	Analytical approach for the analysis of laminated composite structures, including stress-strain relations, transformation of elastic properties, and evaluation of laminate stiffness. Constitutive formulation based on Classical Laminate Theory (CLT) and First Order Shear deformation theory (FSDT), development of laminate stiffness matrices (ABD matrices), and prediction of laminate response under mechanical loading	8

Learning Resources

Text Books	*Reference Books*
Mechanics of Composite Materials", R.M. Jones, Taylor & Francis	Autar K Kaw, Mechanics of Composite Materials, CRC Press
Analysis and Performance of Fiber Composites, B. D. Aggarwal, L. J. Broutman and K. Chandrashekhara, John Wiley & Sons	

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 and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	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

Mapping Between Course Outcomes and Program Outcomes						
CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	1	1	2	1	2	2
CO2	2	2	2	2	2	2
CO3	3	2	3	2	2	3
CO4	3	2	3	2	2	3
CO5	2	3	3	3	2	2

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 (SL) such as use of NPTEL materials and internets
CD7	Simulation

Mapping Between Course Outcomes and Course Delivery Method	
Course Outcomes	**Course Delivery Method**
CO1	CD1,CD2,CD3, CD6
CO2	CD1, CD3, CD6
CO3	CD1, CD6, CD7
CO4	CD1, CD2, CD3, CD6
CO5	CD1,CD3, CD6, CD7

Course Designers		
Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

COURSE INFORMATION

Course code	**SR 26594**
Course title	**Finite Element Methods**
Pre-requisite(s)	**Solid Mechanics and Theory of Elasticity**
Co-requisite	Engineering Mathematics
Credits	L: 3 T:0 P:0 SL: 0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace Engineering
Name of Teacher	Dr. Abha Gupta

Course Objectives *This course aims to provide students with:*	
Sl No.	Objectives
1.	Introduce fundamental computational methods, elasticity equations, variational principles, and types of engineering problems.
2.	Analyse finite element modeling, discretization, shape functions, stiffness matrix formulation, and numerical integration techniques.
3.	Interpret and solve 1-D structural problems including bars, trusses, and beams using finite element analysis.
4.	Analyse 2-D structural problems such as plane stress, plane strain, and plate behavior under mechanical and thermal loads.
5.	Apply finite element methods to study nonlinear behavior in structural systems.

Course Outcomes (COs) *Upon successful completion of the course, students will be able to*	
CO	Course Outcomes
CO1.	Explain elasticity solutions, weighted residual methods, and different types of computational problems.
CO2.	Analyze engineering problems using finite element discretization, stiffness formulation, and numerical integration techniques.
CO3.	Analyze 1-D structural elements such as bars, trusses, and beams using Finite Element Method.
CO4.	Analyze 2-D structural and plate problems using Finite Element Method and plate theories.
CO5.	To understand nonlinear finite element methods and its fundamentals

Syllabus

Module No.	*Module name*	*Detailed Contents*	*No. of Lecture*
1	**Introduction to Computational Method**	Basic equations in elasticity. Strong form and weak form; 3D Elasticity solution, 2D Elasticity - Navier Solution/closed-form solution; Variational Methods and Weighted Residual Methods; Types of problems (boundary value problem, eigenvalue problem, initial value problem).	7
2	**Introduction to Finite Element Method**	Finite element modeling, Discretization of a structure, Element Shapes, Nodes, Nodal Unknown, Linear and quadratic shape functions and its derivation for constant strain triangle, Lagrange and Serendipity elements, Convergence requirement; Coordinate systems, Strain displacement matrix, elemental stiffness matrix and load vector, Assembly to global stiffness matrix and global load vector; Properties of Stiffness Matrix, Boundary Condition, Stress calculation, Isoparametric formulation, Numerical Integration techniques, Refinement.	10
3	**Finite Element Analysis of 1-D Structures**	Fundamentals of the finite element method for one-dimensional structural members, including formulation and structural analysis of bars and trusses under axial loading. Finite element modeling of beam elements based on Euler-Bernoulli and Timoshenko beam theories, development of element stiffness matrices, and evaluation of displacement, stress, and deformation characteristics of structural systems.	10
4	**Finite Element Analysis of 2-D Structures**	Finite element formulation and structural analysis of two-dimensional continuum problems under plane stress and plane strain conditions. Finite element modeling of plate structures based on Kirchhoff and Mindlin plate theories, including development of element formulations and evaluation of displacement, stress, strain, and bending response.	10
5	**Introduction to Nonlinear FEM**	Introduction to Nonlinear problems- Material Nonlinearity, Geometry Nonlinearity; Analysis of geometric non-linear problems, iterative techniques.	3

Learning Resources

Text Books	*Reference Books*
1. Bhavikatti, S. S. Finite element analysis. New Age International, 2005	1. Introduction to finite elements in engineering", T.R.Chandrupatla and A.D.Belegundu, 4th Ed. , Prentice- Hall of India.

2. An Introduction to finite elements method, J.N. Reddy,Mc- Graw Hill .3rd Ed.	

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 and Evaluation Procedure

<table>
<tr><td rowspan="11">Direct Assessment</td><td>Assessment Tool</td><td colspan="5">% Contribution during CO Assessment</td></tr>
<tr><td>Continuous Internal Assessment</td><td colspan="5">50%</td></tr>
<tr><td>Semester End Examination</td><td colspan="5">50%</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td>Continuous Internal Assessment</td><td colspan="5">% Distribution</td></tr>
<tr><td>Best 2 Quiz marks out of 3 Quizzes of 15 marks each.</td><td colspan="5">30%</td></tr>
<tr><td>Assignment(s)</td><td colspan="5">10%</td></tr>
<tr><td>Seminar before a Committee</td><td colspan="5">10%</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td>Assessment Components</td><td>CO1</td><td>CO2</td><td>CO3</td><td>CO4</td><td>CO5</td></tr>
</table>

	Continuous Internal Assessment					
	Semester End Examination					

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

Mapping Between Course Outcomes and Program Outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	2	1	2	2
CO2	2	1	2	2	1	2
CO3	3	2	2	2	2	3
CO4	3	2	3	2	2	3
CO5	2	3	3	3	2	2

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 (SL) such as use of NPTEL materials and internets
CD7	Simulation

Mapping Between Course Outcomes and Course Delivery Method	
Course Outcomes	**Course Delivery Method**
CO1	CD1,CD2,CD3, CD6
CO2	CD1, CD3, CD6
CO3	CD1, CD6, CD7
CO4	CD1, CD2, CD3, CD6
CO5	CD1,CD3, CD6, CD7

Course Designers		
Experts from Industry	*Experts from Higher Technical Institutions*	*Internal Experts*

COURSE INFORMATION

Course code	**SR 26595**
Course title	**Beam, Plate, and Shell**
Pre-requisite(s)	**Solids Mechanics, Theory of Elasticity**
Co-requisite	Engineering Mathematics
Credits	L: 3 T:0 P:0 SL: 0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace Engineering
Name of Teacher	Dr. Abha Gupta

Course Objectives *This course aims to provide students with:*	
Sl No.	Objectives
1.	To understand the fundamental theories of beams, plates, and shells.
2.	To formulate governing equations and boundary conditions for structural elements.
3.	To analyze bending and vibration behavior of beam and plate structures.
4.	Interpret shell geometry, first-order shell theories, and structural responses using analytical and numerical methods.
5.	Apply flat shell element modeling techniques to analyze flat and folded shell structures.

Course Outcomes (COs) *Upon successful completion of the course, students will be able to*	
CO	Course Outcomes
CO1.	Apply beam theories for bending and vibration analysis.
CO2.	Formulate and analyze plate structures using classical and shear deformation theories.
CO3.	Evaluate static and dynamic responses of plate structures.
CO4.	Analyze shell structures using appropriate shell theories.
CO5.	Model flat and folded shell structures using numerical methods.

Syllabus

Module No.	*Module name*	*Detailed Contents*	*No. of Lecture*
1	**Euler and Timoshenko beam theories**	Modelling and approximation of beam; Derivation of governing equations and boundary conditions for isotropic beam structures; Analytical and numerical solution for bending and vibration analysis.	8
2	**Kirchoff and Mindlin plate theories**	Modeling and approximation of plate structures using Kirchhoff and Mindlin plate theories. Derivation of governing equations and boundary conditions for isotropic plate structures, including the effects of transverse shear deformation and their applicability to thin and moderately thick plates.	8
3	**Bending and Vibration Analysis of Plate Structures**	Analytical and numerical methods for the bending and vibration analysis of isotropic plate structures; Evaluation of static and dynamic responses, natural frequencies, and mode shapes under various loading and boundary conditions, with applications to aerospace structural components.	8
4	**Introduction to Shell Structures**	Differential geometry, Shell geometry, Basis vectors Love and Sander first order shell theories; Modelling and approximation of shell structures: Displacement, Strain, Stress; Analytical and numerical solution.	8
5	**Flat and Folded structures**	Modelling of shell structures using flat shell element; Modelling and approximation of flat shell element; Application of flat shell element for folded structures.	8

Learning Resources

Text Books	*Reference Books*
1. Structural Analysis with the Finite Element Method. Linear Statics: Volume 2: Beams, Plates and Shells. Eugenio Oñate.	1. Theory of Plates and Shells. Christian Mittelstedt. 1st ed. 2023
2. Stresses in Beams, Plates, and Shells, Ansel C. Ugural. Third Edition (Applied and Computational Mechanics)	

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 and Evaluation Procedure

<table>
<tr><td rowspan="12">Direct Assessment</td><td>Assessment Tool</td><td colspan="5">% Contribution during CO Assessment</td></tr>
<tr><td>Continuous Internal Assessment</td><td colspan="5">50%</td></tr>
<tr><td>Semester End Examination</td><td colspan="5">50%</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td>Continuous Internal Assessment</td><td colspan="5">% Distribution</td></tr>
<tr><td>Best 2 Quiz marks out of 3 Quizzes of 15 marks each.</td><td colspan="5">30%</td></tr>
<tr><td>Assignment(s)</td><td colspan="5">10%</td></tr>
<tr><td>Seminar before a Committee</td><td colspan="5">10%</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td>Assessment Components</td><td>CO1</td><td>CO2</td><td>CO3</td><td>CO4</td><td>CO5</td></tr>
<tr><td>Continuous Internal Assessment</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Semester End Examination</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

<table>
<tr><td rowspan="2">Indirect Assessment</td><td>1. Student Feedback on Faculty</td></tr>
<tr><td>2. Student Feedback on Course Outcome</td></tr>
</table>

Mapping Between Course Outcomes and Program Outcomes						
CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	2	2	1	2	2
CO2	2	3	2	2	1	2
CO3	3	2	3	3	2	3
CO4	3	2	3	2	3	3

CO5	2	1	2	2	1	2

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 (SL) such as use of NPTEL materials and internets
CD7	Simulation

Mapping Between Course Outcomes and Course Delivery Method	
Course Outcomes	**Course Delivery Method**
CO1	CD1,CD2,CD3, CD6
CO2	CD1, CD3, CD6
CO3	CD1, CD6, CD7
CO4	CD1, CD2, CD3, CD6
CO5	CD1, CD2, CD3, CD6

Course Designers		
Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

COURSE INFORMATION

Course code	**SR 26596**
Course title	**Aeroelasticity**
Pre-requisite(s)	**NA**
Co-requisite	NA
Credits	L: 3 T:0 P:0 SL: 0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace Engineering
Name of Teacher	Dr Priyank Kumar / Dr. Abha Gupta

Course Objectives *This course aims to provide students with:*	
Sl No.	Objectives
1.	Introduce fundamental concepts of aeroelasticity, structural flexibility, influence functions, and beam/torsion equations.
2.	Analyse static aeroelastic phenomena including static divergence of wings with different aspect ratios and sweep angles.
3.	Interpret control reversal effects in subsonic and supersonic flows for finite cantilevered wings.
4.	To understand the dynamic aeroelastic behavior of aerospace structures.
5.	To understand stability and flutter characteristics of aeroelastic systems.

Course Outcomes (COs) *Upon successful completion of the course, students will be able to*	
CO	Course Outcomes
CO1.	To identify fundamental aeroelastic concepts, structural flexibility, influence functions, and governing equations of beams and torsion members.
CO2.	To analyse static aeroelastic phenomena such as static divergence of unswept and swept wings.
CO3.	To interpret control reversal effects in subsonic and supersonic flows for finite cantilevered wings.
CO4.	Analyze frequency and damping characteristics of aeroelastic systems with variation in airspeed.
CO5.	Analyze stability, damping, and flutter behavior of aeroelastic systems using representative models.

Syllabus

Module No.	*Module name*	*Detailed Contents*	*No. of Lecture*
1	**Introduction to Aerospace Structures and Materials**	Introduction to aircraft structures; Basic structural components - wing, fuselage, fins, shell, motor casing, missile body etc; Aircraft material – Wood, Steel, Aluminum alloy, Titanium alloy, Composite materials; Loads on structural components; V-n diagrams; Area properties – Center of gravity, First moment of area, Second moment of area; Calculation of sectional properties	8
2	**Introduction to Aeroelastic modeling**	Static aeroelasticity Modeling of static aeroelastic. Static divergence of representative section. Static Divergence of Large-aspect-ratio unswept wings. Static Divergence of sweep wings	8
3	**Control Reversal**	Introduction. 2D case: subsonic and supersonic. Cantilevered finite wings. Dynamic control Reversal	8
4	**Dynamic Aeroelasticity**	Solution of Equations for 1D system, Frequency and Damping, Variation with air speed.	8
5	**Type of system response**	Subcritical, Critical, Supercritical. Stability Analysis, Routh-Hurwitz. Representative section, Representative section with no control section. Finite wing, One and two-degree of freedom flutter, flutter boundary characteristics.	8

Learning Resources

Text Books	*Reference Books*
1. Aero-Elasticity. Raymond L. Bisplinghoff, Holt Ashley and Robert L. Halfman. Addison Wesley Publishing Co. Inc., Cambridge,	1. Aircraft Structures for Engineering Students, T.H.G. Megson, 4th Ed., Elsevier Ltd, 2012.

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 and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	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

Mapping Between Course Outcomes and Program Outcomes

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	1	2	2	2	2
CO2	1	1	2	1	2	2
CO3	2	2	3	2	2	3
CO4	3	2	3	2	2	3
CO5	2	1	3	2	2	2

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 (SL) such as use of NPTEL materials and internets
CD7	Simulation

Mapping Between Course Outcomes and Course Delivery Method	
Course Outcomes	**Course Delivery Method**
CO1	CD1,CD2,CD3, CD6
CO2	CD1, CD3, CD6
CO3	CD1, CD6, CD7
CO4	CD1, CD2, CD3, CD6
CO5	CD1,CD3, CD6, CD7

Course Designers		
Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

<u>**COURSE INFORMATION SHEET**</u>

Course code: SR 26597
Course title: Computational Structures Laboratory
Pre-requisite(s): FEM and Aerospace Structures
Co- requisite(s): NA
Credits: L:2 T:0 P:0
Class schedule per week: 02
Class: M.Tech
Semester / Level: II/05
Branch: SER
Name of Teacher: Dr Abha Gupta

Course Objectives: This course enables the students to:

1.	Introduce the fundamental environment, syntax, and operations of MATLAB for engineering problem-solving.
2.	Develop the ability to model and analyse truss and bar structures using the Finite Element Method.
3.	Enable students to perform FEM-based bending analysis of beams, and plates
4.	Strengthen understanding of static and dynamic behaviour of isotropic and composite plates through numerical simulations.
5.	Apply transient and vibration analysis techniques to evaluate time-dependent and frequency-dependent responses of plate structures.

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

1.	Carry out MATLAB programming for solving basic engineering and numerical computation problems.
2.	Analyse truss and bar structures using FEM to compute nodal displacements, stress, and internal forces.
3.	Compute bending responses of beams and plates using FEM-based numerical models.
4.	Explain static and dynamic behaviour of isotropic and laminated composite plates
5.	Work with transient and free vibration FEM simulations

List of the Experiments:

1. <u>**Experiment No. 1**</u>
   Name : Introduction to MATLAB
   Objective :To familiarize students with the MATLAB environment, basic syntax, variables, and fundamental operations for engineering computations.

2. <u>**Experiment No. 2**</u>
   Name : Matrix Operations and Solution of Linear Systems using MATLAB
   Objective :To solve systems of linear equations using MATLAB.

3. **Experiment No. 3**
Name : Numerical Differentiation and Integration using MATLAB
Objective :To implement and analyze numerical methods for differentiation and integration using MATLAB.

4. **Experiment No. 4**
Name : Generation of Rectangular and Circular Mesh using MATLAB
Objective :To understand the fundamentals of computational mesh generation techniques.

5. **Experiment No. 5**
Name : Calculation and Plotting of Shape Functions using MATLAB
Objective : To understand the concept and formulation of shape functions used in finite element analysis.

6. **Experiment No. 6**
Name : Bending analysis of trusses and bars using FEM
Objective : To conduct FEM-based bending analysis of truss and bar structures using Euler–Bernoulli and Timoshenko beam theories.

7. **Experiment No. 7**
Name : Bending analysis of beams using FEM
Objective : To conduct FEM-based bending analysis of beam structures using Euler–Bernoulli and Timoshenko beam theories.

8. **Experiment No. 8**
Name : Compute laminate properties for given stacking sequences using MATLAB
Objective : Calculation of Laminate Stiffness Matrix [A], [B], [D] Using Classical Laminate Theory (CLT)

9. **Experiment No. 9**
Name : Bending analysis of plates using FEM
Objective : To conduct FEM-based bending analysis of plate structures using Kirchoff and Mindlin plate theories.

10. **Experiment No. 10**
Name : Bending analysis of laminated and sandwich composite plates using FEM
Objective : To conduct FEM-based bending analysis of laminated and sandwich compoiste structures using CLPT and FSDT.

11. **Experiment No. 11**
Name : Free Vibration analysis of isotropic and laminated composite plates
Objective : To conduct FEM-based Free Vibration analysis of Isotropic and laminated composite structures using CLPT and FSDT.

12. **Experiment No. 12**
Name : Transient analysis of isotropic and laminated composite plates
Objective : To conduct FEM-based Transient analysis of Isotropic and laminated compoiste structures using CLPT and FSDT.

Reference books:

1. Ferreira, A. J. M. (2009). MATLAB codes for finite element analysis: Solids and structures (Vol. 157). Springer.

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

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

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

Mapping Between COs and Course Delivery (CD) methods

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

COURSE INFORMATION SHEET

Course code: SR 26598
Course title: Experimental Structures Laboratory
Pre-requisite(s): NA
Co- requisite(s): NA
Credits: L:2 T:0 P:0
Class schedule per week: 02
Class: M.Tech
Semester / Level: II/05
Branch: SER
Name of Teacher: Dr. Abha Gupta

Course Objectives: This course enables the students to:

1.	To understand the structural behavior of aerospace components under different loading conditions.	
2.	To study buckling, torsion, and shear characteristics of engineering structures.	
3.	To understand fabrication techniques of polymer and composite materials.	
4.	To investigate the mechanical properties of engineering materials using standard testing methods.	
5.	To enhance experimental skills, data interpretation ability, technical reporting, and understanding of the relationship between theoretical concepts and laboratory observations in structural and composite engineering.	

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

1.	Analyze shear center, buckling, and torsional behavior of structural members.
2.	Carry out fabrication of polymer and composite materials using different manufacturing techniques.
3.	Perform hardness and impact testing of engineering materials.
4.	Evaluate mechanical properties of materials using experimental methods.
5.	Analyze experimental results, compare them with theoretical predictions, and prepare technical laboratory reports with proper interpretation and conclusions.

List of the Experiments:

1. **Experiment No. 1**
   Name : To find shear center of Channel section
   Objective : To determine the location of the shear center for channel and Z-sections subjected to transverse loading.

2. **Experiment No. 2**
   Name : Column Buckling Test
   Objective : To verify the Euler buckling equation for steel columns of various lengths subjected to different end conditions

3. **<u>Experiment No. 3</u>**

Name : Effect of Carbon Black on the properties of Natural Rubber Compound
Objective :

4. **<u>Experiment No. 4</u>**

Name : Fabrication -I – Preparation of Polymer Composite
Objective : To prepare and study polymer composites for engineering applications.

5. **<u>Experiment No. 5</u>**

Name : Fabrication -II – GFRP Polyester Sheet
Objective : To fabricate a composite laminate using the hand lay-up process and understand the basic steps involved in it.

6. **<u>Experiment No. 6</u>**

Name : Fabrication -III – Natural fiber reinforce polymer composite
Objective : To prepare a jute fiber reinforced polyester resin composite and study its applications.

7. **<u>Experiment No. 7</u>**

Name : Brinell Hardness Test
Objective : To determine the hardness of engineering materials using the Brinell hardness testing method.

8. **<u>Experiment No. 8</u>**

Name : Rockwell Hardness Test
Objective : To understand the principle and procedure of the Rockwell Hardness Test.

9. **<u>Experiment No. 9</u>**

Name : Charpy Test
Objective : To determine the impact strength and toughness of engineering materials using the Charpy test method.

10. **<u>Experiment No. 10</u>**

Name : Torsion Test
Objective : To find the angle of twist corresponding to particular torque and the to calculate the modulus of rigidity of the material of the specimen.

Reference books:

1. Analysis and Performance of Fiber Composites, B. D. Aggarwal, L. J. Broutman and K. Chandrashekhara, John Wiley & Sons

2. Aircraft Structures for Engineering Students, T.H.G. Megson, 4th Ed., Elsevier Ltd, 2012

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

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

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

Mapping Between COs and Course Delivery (CD) methods

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

OPEN Electives

COURSE INFORMATION

Course code	SR26504
Course title	Fundamentals of Combustion
Pre-requisite(s)	NA
Co-requisite	NA
Credits	L: 3 T:0 P:0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Open Elective
Name of Teacher	Dr. Shelly Biswas

Course Objectives *This course aims to provide students with:*	
Sl No.	Objectives
1	Understand the concept of thermochemistry, enthalpy, adiabatic flame temperature, combustion products and their application to combustion related problems
2	Apply the concept of chemical rates of reaction, collision theory and Arrhenius equation for analysing the different types of reactions.
3	Compare the properties and characteristics of different type of flames and apply the same to combustion phenomenon in rocket motors and its exhaust.
4	Comprehend subsonic and supersonic combustion phenomenon, their transition and properties related to Detonation
5	Interpret the various combustion processes that takes place in a solid rocket motor, liquid rocket engine and the hybrid rocket motor.

Course Outcomes (COs) *Upon successful completion of the course, students will be able to*	
CO	Course Outcomes
1	Apply the basic concept of thermochemistry to combustion related problems.
2	Demonstrate the utilization of the concept of chemical kinetics in combustion reactions.
3	Distinguish between premixed and diffusion flames including their properties, and their use in combustion devices and rockets.
4	Differentiate between deflagration and detonation process and interpret the concept for computation and analysis of the transition phenomenon.
5	Evaluate the combustion processes taking place in different types of chemical rockets.

Syllabus

Module No.	*Module name*	*Detailed Contents*	*No. of Lecture*
1	Thermochemistry:	Stoichiometry; Absolute Enthalpy and Enthalpy of Formation; Enthalpy of Combustion and Heating Value; Laws of Thermochemistry; Pressure and Temperature Effect on Enthalpy of Formation; Adiabatic Flame Temperature; Chemical and Equilibrium Products of Combustion; Some Applications; Sample Calculations.	8
2	Combustion Kinetics:	Rate and Order of Reaction; First, Second and Third Order Reaction, Reversible Reactions; Arrhenius Equation; Molecular Kinetics: Molecularity and Order, Theories of Collision; Chain Reaction, Explosion Limits Equilibrium constants and their Relationship; Dissociation and Reassociation; Combustion Products in Equilibrium; Gibbs phase rule.	8
3	Flames:	Concept of Flame; Definition, Classification and Properties of Premixed Flames; Properties of Diffusion Flames; Measurement of Burning Velocity; Flame Stabilization; Quenching; Flame Temperature Measurement Techniques; Ionization in Rocket Exhaust.	8
4	Detonation:	Detonation Wave and their Characteristics; Deflagration to Detonation Transition; Derivation of Rankine- Hugoniot equation; Chapman- Jouguet States and their Properties; Computation of Detonation Velocity.	8
5	Combustion in Rocket Motors:	Solid Propellant Combustion- Composite and Double Base Propellants, Combustion in a Liquid Propellant Rocket Motor; Combustion in a Hybrid Rocket Motor, Various Process of Ignition and Extinction in Chemical Rockets.	8

Learning Resources	
Text Books	***Reference Books***
1. S. R. Turn, An Introduction to Combustion - Concepts and Applications, 3rd Edition, McGraw-Hill, India, 2012.(T1) 2. K. K. Kuo, Principles of Combustion, John Wiley and Sons, New York, 1986. (T2)	1. B. Lewis and G. von Elbe, Combustion, Flames and Explosions of Gases, 3rd Edition, Academic Press, Orlando, 1987. (R1) 2. A. G. Gaydon and H. D. Wolfhard, Flames: Their Structure, Radiation and Temperature, 3rd Edition, Springer NY, USA, 1970. (R2)

Gaps in the Syllabus (to meet Industry/Profession requirements)	Experimental exposure to detonation process involves safety issues and is deliberately left out.
Pos met through Gaps in the Syllabus	PO 5 will be met through assignment and seminar/ presentation.
Topics beyond syllabus/Advanced topics/Design	Heat and Mass Transfer and Turbulent Flames are not covered in this syllabus.
Pos met through Topics beyond syllabus/Advanced topics/Design	Information shared through relevant research papers and invited expert lectures/industrial visit.

Course Outcome (Co) Attainment Assessment Tools and Evaluation Procedure

<table>
<tr><td rowspan="13">Direct Assessment</td><td>Assessment Tool</td><td colspan="5">% Contribution during CO Assessment</td></tr>
<tr><td>Continuous Internal Assessment</td><td colspan="5">50%</td></tr>
<tr><td>Semester End Examination</td><td colspan="5">50%</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td>Continuous Internal Assessment</td><td colspan="5">% Distribution</td></tr>
<tr><td>Best 2 Quiz marks out of 3 Quizzes of 15 marks each.</td><td colspan="5">30%</td></tr>
<tr><td>Assignment(s)</td><td colspan="5">10%</td></tr>
<tr><td>Seminar before a Committee</td><td colspan="5">10%</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td>Assessment Components</td><td>CO1</td><td>CO2</td><td>CO3</td><td>CO4</td><td>CO5</td></tr>
<tr><td>Continuous Internal Assessment</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Semester End Examination</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Indirect Assessment	Student Feedback on Faculty
	Student Feedback on Course Outcome

Mapping Between Course Outcomes and Program Outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	2	1	1	2
CO2	3	-	3	1	1	2
CO3	3	3	3	3	1	3
CO4	3	-	3	2	1	3
CO5	3	3	3	3	3	3

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 Course Outcomes and Course Delivery Method

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

Course Designers

Experts from Industry	*Experts from Higher Technical Institutions*	*Internal Experts*

COURSE INFORMATION

Course code	SR 26510
Course title	Fundamentals of Aerospace Engineering
Pre-requisite(s)	NA
Co-requisite	NA
Credits	L: 3 T:0 P:0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Aerospace Engineering
Name of Teacher	Dr. Rajiv Kumar/ Dr. Sudip Das

Course Objectives

This course aims to provide students with:

Sl No.	Objectives
1	Understand the basics of fluid dynamics and aircraft aerodynamics
2	Understand the concept of high speed aerodynamics
3	Describe various types of airbreating propulsion system with their merits and challenges.
4	Classify various types of chemical rocket propulsion and their various parameters governing it.
5	Describe the fundamentals of orbital mechanics and motion in space

Course Outcomes (COs)

Upon successful completion of the course, students will be able to

CO	Course Outcomes
1	Implementation of basic concept of fluid dynamics and aircraft aerodynamics for analysing the operational parameters of hydraulic problems and aircraft performance
2	Implementation of basis of high speed aerodynamics for simple problem solving
3	Analyze the propulsion system along with performance parameters for solving the designing challenges.
4	Understand and examine various parameters used in a chemical rockets, especially in solid rocket motor and a liquid rocket engine.
5	Analyze space dynamics and its effects on motions in space

Syllabus

Module No.	*Module name*	*Detailed Contents*	*No. of Lecture*
1	Fluid dynamics and basics of aerodynamics:	Fluid Dynamics: Continuity equation, Basic laws of fluid dynamics – conservation of mass, conservation of linear momentum, conservation of energy, Ideal fluid flow, Application of Bernoulli's equation, Real fluid flow, Viscosity, Determination of losses, Reynolds experiment, Laminar and turbulent flow, Boundary layer, Velocity profile, Flow past a body, Flow Separation, Generation of Lift, Drag & Moment, Nondimensional coefficients, Airfoils & Wings.	8
2	Aerodynamics of high speed flights:	Flow regimes, compressible flow, Speed of sound, Normal shock, oblique shock, expansion fans, governing equation for quasi one dimensional flow, Nozzle, Supersonic Wind tunnels.	8
3	Air-breathing Propulsion:	Principles of propulsion, Various air-breathing propulsion systems: Piston Engine-propeller, Turbojet, Turbo-prop, Turbofan, Turboshaft, Pulsejet, Ramjet and Scramjets, Thrust and other performance parameters, Efficiencies, Cycle analysis.	8
4	Non-air breathing Propulsion:	Introduction, Classifications of rockets, Description and Application; Various propulsive devices used for aerospace applications, Chemical, Electrical, Nuclear and other Advanced Propulsion Systems. Basic requirements, Thrust Equation; Specific Impulse, Thrust Coefficient, Characteristic Velocity and other Performance Parameters.	8
5	Motion in Space:	Requirement for orbits, Motion of bodies in Space, Equation of Motion of an Ideal Rocket, Motion of a Rocket in a Gravitational Field, Simplified Vertical Trajectory, Burn- out Velocity and Burn- out Height; Orbits and Trajectories; Conic Sections; Kepler's Laws of Satellite Motion; Orbital Velocity of Satellites; Orbital Periods; Eccentric Elliptical Orbits; Geosynchronous and geostationary orbits, Energy and velocity requirements to reach a particular orbit, Escape velocity, Free falling bodies.	8

Learning Resources	
Text Books	***Reference Books***
1. Fundamentals of Aerodynamics – Anderson, J. D., Tata McGraw-Hill Education, New Delhi, 2007. (T1) 2. Understanding Chemical Rocket Propulsion, Mukunda, H.S., I K International Publishing House, 2017. (T2) 3. Rocket Propulsion Elements, Sutton, G.P., Biblarz, O., 7th Ed. John Wiley & Sons, Inc., New York, 2001. (T3) 4. Source book on the Space Science, Glasstone, S, 1st Edition D. Van Nostrand Co., 1965. (T4)	1. Rocket Propulsion, Ramamurthi, K., 2nd Edition, Trinity Press of Laxmi Publications Private Limited, India, 2016. **(R1)** 2. Mechanics and Thermodynamics of Propulsion, Hill P. and Peterson C., 2nd Edition, Pearson Publisher. 1991. **(R3)** 3. Introduction to Flight, Anderson, J. D., 5th Edition, Tata McGraw-Hill Education, New Delhi, 2007. (**R4**) 4. Rocket and Spacecraft Propulsion: Principle, Practice and New Developments, Turner, M. J. L., Springer Verlag. 2000.**(R2)**

Gaps in the Syllabus (to meet Industry/Profession requirements)	
Pos met through Gaps in the Syllabus	PO3, PO6
Topics beyond syllabus/Advanced topics/Design	Types of Error in the Measurements
Pos met through Topics beyond syllabus/Advanced topics/Design	PO4, PO6

Course Outcome (Co) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	Assignment(s)	10%				
	Seminar before a Committee	10%				
	Assessment Components	***CO1***	***CO2***	***CO3***	***CO4***	***CO5***
	Continuous Internal Assessment					
	Semester End Examination					

Indirect Assessment	Student Feedback on Faculty
	Student Feedback on Course Outcome

Mapping Between Course Outcomes and Program Outcomes

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	2	3	1	1	3
CO2	1	1	2	1	-	3
CO3	1	1	2	2	1	3
CO4	3	2	3	1	-	2
CO5	1	-	2	-	1	1

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 Course Outcomes and Course Delivery Method	
Course Outcomes	**Course Delivery Method**
CO1	CD1,CD2,CD3, CD6
CO2	CD1, CD3, CD6
CO3	CD1, CD6
CO4	CD1, CD2, CD3, CD6
CO5	CD1,CD3, CD6

Course Designers		
Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

COURSE INFORMATION

Course code	SR 26511
Course title	Fundamentals of Fuels and Combustion
Pre-requisite(s)	NA
Co-requisite	NA
Credits	L: 3 T:0 P:0 SL: 0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Open Elective
Name of Teacher	Dr. Shelly Biswas

Course Objectives

This course aims to provide students with:

Sl No.	Objectives
1.	Introduction to the various classification of fuel energy sources
2.	Identify the manufacture methods of various types of derived fuels and their applicability in the fuel industry
3.	Understand the concept of thermochemistry, enthalpy, adiabatic flame temperature, ignition, combustion products and their application to combustion related problems
4.	Apply the concept of chemical rates of reaction, collision theory and Arrhenius equation for analysing the different types of reactions.
5.	Compare the properties and characteristics of different type of flames and apply the same to combustion phenomenon in rocket motors and its exhaust.

Course Outcomes (COs) *Upon successful completion of the course, students will be able to*	
CO	Course Outcomes
1.	Classification of various fuel energy sources and their ways of utilization
2.	Analyse the various types of derived fuels with methods of manufacture and their utilization
3.	Apply the basic concept of thermochemistry, adiabatic flame temperature and ignition to combustion related problems
4.	Demonstrate the utilization of the concept of chemical kinetics in combustion reactions.
5.	Distinguish between premixed, diffusion flames an laminar and turbulent flames and their use in combustion devices.

Syllabus

Module No.	***Module name***	***Detailed Contents***	***No. of Lecture***
1	Fuels and their classification:	Different fuel energy sources, Classification of fuels sources -Non-renewable and Renewable fuels, primary fuels and secondary fuels and solid, liquid and gaseous fuels	8
2	Manufactured fuels and derived fuels:	Manufactured liquid and gaseous fuels. Derived fuels from coal- coal gasification, liquefaction and carbonization of coal, refuse derived fuels, bio-fuels, biomass, algae, bio-diesel, alcohol fuels	8
3	Thermochemistry:	Stoichiometry; Absolute Enthalpy and Enthalpy of Formation, Enthalpy of Combustion, Pressure and Temperature Effect on Enthalpy of Formation, Adiabatic Flame Temperature, Chemical and Equilibrium Products of Combustion, Equilibrium constants and their Relationship, Combustion Products in Equilibrium, Gibbs phase rule.	8
4	Combustion Kinetics:	Rate and order of Reaction; First, Second and Third Order Reaction, Reversible Reactions, Arrhenius Equation, Molecular Kinetics: Molecularity and Order, Theories of Collision, Chain Reaction, Explosion Limits, Ignition-Self Ignition and Forced Ignition, Factors affecting Ignition Energy.	7
5	Flames and Combustion:	Concept of Flame; Definition, Classification and Properties of Premixed Flames; Properties of Diffusion Flames; Measurement of Burning Velocity, Flame Stabilization; Quenching; Flame Temperature Measurement Techniques Structure of Laminar Flame, Laminar Flame Propagation in Tubes, Description of Turbulent Flames, Concept of Turbulent Flow; Turbulent Burning Velocity, Solid fuel combustion and Liquid droplet combustion.	9

Learning Resources	
Text Books	***Reference Books***
1. S. Sarkar, Fuels and Combustion, Orient Longman, 2nd edition, 1990. **(T1)** 2. Fuels & Combustion – Sharma, S.P. & Mohan, C., Tata- McGraw Hill, 1984. **(T2)** 3. S. R. Turn, An Introduction to Combustion - Concepts and Applications, 3rd Edition, McGraw-Hill, India, 2012. **(T3)**	**1.** J.G. Speight, The Chemistry and Technology of Coal, CRC Press. 2013. **(R1)** **2.** J.G. Speight, The Chemistry and Technology of Petroleum, 4th Edition, CRC Press. 2006 **(R2)** **3.** K. K. Kuo, Principles of Combustion, John Wiley and Sons, New York, 1986. **(R3)**Publishers, 10 th Edition, New Delhi, 2015.

Gaps in the Syllabus (to meet Industry/Profession requirements)	Petroleum fuels and their distillation process not included
Pos met through Gaps in the Syllabus	PO5 will be met through assignment and seminar/ presentation.
Topics beyond syllabus/Advanced topics/Design	Detonation not covered in this syllabus
Pos met through Topics beyond syllabus/Advanced topics/Design	PO4, PO6

Course Outcome (Co) Attainment Assessment Tools and Evaluation Procedure

<table>
<tr><td rowspan="12">Direct Assessment</td><td>Assessment Tool</td><td colspan="5">% Contribution during CO Assessment</td></tr>
<tr><td>Continuous Internal Assessment</td><td colspan="5">50%</td></tr>
<tr><td>Semester End Examination</td><td colspan="5">50%</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td>Continuous Internal Assessment</td><td colspan="5">% Distribution</td></tr>
<tr><td>Best 2 Quiz marks out of 3 Quizzes of 15 marks each.</td><td colspan="5">30%</td></tr>
<tr><td>Assignment(s)</td><td colspan="5">10%</td></tr>
<tr><td>Seminar before a Committee</td><td colspan="5">10%</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td>Assessment Components</td><td>CO1</td><td>CO2</td><td>CO3</td><td>CO4</td><td>CO5</td></tr>
<tr><td>Continuous Internal Assessment</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Semester End Examination</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

<table>
<tr><td rowspan="2">Indirect Assessment</td><td>1. Student Feedback on Faculty</td></tr>
<tr><td>2. Student Feedback on Course Outcome</td></tr>
</table>

Mapping Between Course Outcomes and Program Outcomes

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	-	2	-	1	2
CO2	3	-	3	-	3	2
CO3	3	-	3	-	1	3
CO4	3	-	2	-	1	3
CO5	3	-	3	-	3	3

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 (SL) such as use of NPTEL materials and internets
CD7	Simulation

Mapping Between Course Outcomes and Course Delivery Method	
Course Outcomes	**Course Delivery Method**
CO1	CD1,CD2,CD3, CD5
CO2	CD1, CD3, CD5
CO3	CD1, CD5
CO4	CD1, CD2, CD4, CD5
CO5	CD1,CD4, CD5

Course Designers		
Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

COURSE INFORMATION

Course code	SR 26578
Course title	Computational Fluid Dynamics
Pre-requisite(s)	Fluid Mechanics, Numerical Analysis
Co-requisite	Nil
Credits	L: 3 T:0 P:0 SL: 0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Open Elective
Name of Teacher	Dr. Partha Mondal

Course Objectives

This course aims to provide students with:

Sl No.	Objectives
1.	Know classification of partial differential equations, finite difference method, stability analysis.
2.	Learn the solution methods of finite difference equations of elliptic, parabolic and hyperbolic partial differential equations.
3.	Apply the methods to solve finite difference equations
4.	Understand the numerical techniques to solve incompressible Navier-Stokes equations.
5.	Know the finite volume method and apply it for inviscid problems.

Course Outcomes (COs) *Upon successful completion of the course, students will be able to*	
CO	Course Outcomes
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 procedure to solve the Euler equations by finite volume method.

Syllabus

Module No.	*Module name*	*Detailed Contents*	*No. of Lecture*
1	**Introduction**	Computational Fluid Dynamics; Conservation Laws of Fluid Motion, Linear and Non-linear Partial Differential Equations, Classification of Partial Differential Equations; 2nd order Partial Difference Equations, Model Equations: Elliptic Equation, Parabolic Equation and Hyperbolic Equation; System of 1st order Partial Differential Equations; System of 2nd order Partial Difference Equations; Initial and Boundary Conditions.	8
2	**Finite Difference Formulations**	Introduction; Taylor Series Expansion; Finite Difference by Polynomial; Finite Difference Equations; Higher Order Derivatives; Multidimensional Finite Difference Formulas; Finite Difference Approximation of Mixed Partial Derivatives; Stability Analysis; Von Neumann Stability Analysis; Modified Partial Differential Equations, Artificial Viscosity, Numerical Dissipation and Dispersion.	8
3	**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, Parabolic Equations – Finite Difference Formulations, Explicit Schemes, Implicit Schemes, Alternating Direction Implicit Schemes, Parabolic Equations in Two-space Dimensions, Fractional Step Methods; Hyperbolic Equations – Explicit and Implicit Schemes, Multistep Methods, Runge-Kutta Method, Modified Runge-Kutta Method, Flux Corrected Transport, Classification of Numerical Schemes (Monotone, TVD and ENO Schemes).	10
4	**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; Crank Nicolson Implicit Method; Staggered Grid; Marker and Cell Method; Use of the Poisson Equation for Pressure; The SIMPLE Algorithm.	10
5	**Euler Equations and Finite**	Euler Equations, Finite Volume Method, Explicit and Implicit Procedures, Flux	8

	Volume Method	Vector Splitting, Flux Difference Splitting, Steger and Warming Flux Vector Splitting, Van Leer Flux Vector Splitting, Roe's Flux Difference Splitting, Runge-Kutta Formulation, Boundary Conditions; Global Time Step and Local Time Steps; Cell-centered and Vertex-Centered Schemes, Application – Diverging Nozzle Configuration, Shock Tube or Reimann Problem, Supersonic Channel Flow.	

Learning Resources	
Text Books	***Reference Books***
1. Hoffmann, K.A. and Chiang, S.T., Computational Fluid Dynamics (Vol. I & II), Engineering Education System, 2000.	1. Hirsch, C., Numerical Computation of Internal and External Flows (Vol. I & II), John Wiley and Sons, 1994.
2. Versteeg, H. K. and Malalasekera, W., An Introduction to Computational Fluid Dynamics: The Finite Volume Method, Pearson Education Limited, 2007	2. Anderson, John D., Computational Fluid Dynamics, McGraw-Hill, 1995.

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 and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	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

Mapping Between Course Outcomes and Program Outcomes						
CO	**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

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 (SL) such as use of NPTEL materials and internets
CD7	Simulation

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 Designers

Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

COURSE INFORMATION

Course code	SR 26579
Course title	Experimental Aerodynamics
Pre-requisite(s)	Engineering Mathematics, Fluid dynamics
Co-requisite	NA
Credits	L: 3 T: 0 P: 0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Open Elective
Name of Teacher	Dr. Sudip Das

Course Objectives
This course aims to provide students with:

Sl No.	Objectives
1	To understand the basics of Wind Tunnel and its components with specific
2	orientation to its operation.
3	To describe and implement the different wind tunnel measurement techniques
4	adopted recently and in the past.
5	To understand the basics of advanced flow diagnostic systems with knowledge

Course Outcomes (COs)
Upon successful completion of the course, students will be able to

CO	Course Outcomes
1	Describe wind tunnels and their components.
2	Organise in performing experiments using wind tunnel measurement techniques which are in practice.
3	Demonstrate the advanced measurement techniques for wind tunnel tests.
4	Implement the unsteady flow measurements with possible recognition to its stochastic behaviour and analysis.
5	Perform experiments with advanced data acquisition system with good level of confidence and minimal error.

Syllabus

Module No.	*Module name*	*Detailed Contents*	*No. of Lecture*
1	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
2	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
3	Pressure, Velocity, Force and Moment Measurement	Pitot Static Probe; Laser Doppler Velocimeter; Water and Mercury Manometers; Principle of Pressure Transducer; Different Types of Pressure Transducers; Electronic Pressure Scanner; Pressure Sensitive Paint; Definition of Forces and Moments on Aerospace Vehicles; Major Components for Force and Moment Measuring Systems.	8
4	Unsteady Measurement	Introduction to Unsteady data and turbulence; Basic Principle of Hot Wire Anemometer; Measurement of Unsteady parameters Using Hot Wire Anemometers, calibration; Single and Multiple Hot Wire Probes, directional aspects of hot wire; Basic Principles of Unsteady Pressure Transducers; Calibration of Steady and Unsteady Pressure Transducers.	8
5	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

Learning Resources	
Text Books	***Reference Books***
3. High Speed Wind Tunnel Testing, Roe, W. H. and Pope, A., Wiley, 1965. (T1) 4. Low Speed Wind Tunnel Testing, Pope, A. and Goin, L., Wiley, 1966. (T2)	1. 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)	1) Emphasis on data analysis 2) 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	1) Elaborate studies on PIV instrumentation and data interpretation 2) Compressible boundary layer measurement techniques
Pos met through Topics beyond syllabus/Advanced topics/Design	PO4, PO5, PO6

Course Outcome (Co) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	Assignment(s)	10%				
	Seminar before a Committee	10%				
	Assessment Components	***CO1***	***CO2***	***CO3***	***CO4***	***CO5***
	Continuous Internal Assessment					
	Semester End Examination					
Indirect Assessment	Student Feedback on Faculty					
	Student Feedback on Course Outcome					

Mapping Between Course Outcomes and Program Outcomes						
CO	**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

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 Course Outcomes and Course Delivery Method

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

Course Designers

Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***

COURSE INFORMATION

Course code	SR 26512
Course title	Acoustics
Pre-requisite(s)	Engineering Mathematics
Co-requisite	NA
Credits	L: 3 T: 0 P: 0
Class schedule per week	3
Class	MTECH
Semester / Level	5
Branch	Open Elective
Name of Teacher	Dr. Sudip Das

Course Objectives
This course aims to provide students with:

Sl No.	Objectives
1	Associate vibration basics with concept of wave traversing
2	Relate free, forced and damped vibration in membranes.
3	Understand the acoustic equations and its applications
4	Illustrate the transmission of waves in pipes
5	Interpret various factors of sound generation and measurement

Course Outcomes (COs)
Upon successful completion of the course, students will be able to

CO	Course Outcomes
1	Substantiate theory of string vibrations
2	Categorise the vibration of planar membranes
3	Appraise the characteristics of linear wave acoustic equations
4	Evaluate the acoustics of pipes flows and resonating devices.
5	To appraise the generated sound and methods to measure it.

Syllabus

Module No.	*Module name*	*Detailed Contents*	*No. of Lecture*
1	Introduction:	Concept of complex variable, Fundamental of vibration: simple oscillator, damped oscillation, forced oscillation, transient response, power, resonance and frequency; Vibrating string: 1-D wave equation, forced vibration of infinite and finite strings; Vibration of bars: longitudinal and transverse vibrations, forced vibration of bars; Concepts of String Instruments.	8
2	Two-dimensional wave equations:	Vibration of plane surface, Free vibrations, Symmetric vibrations, Damped free vibration, Forced vibration of a membrane, Vibration of thin plates, Concepts of percussion instruments.	6
3	Acoustic Wave equation:	Euler's equation, Linear wave equation, Harmonic plane wave, Acoustic intensities, Spherical waves, Reflection and transmission, Radiation and reception of acoustic waves.	8
4	Pipes, Resonators and Filters	Resonance in pipe, Radiation from open ended pipes, Acoustic impedance, Helmholtz resonator, reflection and transmission of waves in a pipe, Acoustic filters.	8
5	Noise, Signal, Hearing and Speech	Measurement of sound, Microphones, Spectrum and band level, Tones, Signals in noise, detection threshold, Ear, Loudness, Pitch and frequency, Voice, Monopole, Dipole and Quadrupole sound sources, Environmental acoustics, Control techniques.	8

Learning Resources	
Text Books	***Reference Books***
1. Fundamentals of Acoustics, L.E. Kinsler, A.R. Frey, A.B.Coppens and J.V.Sanders, John Wiley & Sons, Inc.	1. Theoretical Acoustics, P.M.Morse and K.U.Ingard, McGraw-Hill Book Company. 2. Principles of Musical Acoustics, William M. Hartmann, Springer. 3. Master Handbook of Acoustics, 6th Edition, F. Alton Everest and Ken Pohlmann, McGraw-Hill Education 4. Acoustics of Ducts and Mufflers, 2nd Edition, M. L. Munjal, Wiley

Gaps in the Syllabus (to meet Industry/Profession requirements)	Non Linear acoustics
Pos met through Gaps in the Syllabus	PO6
Topics beyond syllabus/Advanced topics/Design	1) Aeroacoustics 2) Acoustics of moving sources
Pos met through Topics beyond syllabus/Advanced topics/Design	PO5, PO6

Course Outcome (Co) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment	***Assessment Tool***	***% Contribution during CO Assessment***				
	Continuous Internal Assessment	50%				
	Semester End Examination	50%				
	Continuous Internal Assessment	***% Distribution***				
	Best 2 Quiz marks out of 3 Quizzes of 15 marks each.	30%				
	Assignment(s)	10%				
	Seminar before a Committee	10%				
	Assessment Components	***CO1***	***CO2***	***CO3***	***CO4***	***CO5***
	Continuous Internal Assessment					
	Semester End Examination					
Indirect Assessment	Student Feedback on Faculty					
	Student Feedback on Course Outcome					

Mapping Between Course Outcomes and Program Outcomes						
CO	**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

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 Course Outcomes and Course Delivery Method

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

Course Designers

Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***