ACADEMIC CURRICULA

POST GRADUATE DEGREE PROGRAMMES

Master of Technology

(Choice Based Flexible Credit System)

Regulations 2021

Volume – 25
Syllabi for School of Mechanical Engineering Programmes

Professional Core and Elective Courses

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

(Deemed to be University u/s 3 of UGC Act, 1956)

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

ACADEMIC CURRICULA

School of Mechanical Engineering

Professional Core Course

Regulations 2021

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

(Deemed to be University u/s 3 of UGC Act, 1956)

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

Course Code	21MAC501T	Course Name	COMPUTATIONAL METHODS	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	1	0	4

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mathematics*	Data Book / Codes / Standards	*Statistical Tables*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*learn the concept of one dimensional wave equations and diffusion equation*
CLR-2:	*construct Fourier series for periodic functions and transform technique to solve elliptic equation*
CLR-3:	*understand the concepts of Euler's equations*
CLR-4:	*identify numerical technique to solve algebraic transcendental equations, ODE and PDE*
CLR-5:	*infer the concepts of probability, correlation and regression*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*explain analytical solution of partial differential equation*	*3*	*3*	
CO-2:	*justify the solution of elliptic type PDE and periodic functions*	*3*	*3*	
CO-3:	*evaluate the solution of functional and vibrational problems*	*3*	*3*	
CO-4:	*adapt numerical solutions for algebraic, transcendental, ODE and PDE*	*3*	*3*	
CO-5:	*solve Statistical problems related to day to day life*	*3*	*3*	

Module-1 - Transform Techniques	***12 Hour***
Laplace transform - Fourier transform - One-dimensional wave equation using Laplace transform methods - Displacements in long string - Longitudinal vibration of an elastic bar - One -dimensional diffusion equation using Fourier transform methods – One-dimensional diffusion equation using Fourier sine transform methods – One-dimensional diffusion equation using Fourier cosine transform methods. .	
Module-2 - Fourier Series and Elliptic Equation	***12 Hour***
Fourier series representation of periodic functions - Fourier transform methods for Laplace equation.	
Module-3 - Calculus of Variations	***12 Hour***
Euler's Equations - Functional involving x, y, y' - Functional on higher order derivatives - Functional dependent on functions of independent variables - Rayleigh-Ritz method.	
Module-4 – Numerical Methods	***12 Hour***
Solution of algebraic and transcendental equations-Iteration method-Newton's method- solution to ODE- Runge Kutta method of 4th order- Milne's predictor corrector method. Solution to PDE- Solution to Laplace equation-Leibman's method- Solution to Poisson equation- Solution to Parabolic type PDE- Bender Schmidt method-Crank Nicholson method.	
Module-5 - Statistical Techniques	***12 Hour***
Random Variables –Discrete and continuous random variables-Mean, median, variance, Standard deviation, moments, skewness, kurtosis, correlation, regression, coherence, multiple and partial correlation.	

Learning Resources	1. *Sankara Rao, K., "Introduction to Partial Differential Equations", PHI, New Delhi, 3rd edition 2011.* 2. *B .V. Ramana, "Higher Engineering Mathematics", McGraw Hill Publication, 2017.* 3. *Elsgolts, L., "Differential Equations and Calculus of Variations", Mir Publishers, Moscow, 2013.*	4. *S. S. Sastry, Introductory Methods of Numerical Analysis, 5thEdition, PH1, 2012* 5. *S.C. Gupta, V.K. Kapoor, Fundamentals of Mathematical Statistics, Sultan Chand & Sons, 11th Edition, 2015.* 6. *S. Ross, A First Course in Probability, 8th Edition., Pearson Education India, 2010.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	15%	-	15%	-	15%	-
Level 2	Understand	25%	-	25%	-	25%	-
Level 3	Apply	30%	-	30%	-	30%	-
Level 4	Analyze	30%	-	30%	-	30%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr. Madhan Shanmugasundaram, Infosys Technologies, madshan@gmail.com*	1. *Prof. Y.V.S.S. Sanyasiraju, IIT Madras, sryedida@iitm.ac.in*	1. *Dr. V. Subburayan, SRMIST*
	2. *Prof. K.C. Sivakumar, IIT Madras, kcskumar@iitm.ac.in*	2. *Dr. P.Sambath. SRM IST*

ACADEMIC CURRICULA

Aerospace Engineering

Professional Core Courses

Regulations 2021

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

(Deemed to be University u/s 3 of UGC Act, 1956)

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

Course Code	21ASC511J	Course Name	AERODYNAMICS AND AIRCRAFT PERFORMANCE	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	2	4

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Aerospace Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*determine the aerodynamic forces and moments acting on different bodies*
CLR-2:	*determine the airfoil and wing flow characteristics*
CLR-3:	*apply the appropriate methods for flow over a body.*
CLR-4:	*apply the boundary layer separation control methods*
CLR-5:	*examine the aircraft for optimum performance*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*calculate the distribution of pressure and shear stress on various bodies.*	*2*	*2*	*3*
CO-2:	*calculate the aerodynamic forces and moments of the thin airfoil and wing.*	*2*	*-*	*3*
CO-3:	*examine the flow properties on body using numerical and experimental methods*	*2*	*2*	*3*
CO-4:	*examine the boundary layer and flow separation phenomenon*	*3*	*-*	*3*
CO-5:	*calculate the performance parameters of an aircraft*	*2*	*-*	*3*

Module-1 - Aerodynamic Forces and Moments	***15 Hour***
Introduction to Potential flow theory – Elementary flows and Combinations - Airfoil, & Wing geometrical parameters - Types of vortices - Kutta condition - Kutta Joukowski theorem - Aerodynamic forces and moments - Centre of pressure and Aerodynamic Centre *1. Calibration of subsonic wind tunnel* *2. Flow Visualization over a bluff & streamlined body.*	
Module-2 - Airfoil & Wing Theory	***15 Hour***
Thin airfoil theory assumptions, limitations & applications (Symmetric, Asymmetric, & Flapped Airfoils) - The Biot-savart law and its Application - Bound and horseshoe vortex - Prandtl's lifting line theory and its applications (Elliptical and General lift distributions) - Effect of sweep back and delta wings. *1. Estimation of pressure distribution over a symmetrical/ Unsymmetrical airfoil.* *2. Estimation of pressure distribution over a symmetrical/ Unsymmetrical airfoil with flap*	
Module-3 - Numerical and Experimental Methods	***15 Hour***
Introduction to panel method and its Application (Non lifting and Lifting bodies) - Vortex lattice method and its application —Flow past bodies using computational tools - Introduction to CFD. Non-dimensional numbers - Types of similarities – Low speed wind tunnel design parameters - Wind tunnel techniques *1. Estimation of pressure distribution over a finite wing* *2. Estimation of pressure distribution over a finite wing with winglet*	

Module-4 - Boundary Layer and Flow Control	**15 Hour**
Introduction to Boundary Layer and its Parameters - Prandtl's Boundary Layer Equations, Laminar Boundary layer over various bodies, Introduction to Turbulent Flows, Turbulent Boundary Layer, Flow Separation and its control methods (Passive and Active Methods) *1. Force measurements over a body using Pressure distribution* *2. Force measurements over a body using force balance method*	
Module-5 – Aircraft Performance	**15 Hour**
Standard Atmosphere - Types of drags - Drag polar - Steady flight: cruise, climb, glide, range, endurance - Accelerated flight: level turn, pull-up, pull-down, V-n diagram - Takeoff and landing. *1. Estimation of Drag polar of an airplane model* *2. Performance analysis of fixed / rotary wing UAV*	

Learning Resources	*1. Anderson, JD, Fundamentals of Aerodynamics,6th ed., McGraw Hill, 2016* *2. Houghton EL, Carpenter PW. Aerodynamics for engineering students. 5th ed., Elsevier; 2003* *3. Anderson, JD, Aircraft Performance & Design, McGraw Hill, 1999*	*3. Clancy, L, J., Aerodynamics, Pitman, 1986* *4. John J. Bertin, Russell M. Cummings, Aerodynamics for Engineers, 2013* *5. Sighard F. Hoerner, Fluid-dynamic Drag: Practical Information on Aerodynamic Drag and Hydrodynamic Resistance, 1965*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA) Formative CLA-1 Average of unit test (45%)		Continuous Learning Assessment (CLA) Life-Long Learning CLA-2 (15%)		Summative Final Examination (40% weightage)	
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20 %	-	-	20 %	20%	-
Level 2	Understand	20 %	-	-	20 %	20%	-
Level 3	Apply	60 %	-	-	30 %	60%	-
Level 4	Analyze	-	-	-	30 %	-	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100%		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. R. Krishnamurthy, DRDL- DRDO, Hyderabad	1. Dr. Lakshmana Dora C, IIT Hyderabad, Hyderabad	1. Dr. Mohamed Arif R, SRMIST
2. Dr. Saurav Kumar Ghosh, CSIR-NAL, Bangalore	2. Dr. T Chandra Sekar, IIT Bombay, Mumbai	2. Dr. Bharadwaj K K, SRMIST 3. Dr. Allwyn K, SRMIST

Course Code	21ASC512J	Course Name	AEROSPACE STRUCTURAL MECHANICS	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	2	4

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Aerospace Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*describe the concepts of bending in aircraft structural components*
CLR-2:	*evaluate the shear flow distribution and shear center on thin-walled open sections due to bending and torsion loads*
CLR-3:	*determine the shear flow distribution and shear center on thin-walled closed sections due to bending and torsion loads*
CLR-4:	*analyze the behavior of thin plates subjected to bending and buckling loads*
CLR-5:	*interpret the variation of stress and strain in aircraft components*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*apply the concepts of bending in various aircraft structural components*	2	-	3
CO-2:	*analyze the shear flow distribution due to shear and torsion loads in thin-walled open sections*	2	2	3
CO-3:	*evaluate the shear flow distribution due to shear and torsion loads in thin-walled closed sections*	2	-	3
CO-4:	*explain the concept of various theories of thin plates*	2	-	3
CO-5:	*analyze the stress and strain of various aircraft components using experimental techniques*	3	2	3

Module-1 - Bending of Beams	***15 Hour***
Overview of various loads on aircraft structural components - Aircraft materials - State of stress at a point - Concept of strain - Constitutive behavior of materials - Modelling the components in terms of 1-D or 2-D structural elements - Euler-Bernoulli beam theory - Timoshenko beam theory - Analysis of symmetrical and unsymmetrical sections - Thin-walled approximations - Box beams - Determination of bending stress determination - Deflection of beams using modern tools *1. Deflection of beams with various end conditions, 2. Unsymmetrical bending of beams, 3. Constant strength beam*	
Module-2 - Shear Flow in Thin-Walled Open Sections	***15 Hour***
Relationships between stress, strain and displacement for open section thin-walled beams - Concept of shear flow - Determination of the shear center - Symmetrical and unsymmetrical cross-sections - Shear flow due to bending in open sections - Torsion of thin-walled open section members and determination of stresses *1. Shear center location for various open thin-walled sections*	
Module-3 - Shear Flow in Thin-Walled Closed Sections	***15 Hour***
Shear flow in thin-walled closed sections - Determination of the shear center - Symmetrical and unsymmetrical sections - Flexural shear flow in multi-flange box beams - Bredt-Batho theory - Torsional shear flow in multi-cell tubes - Shear flow due to combined bending and torsion *1. Shear center location for various closed thin-walled sections, 2. Beam subjected to combined bending and torsion*	

Module-4 - Structural Problems of Thin-Walled Structures	***15 Hour***
Columns and beam-columns - Classical Kirchhoff-Love theory of plate - First order shear deformation plate theory - Classical laminate theory - Bending and buckling of plates and sheet stringer combination - Failure stress in plates and stiffened panels - Wagner beam theory - Shear lag concept	
1. Buckling of columns with different end conditions, 2. Experimental verification of the Wagner beam theory	
Module-5 – Analysis of Aircraft Structural Components and Experimental Techniques	***15 Hour***
Stress analysis of various aircraft structural components - Tapered wing spar - Structural idealization of wings and fuselage and preliminary analysis - Elements of structural testing and experimentation - Strain measurements – Birefringence effect – Interpretation of fringe patterns in photoelasticity - Fundamentals of vibration and aeroelasticity	
1. Fabrication of composite laminates, 2. Estimation of mechanical properties of composite laminates, 3. Determination of fringe order using photoelasticity setup, 4. Vibration of beams	

Learning Resources	*1. Megson T H G,'Aircraft Structures for Engineering Students', Elsevier, Fifth edition, 2013* *2. Bruhn. E.F., 'Analysis and Design of Flight Vehicles Structures', Tri-state offset company, USA 1985 Aircraft Structures Laboratory manual* *3. Peery, D.J., Aircraft Structures, 2md edition, McGraw-Hill, N.Y., 1999* *4. Rivello, R.M., Theory and Analysis of Flight Structures, McGraw Hill, 1993.*	*5. B.K. Donaldson, "Analysis of Aircraft Structures - An Introduction", Second edition, Cambridge University Press, 2012.* *6. Autar K Kaw, "Mechanics of Composite Materials", CRC Press, 2nd edition, 2005.* *7. Dally, J.W., and Riley, W.F., Experimental Stress Analysis, McGraw Hill Inc., New York, 1978* *8. Timoshenko S., "Vibration Problems in Engineering" – John Wiley and Sons, New York, 1993*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (45%)		Life-Long Learning CLA-2 (15%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20 %	-	-	20 %	20%	-
Level 2	Understand	20 %	-	-	20 %	20%	-
Level 3	Apply	60 %	-	-	30 %	60%	-
Level 4	Analyze	-	-	-	30 %	-	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. D. Saji, National Aerospace Laboratories, Bangalore	*1. Dr. V. Arumugam, Madras Institute of Technology, Chennai*	*1. Dr. S. Gurusideswar, SRMIST*
2. Dr. Manoj Kumar Buragohain, Defense Research and Development Organization, Hyderabad	*2. Dr. K. Vadivuchezhian, National Institute of Technology Karnataka, Surathkal*	*2. Dr. K. Saravanakumar, SRMIST*

Course Code	21ASC513J	Course Name	GAS DYNAMICS AND PROPULSION	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	2	4

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Aerospace Engineering*	Data Book / Codes / Standards	*Gas Tables*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*describe the basic principles of gas dynamics*
CLR-2:	*explain the effect of friction and heat transfer for flow in a constant area duct*
CLR-3:	*explain the properties of shock and its relations*
CLR-4:	*examine the theory and operating principles of jet propulsion*
CLR-5:	*acquire knowledge on the basic concepts of space propulsion*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes(PO)***		
		1	***2***	***3***
CO-1:	*understand the equations and measurements of compressible flow*	2	-	3
CO-2:	*describe the flow with heat transfer and friction*	2	-	3
CO-3:	*determine the shock relations and its applications*	2	2	3
CO-4:	*describe the operating principle and performance of various jet engines*	2	2	3
CO-5:	*describe the various types, staging and performance of rockets*	2	-	3

Module-1 - Basic Concepts and Isentropic Flows ***15 Hour***

Compressibility - Energy and momentum equations of compressible fluid flows – Stagnation states, critical Mach number, Mach Angle, Mach waves and Mach cone–Effect of Mach number on compressibility–Measurements in compressible flow.
Lab1: Study of SRM supersonic wind tunnel and its instrumentations.
Lab2: Calibration of supersonic wind tunnel

Module-2 - Flow with Friction and Heat Transfer ***15 Hour***

Flow in constant area duct with Friction (Fanno flow)–Fanno curve and fanno flow equations, variation of flow properties, Flow in constant area duct with heat transfer (Rayleigh flow), Rayleigh line and Rayleigh flow equations, maximum heat transfer, flow with heating or cooling in ducts.
Lab 3: Experiment with constant area duct in open jet test facility
Lab 4: Determination of convective heat transfer coefficient over a flat plate by forced convection

Module-3 - Normal and Oblique Shocks ***15 Hour***

Equations of motion for a normal shock wave – Normal shock relations for a perfect gas –Hugoniot equation – Shock tube - Oblique shock relations – Shock polar -Supersonic flow over a wedge - Prandtl – Meyer relations–Applications.
Lab5: Study of various Supersonic flow visualization techniques and its applications.
Lab 6: Visualization of shock wave pattern on ramp model using Schlieren flow visualization technique

Module-4 - Jet Propulsion	*15 Hour*
Theory of jet propulsion–Thrust equation–Thrust power and propulsive efficiency–Operating principle, cycle analysis and use of stagnation state performance of ramjet, pulsejet, turbojet, turbofan, and turbo prop engines, thrust augmentation *Lab 7: Thrust measurement of a Ramjet engine* *Lab 8: Characteristic plots of a free jet through a non-circular orifice*	
Module-5 – Space Propulsion	*15 Hour*
Types of rocket engines – Propellants – solid and liquid propellants -feeding systems – Ignition and combustion –Theory of rocket propulsion–Performance study–Staging–Terminal and characteristic velocity–specific impulse, Applications–spaceflights. *Lab 9 : Solid Rocket motor propellant preparation* *Lab 10: Hybrid Rocket motor fuel grain preparation*	

Learning Resources	*1.Anderson,J.D.,"ModernCompressibleflow",3rdEdition,McGrawHill,2003.* *2. Yahya,S.M., "Fundamentals of Compressible Flow", New Age International (P) Limited, New Delhi, 1996.* *3. Ethirajan Rathakrishnan, "GasDynamics", 7th Edition, PHI Learning Pvt. Ltd.,2020.* *4. Hill. P. and C. Peterson, "Mechanics and Thermodynamics of Propulsion", Addison–Wesley Publishing company, 1992.* *5. Zucrow. N. J., "Aircraft and Missile Propulsion", Vol. 1 & II, John Wiley, 1975*	*6. Zucrow. N. J., "Principles of Jet Propulsion and Gas Turbines", John Wiley, New York, 1970.* *7. Sutton. G. P., "Rocket Propulsion Elements", John Wiley, New York, 1986,.* *8. Shapiro. A. H., "Dynamics and Thermodynamics of Compressible fluid Flow",John Wiley, New York, 1953.* *9. Cohen.H., G.E.C. Rogers and Saravanamutto, "Gas Turbine Theory", Longman Group Ltd.,1980.* *10. Yahya, S.M, " Gas Tables", New Age International Publishers, 2018*

Learning Assessment							
	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (45%)		*Life-Long Learning CLA-2 (15%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20 %*	*-*	*-*	*20 %*	*20%*	*-*
Level 2	*Understand*	*20 %*	*-*	*-*	*20 %*	*20%*	*-*
Level 3	*Apply*	*60 %*	*-*	*-*	*30 %*	*60%*	*-*
Level 4	*Analyze*	*-*	*-*	*-*	*30 %*	*-*	*-*
Level 5	*Evaluate*	*-*	*-*	*-*	*-*	*-*	*-*
Level 6	*Create*	*-*	*-*	*-*	*-*	*-*	*-*
	Total	*100%*		*100%*		*100%*	

Course Designers		
Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr. R.S .Praveen, VSSC, ISRO, Thiruvananthapuram	*1. Dr.S.R.Chakravarthy, IIT Madras, Chennai*	*1. Dr. G. Saravanan, SRMIST*
2. Dr .Lakshmi V.M., VSSC, ISRO, Thiruvananthapuram	*2. Dr. Rajesh Sadanandan, IIST, Thiruvananthapuram*	*2. Dr. A. .Muthuram, SRMIST*

Course Code	21ASC514T	Course Name	ATMOSPHERIC AND SPACE FLIGHT MECHANICS	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Aerospace Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*acquire knowledge on the basic aspects of stability and control of an airplane about three axis.*
CLR-2:	*acquire adequate knowledge on various parameters that decide the stability level of an airplane.*
CLR-3:	*familiarize with the aspects of control in longitudinal, lateral and directional modes.*
CLR-4:	*get introduced to the characteristics of various orbits and the importance of orbital elements.*
CLR-5:	*get familiarized with the basic aspects of satellite injection and the types of satellite perturbations.*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*determine the fixed neutral point and the stick fixed static margin.*	-	-	3
CO-2:	*describe the effect of change in cg on the aircraft stability.*	-	-	3
CO-3:	*apply the small disturbance equations of motion, and identify longitudinal and lateral sets of equations, construct state space models for longitudinal and lateral aircraft dynamics.*	2	-	3
CO-4:	*estimate the time and position of an object in various orbits.*	2	2	3
CO-5:	*acquire knowledge on the basic concepts of satellite injection and satellite perturbations.*	-	-	3

Module-1 - Static Longitudinal Stability and Control	***9 Hour***
Static equilibrium and stability – Pitch stability of conventional and canard aircraft – control fixed neutral point and static margin – effect of fuselage and running propellers on pitch stability – control surface hinge moment – control free neutral point – limit on forward CG travel – maneuver stability: Pull – up & level turn – control force and trim tabs – control force for maneuver – measurement of neutral point and maneuver point by flight tests.	
Module-2 - Static Lateral, Directional Stability and Control	***9 Hour***
Yaw and side slip, effect of wing sweep, wing dihedral and vertical tail on directional stability – rudder fixed and rudder free – yaw control – rudder sizing – pedal force - dihedral effect: contribution of various components- roll control.	
Module-3 - Aircraft Dynamics	***9 Hour***
Rigid body equations of motion - Axes systems and their significance – Euler angles – linearization of longitudinal equations – force and moment derivatives – short period and phugoid approximations – pure pitching motion – linearization of equations for lateral – directional motion – roll, spiral and Dutch roll approximations- Pure rolling- Pure yawing – Inertia coupling.	
Module-4 - Characteristics of Various Orbits	***9 Hour***
Properties of elliptic, Parabolic and hyperbolic properties in terms of orbital elements – relations between position and time – Barker's theorem – Whittaker's theory – Sphere of influence.	

Module-5 – Satellite Injection and Satellite Perturbations	***9 Hour***
General aspects of satellite injection – satellite orbit transfer – various cases – orbit deviations due to injection errors – special and general perturbations – Cowell's method and Enake's method – method of variations of orbital elements – general perturbations approach.	

Learning Resources	*1. Michael V. Cook, "Flight Dynamics Principles", Second edition, Elsevier, 2007.* *2. Nelson, RC, "Flight Stability & Automatic Control", Second edition, McGraw-Hill, 2017.* *3. Perkins CD & Hage, RE, "Airplane performance, stability and control", Wiley India Pvt Ltd, 2011.* *4. Cornelisse, JW, Schoyer, HFR & Wakker, KF, "Rocket Propulsion and Space Dynamics", Pitman Publishing, 1979.*	*5. Howard D. Curtis, "Orbital Mechanics for Engineering Students", 3rd Edition, ButterworthHeinemann, 2013.* *6. Parker, ER, "Materials for Missiles and Spacecraft", Mc.Graw Hill Book Co. Inc., 1982.* *7. Suresh. BN & Sivan. K, "Integrated Design for Space Transportation System", Springer India, 2015.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*40%*	-	*40%*	-	*40%*	-
Level 3	*Apply*	*40%*	-	*40%*	-	*40%*	-
Level 4	*Analyze*		-		-	-	-
Level 5	*Evaluate*	-	-		-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr. Roshan Dinesh Kumar, GE Industry India Ltd., Bangalore	*1. Dr. Lakshmana Dora C, IIT Hyderabad, Hyderabad*	*1. Dr. K. Allwyn, SRMIST*
2. Dr. Saurav Kumar Ghosh, CSIR-NAL, Bangalore	*2. Dr. T Chandra Sekar, IIT Bombay. Mumbai*	*2. Dr. M. Vignesh Kumar, SRMIST* *3. Dr. S. M. Aravindh Kumar, SRMIST*

ACADEMIC CURRICULA

Aerospace Engineering

Professional Elective Courses

Regulations 2021

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

(Deemed to be University u/s 3 of UGC Act, 1956)

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

Course Code	21ASE511J	Course Name	APPLIED COMPUTATIONAL FLUID DYNAMICS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	0	2	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Aerospace Engineering*	*Data Book / Codes / Standards*	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*derive the governing equations of fluid flows and heat transfer*
CLR-2:	*apply discretization methods to linearize the fluid flow equations*
CLR-3:	*gain knowledge in solving incompressible flows*
CLR-4:	*model fluid flow problem with heat transfer*
CLR-5:	*gain knowledge in solving compressible flows*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*identify physical and mathematical models for flow and heat transfer analysis*	2	-	3
CO-2:	*apply discretization techniques to numerically solve transport equations*	3	-	3
CO-3:	*solve incompressible fluid flows problems numerically*	3	3	3
CO-4:	*predict numerical solutions of flows with heat transfer*	3	3	3
CO-5:	*solve compressible flow problems*	3	3	3

Module-1: Governing Equations and Boundary Conditions	***12 hour***
Fundamental Approaches to problem solving -Analytical, Experimental & Numerical, Computational Fluid Dynamics-Advantages–Applications-Processes, Reynolds transport theorem, Conservation of mass, Conservation of linear momentum: Navier-Stokes equation, Conservation of Energy, General scalar transport equation, Reynolds averaged Navier-Stokes equation, Selection of Physics and Mathematical models, Initial and boundary conditions	
Module -2: Discretization Approaches and Numerical Solutions	***12 hour***
Overview of domain discretization, Equation Discretization using FVM, Convection -Diffusion Equation using FVM, Discretization of Unsteady problem– Implicit- Explicit Schemes, Solution of Discrete system, Stability, Convergence, Relaxation factors, Grid independent and time independent study, post-processing, turbulent flow modelling	
Module -3: Incompressible Flow Computations	***12 hour***
Basics of Pressure-velocity coupling algorithm, Discretization of 2D incompressible continuity and momentum equations, Pressure correction equation formulation, SIMPLE Algorithm, Applications of SIMPLE, Overview of other pressure-velocity coupling algorithms, the basic structure of a CFD code-CFD Solution of Simple flows using ANSYS-FLUENT	
Module -4: Flows with Heat Transfer	***12 hour***
Introduction to Heat Transfer Prediction, Heat Conduction in Solids, Natural Convection in Cavities- Laminar Flow- Turbulent Flow, Effects of Fluid Properties on Natural Convection, Simulation of Forced Convection Heat Transfer, Periodic Heat Transfer, Conjugate Heat Transfer	
Module -5: Compressible Flow Simulations	***12 hour***
Mathematical modelling, Boundary conditions, solution methods, Compressible- Internal and external flows, Flow through C-D Nozzle, Supersonic flow over wedges and airfoils, supersonic jets	

List of Recommended Practical Experiments/Exercises

1. *Geometry and mesh generation for simple flow problems*
2. *Modelling laminar incompressible flow through 2D rectangular channel*
3. *Numerical simulation of incompressible flow through axisymmetric 2D pipe*
4. *Modelling of steady flow past 2D Cylinder*
5. *Numerical simulation of unsteady flow past 2D Cylinder*
6. *Grid independent study for flow past 2D Cylinder*
7. *Numerical simulation of subsonic flow over an airfoil*
8. *Numerical simulation of supersonic flow over an airfoil*
9. *Numerical simulation of supersonic flow over a wedge*
10. *Numerical simulation of turbulent incompressible flow through 2D rectangular channel*
11. *Numerical simulation of flow through nozzle*
12. *Numerical simulation of flow over wing*
13. *Numerical simulation of natural convection heat transfer in cavity – Laminar*
14. *Numerical simulation of forced convection heat transfer*
15. *Numerical simulation of conjugate heat transfer*
16. *Fluid flow and heat transfer in a mixing elbow*
17. *Numerical simulation of high-speed jet*

Learning Resources	*1. Versteeg, H.K. and Malalasekera, W., An Introduction to Computational Fluid Dynamics – The finite volume method, Longman Scientific & Technical, 1995.* *2. Patankar, S.V., Numerical Heat Transfer & Fluid Flow, Hemisphere, 1980.* *3. Hoffmann, K.A. and Chiang, S.T., Computational Fluid Dynamics for Engineers, Engineering Education Systems, 2000.*	*4. Tannehill, J.E., Anderson, D.A., and Pletcher, R.H., Computational Fluid Mechanics and Heat Transfer, 2nd ed., Taylor & Francis, 1997.* *5. Anderson J.D., Computational Fluid Dynamics – The basics with Applications, Mc Graw-Hill, 1995.* *6. ANSYS Fluent Tutorial Guide, Release 18.0, Ansys Inc, 2017*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (40%)		Life Long Learning CLA-2 – (20%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	-	-	-	-	-	-
Level 2	Understand	40%	-	-	20%	40%	-
Level 3	Apply	60%	-	-	40%	60%	-
Level 4	Analyze	-	-	-	30%		-
Level 5	Evaluate	-	-	-	10%	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. R. Krishnamurthy, DRDL- DRDO, Hyderabad	*1. Dr. B. Premachandran, IIT Delhi*	*1. Dr. S. Senthilkumar, SRMIST, KTR*
2. Mr. Abhimanyu Singh, Ansys India, Bangaluru	*2. Dr. M. Arun, National Institute of Technology (NIT), Karnataka*	

Course Code	21ASE512T	Course Name	AERODYNAMICS FOR PRACTICAL APPLICATIONS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	Nil	Co- requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department	Aerospace Engineering	Data Book / Codes / Standards	Nil		

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1:	*apply principles of aerodynamics in fields other than Aerospace*
CLR-2:	*examine the role of atmosphere in industrial aerodynamics*
CLR-3:	*illustrate the importance of aerodynamics in Wind Turbine blade design*
CLR-4:	*use the aerodynamic principles in the design of automobiles and Sports*
CLR-5:	*assess the effect of wind flow on buildings and its impact*

Course Outcomes (CO):	*At the end of this course, learners will be able to:*	*Programme Outcomes (PO)*		
		1	*2*	*3*
CO-1:	*model the terrain and atmospheric boundary layer in a wind tunnel*	2	-	3
CO-2:	*apply aerodynamics in the design of wind turbines*	2	-	3
CO-3:	*apply aerodynamics in streamlining and Drag reduction in Automobiles*	2	-	3
CO-4:	*gain knowledge of the fluid-structure interactions and Aerodynamics in sports*	2	-	3
CO-5:	*use aerodynamics in the design of buildings and ventilation*	2	2	3

Module	Hours
Module-1 : Wind and Atmospheric Boundary Layer	***9 Hour***
Atmospheric circulations, Types of winds - Global and Local, Terrain Types, Atmospheric Boundary Layer (ABL), Mean Velocity Profiles - Power Law and Log Law, Variation of wind velocity with height in ABL for different terrain types, Turbulence Intensity, Variation of Turbulence Intensity and Temperature with height in ABL, ABL simulation in Wind Tunnel, Environmental Wind Tunnels	
Module-2 : Wind Turbine Aerodynamics	***9 Hour***
Aerodynamics in Wind Turbine design, Wind Turbines - Classification, parts, advantages, and disadvantages, HAWTs and VAWTs, Dimensionless numbers - Power coefficient, Torque coefficient, Tip speed ratio and Solidity ratio, Betz limit, Power losses, Performance comparison of different wind turbine designs, Aerodynamic Power Control Techniques, Blade design, Wind turbine siting	
Module-3: Ground Vehicle Aerodynamics	***9 Hour***
Effects of vehicle speed - Rolling resistance, Air resistance, Brief History - Four primary phases of car aerodynamics, Pressure distribution over cars, Aerodynamic forces on Automobiles, Lift, Drag and Moments, Sources of vortices in automobiles, Flow separation and wake dynamics, Aerodynamic coefficients on various vehicles, Common Aerodynamic Features and Improvements in a car, Aerodynamics of roofless vehicles, motor bikes, Trucks/Buses and Trains, Ahmed body – Generic automobile shape, Wind tunnel experiments and numerical simulations	
Module-4: Sports Aerodynamics and Fluid-Structure Interactions	***9 Hour***
Introduction to sports aerodynamics, Aerodynamics of race cars, Ground effects, Down force generation, Frontal and rear wings, Aerodynamic braking - Spoilers, Aerodynamics of wheels, Aerodynamics of Cricket ball, Swing and Spin, Effect of dimples on golf ball, Vortex shedding, Strouhal number, Flow induced vibrations, Fluid-structure interactions, Effect of Reynolds number on wake, Aerodynamic flutter, Wake galloping, Vortex shedding control methods and CFD predictions	

Module-5: Building Aerodynamics	**9 Hour**
Need for Building aerodynamics, Flow over a simplified building, Pressure distribution, Wind loads – TVL Formula, Low-rise buildings (LRB), Effects of Roof suction and corner vortices, High-rise buildings (HRB), Dynamic loads, Aerodynamic load mitigation techniques for LRB and HRB, funneling effect, Ventilation and HVAC, Architectural Aerodynamics, Wind catchers, Building codes, Loads on launch vehicles subjected to winds	

Learning Resources	1. *Tom Lawson, Building aerodynamics.: Imperial College Press, 2001.* 2. *Erich Hau,. Wind turbines: fundamentals, technologies, application, economics. Springer Science & Business Media, 2013.* 3. *Martin OL Hansen, Aerodynamics of wind turbines. Routledge, 2015* 4. *Joseph Katz, Automotive Aerodynamics, John Wiley & Sons, 2016.* 5. *Joseph Katz, Race Car Aerodynamics, Robert Bentley, 1995*	6. *Hucho, Wolf-Heinrich, ed. Aerodynamics of road vehicles: from fluid mechanics to vehicle engineering. Elsevier, 2013.* 7. *Robert D Blevins, Flow-induced vibration. Van Nostrand Reinhold Co., 1977.* 8. *Helge Nørstrud, Sport aerodynamics. Springer Science & Business Media, 2009.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	20%	-	20%	-
Level 2	Understand	20%	-	20%	-	20%	-
Level 3	Apply	60%	-	60%	-	60%	-
Level 4	Analyze	-	-	-	-	-	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Dr. Saurav Kumar Ghosh, CSIR-NAL, Bangalore*	1. *Dr. Lakshmana Dora Chandrala, IIT Hyderabad, Hyderabad*	1. *Dr. K. K. Bharadwaj, SRMIST*
2. *Dr. Roshan Dinesh Kumar, GE Industry India Ltd., Bangalore*	2. *Dr. K. Maruthupandiyan, Institute of Aeronautical Engineering, Hyderabad*	2. *Dr. S. Senthilkumar, SRMIST*

Course Code	21ASE513T	Course Name	INSTRUMENTATION, MEASUREMENTS AND EXPERIMENTS IN FLUIDS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	Nil
Course Offering Department	*Aerospace Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*describe the needs and objectives of experimental studies in fluids*
CLR-2:	*show the importance of different types of wind tunnels and their related instrumentation*
CLR-3:	*demonstrate the various fluid flow visualization and analogue methods in practice*
CLR-4:	*show the methods and instruments used for pressure, velocity, and temperature measurements in fluids*
CLR-5:	*illustrate the data acquisition and processing, and the associated uncertainty in fluid flow measurements*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*use the principles and working of experimental methods in fluids*	-	-	3
CO-2:	*examine the wind tunnel types and their associated design considerations and instrumentation*	-	2	3
CO-3:	*apply flow visualization techniques and analogue methods to fluid flow experiments*	2	-	3
CO-4:	*use the techniques involved in pressure, velocity and temperature measurements in fluids*	2	-	3
CO-5:	*predict the errors and uncertainty related to the acquired data in experiments in fluids*	-	-	3

Module-1 : Experiments in Fluids	***9 Hour***
Fundamentals of fluid mechanics - Fluid properties, Fluid flow analysis, Basic laws, Kinematics of fluid flow, Potential flow, Viscous flows, Gas dynamics, Need and objectives of experimental study - Fluid mechanics measurements, Measurements systems, Quantitates associated with fluid flow measurements	
Module-2 : Wind Tunnels	***9 Hour***
Low-speed wind tunnels, High-speed wind tunnels, Hypersonic tunnels, Hypervelocity facilities, Instrumentation and calibration of wind tunnels, Wind tunnel balance, Losses in wind tunnels	
Module-3: Flow Visualization and Analogue Methods	***9 Hour***
Visualization techniques - Smoke tunnel, Compressible flows - Shadowgraph, Schlieren and Interferometry, Particle image velocimetry, Water flow channel, Analogue methods - Hele-Shaw analogy, Hydraulic analogy, Hydraulic jumps and their applications	
Module-4 : Fluid Flow Measurements	***9 Hour***
Pressure measurement - Barometers, Pressure transducers, Pitot, Static and Pitot-static tubes, Velocity measurement - Laser doppler anemometer, Hot-wire anemometer, Fluid-jet anemometer, Particle image velocimetry, Temperature measurement - Thermometers, Thermocouples	
Module-5: Data Acquisition and Processing	***9 Hour***
Data acquisition principle, Multiplexing, Data conversion, Personal computer hardware, Digitization errors, Uncertainty analysis - Estimation of measurement errors, Uncertainty estimation - Flow Mach number, Calculation	

Learning Resources	1. *Ethirajan Rathakrishnan, "Instrumentation, Measurements, and Experiments in Fluids", Second Edition, CRC Press, 2016.* 2. *Cameron Tropea, Alexander L. Yarin & John F. Foss, "Springer Handbook of Experimental Fluid Mechanics", Springer, 2007.*	3. *Stefano Discetti & Andrea Ianiro, "Experimental Aerodynamics", CRC Press, 2016.* 4. *Bruno Chanetz, Jean Délery, Patrick Gilliéron, Patrick Gnemmi, Erwin R. Gowree & Philippe Perrier, "Experimental Aerodynamics, An Introductory Guide", Springer, 2020.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA) Formative CLA-1 Average of unit test (50%)		Continuous Learning Assessment (CLA) Life-Long Learning CLA-2 (10%)		Summative Final Examination (40% weightage)	
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	20%	-	20%	-	20%	-
Level 2	*Understand*	20%	-	20%	-	20%	-
Level 3	*Apply*	60%	-	60%	-	60%	-
Level 4	*Analyze*	-	-	-	-	-	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Dr. Roshan Dinesh Kumar, GE Industry India Ltd., Bangalore*	1. *Dr. K. Maruthupandiyan, Institute of Aeronautical Engineering, Hyderabad,*	1. *Dr. Aravindh Kumar S.M., SRMIST*
2. *Dr. Saurav Kumar Ghosh, CSIR-NAL, Bangalore,*	2. *Dr. Lakshmana Dora Chandrala, IIT Hyderabad,*	2. *Mr. Rajkumar S, SRMIST*

Course Code	21ASE514T	Course Name	ROCKET PROPULSION ELEMENTS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Aerospace Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*describe the working principle of chemical rockets and advanced nozzles*
CLR-2:	*explain the configuration and analysis of cryogenic engine*
CLR-3:	*explain the working principle, types, and applications of electrical rockets*
CLR-4:	*examine the principle and classification of nuclear and solar rockets*
CLR-5:	*acquire knowledge on other advanced non-chemical rockets*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*explain the equations and measurements of compressible flow*	-	-	3
CO-2:	*describe the configuration, insulation, and safety with cryogenic systems*	-	-	3
CO-3:	*explain the electrical rocket principle and its applications*	2	-	3
CO-4:	*describe the performance analysis of nuclear rockets and principle of solar rockets*	2	-	3
CO-5:	*describe the other advanced rocket propulsion concepts*	2	-	3

Module-1 - Chemical Rockets ***9 Hour***

Basic principles of chemical thermodynamics-basic principle of gas dynamics- Ramjets and scramjets, ram rockets, space planes, Solid rocket motors, Liquid rocket engines, Hybrid propellants rocket propulsion, , Advanced rocket Nozzle-Extendible Nozzle, Dual Bell–Shaped Nozzle, Expansion–Deflection Nozzle, Aerospike Nozzle.

Module-2 - Cryogenic Engines ***9 Hour***

Cryogenic and semi-cryogenic Engines -Basic configuration, Cryogenic Fluids, Insulation, Cryogenic instrumentation, Cryogenic equipment and cryogenic systems analysis, Safety with cryogenic systems.

Module-3 - Electrical Rockets ***9 Hour***

Introduction, Basic principles of electrical rocket engine, Classifications of electrical Rockets, Background Physics of Electrical Rockets, Electrothermal thrusters-Electrostatic thrusters, Electromagnetic thruster, Applications of electric propulsion, Electric Power Generation.

Module-4 - Nuclear Rocket Engines and Solar Energy Rockets ***9 Hour***

Nuclear thermal rockets-Solid core- Classification and performance analysis of nuclear fission and fusion rockets-Liquid core, Gas core, Operational issues, Solar thermal collector, Solar sail, Photon based engines.

Module-5 – Other Advanced Rocket Propulsion ***9 Hour***

Beam-powered propulsion-Laser rockets, Rotating Detonation Rocket Engine, Tether Propulsion, Green Chemical Propulsion, Other advanced rocket propulsion concepts.

Learning Resources	*1. Thomas M. Flynn, "Cryogenic Engineering", 2nd Edition, CRC Press, 2004.* *2. Y.M. Timnat, "Advanced Chemical Rocket Propulsion", Academic Press, 1987.* *3. D.P. Mishra, "Fundamentals of Rocket Propulsion", 1st Edition, CRC Press, 2017.*	*4. Giovanni Vulpetti, Les Johnson & Gregory L. Matloff, "Solar Sails: A Novel Approach to Interplanetary Travel", 2nd Edition, Springer-Praxis Books In Space Exploration, 2015.* *5. Dan M. Goebel & Ira Katz, "Fundamentals of Electric Propulsion: Ion and Hall Thrusters", 1st Edition, Wiley, 2008.* *6. W.H.T. Loh, "Jet, Rocket, Nuclear, Ion and Electric Propulsion: Theory and Design", Springer-Verlag Newyork Inc, 1968.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA) Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)		Summative Final Examination (40% weightage)	
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	20%	-	20%	-	20%	-
Level 2	*Understand*	20%	-	20%	-	20%	-
Level 3	*Apply*	60%	-	60%	-	60%	-
Level 4	*Analyze*	-	-	-	-	-	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	100%		100%		100%	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. RS . Praveen, VSSC, ISRO, Thiruvananthapuram	*1. Dr.S.R.Chakravarthy, IIT Madras, Chennai*	*1. Dr. G. Saravanan, SRMIST*
2. Dr. Lakshmi VM, VSSC, ISRO, Thiruvananthapuram	*2. Dr. Rajesh Sadanandan, IIST, Thiruvananthapuram*	*2. Dr. A. Muthuram, SRMIST*

Course Code	21ASE515T	Course Name	ADVANCED PROPULSION SYSTEMS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	Nil	Co- requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department	Aerospace Engineering	Data Book / Codes / Standards	Nil		

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1:	*explain the basics of advanced propulsion systems and it's applications*
CLR-2:	*predict the performance of electrothermal and electrostatic rocket propulsion systems*
CLR-3:	*explain the operating principle of electromagnetic rocket thruster*
CLR-4:	*describe the working of nuclear propulsion systems*
CLR-5:	*explain the solar rocket propulsion systems*

Course Outcomes (CO):	*At the end of this course, learners will be able to:*	*Programme Outcomes (PO)*		
		1	*2*	*3*
CO-1:	*describe the various advanced rocket propulsion systems*	-	2	3
CO-2:	*explain the working principle of electrothermal and electrostatic thruster*	-	-	3
CO-3:	*describe the different electromagnetic thrusters.*	2	-	3
CO-4:	*explain the operation of nuclear rockets.*	2	-	3
CO-5:	*gain knowledge on various solar rocket systems*	2	-	3

Module-1: Basic Concepts of Advanced Propulsion Systems	***9 Hour***
Advanced propulsion systems - Classifications- Electrothermal, Electrostatic and Electromagnetic-Nuclear propulsion- Solar Propulsion-Advantages and Disadvantages-Applications- Ramjets and scramjets, ram rockets-Tether Propulsion -Green Chemical Propulsion	
Module-2: Electrothermal and Electrostatic Thrusters	***9 Hour***
Arcjets- Introduction to arc discharges and Cathodes-Electrode phenomena, Description, Operating Principle-Resistojets- Description, Operating Principle Ionization. Introduction to rarefied gases. Charged particle motion. -Electrostatic acceleration: 1-D space charge model-Ion production-Ion Thrusters-Operating Principle-Beam Optic Beam Neutralization. -Performance Parameters - Hall Thrusters- Hall Effect Unsteady electromagnetic acceleration-Hall Current Thrusters- Operating Principle	
Module-3: Electromagnetic Propulsion	***9 Hour***
Electromagnetic acceleration-Lorentz Force-MHD channel flow -Magneto Plasma Dynamic (MPD) Thrusters- Description and thrust derivation -Operating Principle-MPD Thruster Design -performance calculation. --Introduction to plasma physics -Ohm's Law for plasma-Pulsed plasma thruster (PPT)- Description-Pulsed plasma thruster (PPT)- Operating Principle-Electric propulsion systems and spacecraft integration. -Overview of advanced concepts-Beamed energy-Fusion propulsion, Antimatter Propulsion	
Module-4: Nuclear Rocket Propulsion	***9 Hour***
Introduction-Nuclear reactions-Nuclear rocket engine design and performance – nuclear rocket reactors -Nuclear rocket nozzles –clear rocket engine control – radioisotope propulsion -Basic thruster configurations – thruster technology -Heat source development – nozzle development -Nozzle performance of radioisotope-propulsion systems.	
Module-5: Solar Propulsion System	***9 Hour***
Introduction-Solar energy technology-Solar radiation- Solar Collectors-Solar Thermal System-Operating Principle, Performance-Solar Electric Propulsion-Operating Principle, Performance-Solar Sail	

Learning Resources	*1. Physics of Electric Propulsion, Robert Jahn, McGraw-Hill, 1968.* *2. Mechanics and Thermodynamics of Propulsion 2nd ed., P. Hill and C. Peterson, Addison-Wesley Publishing Company, 1992 ISBN 0-201-14659-2.* *3. G.P. Sutton, "Rocket Propulsion Elements", John Wiley & Sons Inc., New York,1998.* *4. Space Propulsion Analysis and Design, R. W. Humble, G. N. Henry and W. J. Larson, McGrawHill Inc, 1995*	*5. Introduction to Plasma Physics and Controlled Fusion 2nd ed., F. F. Chen, Plenum Press, 1985* *6. Fundamentals of Plasma Physics 3rd ed., J.A. Bittencourt, Springer Publishing , 2004* *7. J. Dewar, To the End of the Solar System, The Story of the Nuclear Rocket, The University Press of Kentucky, 2004, ISBN 0-8131-2267-*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA) Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)		Summative Final Examination (40% weightage)	
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	20%	-	20%	-	20%	-
Level 2	*Understand*	20%	-	20%	-	20%	-
Level 3	*Apply*	60%	-	60%	-	60%	-
Level 4	*Analyze*	-	-	-	-	-	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. RS .Praveen, VSSC, ISRO,Thiruvananthapuram	*1. Dr. S. R. Chakravarthy, IIT Madras, Chennai*	*1. Dr. G. Saravanan, SRMIST*
2. Dr .Lakshmi V M, VSSC, ISRO, Thiruvananthapuram	*2. Dr. Rajesh Sadanandan, IIST, Thiruvananthapuram*	*2. Dr. A. Muthuram, SRMIST*

Course Code	21ASE516T	Course Name	EXPERIMENTAL STRUCTURAL MECHANICS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Aerospace Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*explain the principles of measurement and instrumentation*
CLR-2:	*distinguish the experimental methods involved in mechanics*
CLR-3:	*analyze the structural integrity using fracture mechanics principles*
CLR-4:	*examine the principles of impact mechanics to predict the structural response*
CLR-5:	*employ numerical methods to simulate dynamic behavior and predict structural responses*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*describe the principles of measurement and instrumentation*	-	-	3
CO-2:	*classify various experimental techniques in mechanics*	-	-	3
CO-3:	*apply fracture mechanics principle to assess the integrity of engineering structures*	2	1	3
CO-4:	*apply concepts of impact mechanics to predict the response of structure subjected to impact loading.*	2	1	3
CO-5:	*analyze structural responses to dynamic loads using mathematical and computational techniques.*	2	2	3

Module-1 - Measurements and Instrumentation	***9 Hour***
Principles of measurements - Conventional measurement methods - Sensors and transducers - Calibration - Fundamentals of data acquisition and processing - Signal conditioning - Statistical analysis of experimental data - Regression analysis - Estimation of measurement errors - Uncertainty calculation	
Module-2 - Experimental Mechanics	***9 Hour***
Displacement measurement: Intrusive and non-intrusive methods - Stress and strain measurements - Strain gauges: Mechanical, electrical, optical, acoustic, pneumatic and other types of strain gauges - Photoelasticity - Moiré - Holography - Speckle pattern interferometry - Digital image correlation technique - Recent advancements in experimental techniques - Testing and analysis of metal and composite specimens	
Module-3 - Fracture Mechanics	***9 Hour***
Linear elastic fracture mechanics - Crack growth and fracture mechanisms - Energy release rate - Stress intensity factor - Test methods for fracture toughness - Fatigue and damage tolerance in aerospace structures - Fatigue mechanism - Fatigue properties - S-N curve - Prediction of fatigue life in metals and composites	
Module-4 - Impact Mechanics	***9 Hour***
Propagation of 1D stress pulse - Coaxial collision of bars, Reflection and superposition - Navier's equations - Dilatational and shear waves - Rayleigh and Lamb waves - Quasi-static material test - Pendulum impact test - Drop weight impact test - Split-Hopkinson's bar test - Taylor impact test - Dynamic buckling of beams	
Module-5 – Structural Dynamics	***9 Hour***
Basic elements of vibration - Degrees of freedom - Equations of motion using Newton's laws and Lagrange equations - Free and forced vibration - Damped and undamped systems - Natural frequency - Multi-degree of freedom systems - Mode shapes - Continuous systems - Vibrations of rods, strings, beams, and plates - Shake table tests - Experimental modal analysis - Structural health monitoring and damage detection	

Learning Resources	*1. Timoshenko S P & Goodier J N, "Theory of Elasticity", Wiley, 2016.* *2. Srinath L S, Advanced mechanics of solids, McGraw Hill, 2017* *3. Dally, J.W., and Riley, W.F., "Experimental Stress Analysis", McGraw Hill Inc., New York, 1978* *4. S Suresh, Fatigue of Materials, Cambridge University Press, 1991.* *5. TL Anderson, Fracture Mechanics: Fundamentals and Applications, 3rd Edition, CRC Press, 2005.*	*6. C. Lakshmana Rao, V. Narayanamurthy, K. R. Y. Simha, "Applied Impact Mechanics", Wiley, 2016* *7. W.J. Stronge, "Impact Mechanics", Cambridge University Press, 2010* *8. L. Meirovitch, Elements of Vibration Analysis, 2nd ed. McGraw-Hill Book Co., 1988* *9. W. Weaver, S.P. Timoshenko and D.H. Young, Vibration Problems in Engineering, 5th ed., John Wiley & Sons, 1990*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA) Formative CLA-1 Average of unit test (50%)		Continuous Learning Assessment (CLA) Life-Long Learning CLA-2 (10%)		Summative Final Examination (40% weightage)	
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	20%	-	20%	-
Level 2	Understand	20%	-	20%	-	20%	-
Level 3	Apply	60%	-	60%	-	60%	-
Level 4	Analyze	-	-	-	-	-	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. D. Saji, National Aerospace Laboratories, Bangalore	1. Dr. V. Arumugam, Madras Institute of Technology, Chennai	*1. Dr. S. Gurusideswar, SRMIST*
2. Manoj Kumar Buragohain, Defense Research and Development Organization, Hyderabad	*1. Dr. K. Vadivuchezhian, National Institute of Technology Karnataka, Surathkal*	*2. Dr. K. Saravanakumar, SRMIST*

Course Code	21ASE517T	Course Name	ANALYSIS AND DESIGN OF COMPOSITE STRUCTURES	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Aerospace Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*describe the key factors influencing the selection of composite materials for aerospace components and structures*
CLR-2:	*estimate the elastic properties of a lamina using micromechanics approach*
CLR-3:	*apply various failure theories to predict the strength of an orthotropic lamina*
CLR-4:	*determine the stress and strain in composite materials using classical laminate theory*
CLR-5:	*evaluate the structural response of composite beams and plates subjected to bending and buckling.*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*examine the fundamentals and properties of composite materials for aerospace applications.*	-	-	3
CO-2:	*evaluate the elastic properties of a lamina using micromechanics approach*	2	-	3
CO-3:	*analyze the strength of an orthotropic lamina using different failure theories*	2	2	3
CO-4:	*evaluate the stress and strain of a composite laminate*	2	2	3
CO-5:	*examine the behavior of composite beams and plates*	2	-	3

Module-1 - Introduction to Composite Materials	***9 Hour***
History of composite materials - Significance – Classification - Fibers – Types - Properties of Fibers – Fabrication of fibers - Polymers - Thermosetting and Thermoplastic Polymers – Properties – Fabrication techniques of fiber reinforced polymers - Scope of composite materials for various aerospace applications – Repair and recycling of composite materials	
Module-2 - Micromechanics Approach	***9 Hour***
Volume and weight fractions - Minimum and critical fiber volume fractions – Longitudinal and transverse behaviour of unidirectional lamina - Factors influencing strength and stiffness – Prediction of elastic properties using micromechanics –Typical unidirectional fiber composite properties – Analysis of a lamina using modern tools	
Module-3 - Macromechanics Approach	***9 Hour***
Generalized Hooke's law - Stiffness and compliance matrices – Orthotropic material - Specially orthotropic material - Transversely isotropic material - Plane stress problem - Stress and strain transformations - Transformation of stiffness and compliance matrices – Analysis of lamina - Strength of an orthotropic lamina using different failure theories – Prediction of composite laminate failure using modern tools	
Module-4 - Analysis of Composite Laminates	***9 Hour***
Laminate - Construction and properties of special laminates – Classical laminate theory - Stiffness matrices - Determination of stresses and strains – Hygrothermal stresses - Analysis of laminates after initial failure – Stress analysis of a composite laminate using modern tools	
Module-5 – Stress Analysis of Composite Beams and Plates	***9 Hour***
Design consideration – Mechanical properties of composite materials - Analysis of composite beams – Thin-walled composite beams – Bending and Buckling analysis of composite plates - Analysis of sandwich plates - Inter-laminar stresses - Delamination models - Preliminary design of composite structures for aerospace applications - Composite tailoring and design issues – Future scope for composites research	

Learning Resources	*1. Autar K Kaw, "Mechanics of Composite Materials" CRC Press, Taylor and Francis Group 2005.* *2. Gibson, R.F. Principles of Composite Material Mechanics (2nd ed.). CRC Press. 2007.* *3. Robert M. Jones, "Mechanics of Composite Materials", CRC Press, 2nd Edition, 2006.* *4. B.D. Agarwal and L.J. Broutman, "Analysis and Performance of fiber composites", John-Wiley and Sons.*	*5. I. M. Daniel and O. Ishai, Engineering Mechanics of Composite Materials, Oxford University Press, 1994* *6. G. Lubin, Handbook of Composites, Van Nostrand Reinhold, 1982* *7. J. N. Reddy, Mechanics of Laminated Composite Plates and Shells: Theory and Analysis, Second Edition, CRC Press, 2003* *8. Buragohain, M.K. Composite Structures: Design, Mechanics, Analysis, Manufacturing, and Testing (1st ed.). CRC Press. 2017*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA) Formative CLA-1 Average of unit test (50%)		Continuous Learning Assessment (CLA) Life-Long Learning CLA-2 (10%)		Summative Final Examination (40% weightage)	
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	-	-	-	-	-	-
Level 2	*Understand*	40%	-	40%	-	40%	-
Level 3	*Apply*	60%	-	60%	-	60%	-
Level 4	*Analyze*	-	-	-	-	-	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. D. Saji, National Aerospace Laboratories, Bangalore	*1. Dr. V. Arumugam, Madras Institute of Technology, Chennai*	*1. Dr. K. Saravanakumar, SRMIST*
2. Manoj Kumar Buragohain, Defense Research and Development Organization, Hyderabad	*2. Dr. K. Vadivuchezhian, National Institute of Technology Karnataka, Surathkal*	*2. Dr. S. Gurusideswar, SRMIST*

Course Code	21ASE611T	Course Name	APPLIED FLIGHT MECHANICS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Aerospace Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the principles and concepts of control and maneuverability in aircraft.*
CLR-2:	*comprehend the fundamentals of control response and flight simulation.*
CLR-3:	*evaluate stability and control through routine wind tunnel and flight tests.*
CLR-4:	*explore the design considerations for achieving longitudinal and lateral stability.*
CLR-5:	*understand stability problems associated with unconventional aircraft configurations.*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*understand factors influencing control and maneuverability.*	-	-	3
CO-2:	*interpret pilot opinions, predict dynamic handling, analyze control response, and apply flight simulation techniques.*	2	-	3
CO-3:	*facilitate wind tunnel and flight tests, interpret data, and understand pilot response characteristics.*	2	-	3
CO-4:	*assess longitudinal and lateral stability, evaluate design parameters, and analyze stability implications.*	2	-	3
CO-5:	*gain knowledge on stability challenges in unconventional aircraft configurations and propulsion systems.*	2	-	3

Module-1 - Control and Maneuverability	***9 Hour***
Longitudinal Control and Maneuverability - Effects of Structural Flexibility - Control Force and Trim Tabs - Stick-Free Neutral and Maneuver Points - Ground Effect, Elevator Sizing, and CG Limits - Stall Recovery - Lateral Control and Maneuverability - Aileron Reversal - Other Control Surface Configurations - Airplane Spin	
Module-2 - Control Response and Flight Simulation	***9 Hour***
Pilot Opinion - Dynamic Handling Quality Prediction - Response to Control Inputs - Nonlinear Effects and Longitudinal-Lateral Coupling - Euler Angle Formulations - Direction-Cosine Formulation - Euler Axis Formulation - The Euler-Rodrigues Quaternion Formulation.	
Module-3 - Testing for Stability and Control	***9 Hour***
Routine low speed wind tunnel tests - Scale effect - Wind tunnel tests at high subsonic and supersonic speeds - Miscellaneous tunnel tests - Routine flight tests - General handling tests - Spinning tests - Flight tests at high speeds - Miscellaneous flight research - Pilot opinion and pilot response characteristics.	
Module-4 - Stability and Design	***9 Hour***
Longitudinal stability and control - Position of the center of gravity - Tailplane section, planform and position - Tail volume - Stick free stability - elevator forces - Aerodynamic servo-controls - Powered controls - Maneuverability, Effects of compressibility and distortion - Lateral stability and control - Fin section, planform and position - Fin volume and wing dihedral - Rudder design - Rudder free stability - Rudder forces - Aileron design - Aileron free stability - Aileron forces	
Module-5 – Stability Problems of Unconventional Aircraft	***9 Hour***
Tailless aircraft - Tail-first aircraft - Aircraft with variable wing sweep - Very high-altitude aircraft - Vertical-take-off aircraft - Tail sitting aircraft - Tilting wing aircraft - Aircraft with deflected propeller slipstream - Aircraft with deflected jet - Aircraft with separate lifting engines - Aircraft using a jet flap or a jet-augmented flap.	

Learning Resources	1. Warren F. Phillips, "Mechanics of Flight", Second edition, John Wiley & Sons Inc., 2009. 2. A. W. Babister, "Aircraft Stability and Control", Pergamon Press, 1961.	3. Nelson, RC, "Flight Stability & Automatic Control", Second edition, McGraw-Hill, 2017. 4. Perkins CD & Hage, RE, "Airplane performance, stability and control", Wiley India Pvt Ltd, 2011.

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	20%	-	20%	-	20%	-
Level 2	*Understand*	40%	-	40%	-	40%	-
Level 3	*Apply*	40%	-	40%	-	40%	-
Level 4	*Analyze*		-		-	-	-
Level 5	*Evaluate*	-	-		-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. Roshan Dinesh Kumar, GE Industry India Ltd., Bangalore	1. Dr. Lakshmana Dora C, IIT Hyderabad, Hyderabad	1. Dr. M. Vignesh Kumar, SRMIST
2. Dr. Saurav Kumar Ghosh, CSIR-NAL, Bangalore	2. Dr. T Chandra Sekar, IIT Bombay, Mumbai	2. Dr. K. Allwyn, SRMIST

Course Code	21ASE612T	Course Name	HYPERSONIC AEROTHERMODYNAMICS FOR SPACE VEHICLES	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Aerospace Engineering*	Data Book / Codes / Standards	*Gas Tables*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*explain the significance of hypersonic flow and it's characteristics*
CLR-2:	*determine the flow properties through shockwave and expansion wave*
CLR-3:	*describe the approximate method, hypersonic small disturbance equation for inviscid flow.*
CLR-4:	*explain the boundary layer equations and simulation technique for hypersonic viscous flow.*
CLR-5:	*describe the aerodynamic heating and role of thermal protection system.*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*define hypersonic flow and importance characteristics of hypersonic flow.*	-	-	3
CO-2:	*describe shock-wave and expansion-wave relations for hypersonic flow*	-	-	3
CO-3:	*illustrate the various simplified method for hypersonic inviscid flow.*	2	-	3
CO-4:	*examine the hypersonic transition and role of hypersonic shock-wave boundary layer interaction*	2	2	3
CO-5:	*describe the aerodynamic heating and thermal protection system*	1	1	3

Module-1 - Basics of Hypersonic Flows	***9 Hour***
Definition, fluid flow regimes, importance and characteristics of hypersonic flow. Historical development and key milestones in hypersonic aerothermodynamics. Challenges and unique features of hypersonic aerodynamics. High temperature flow and communication blackout. Rarefied gas dynamics and its significance at hypersonic speeds.	
Module-2 - Hypersonic Shock-Wave and Expansion Wave	***9 Hour***
Shockwave definition, types. Basics of hypersonic shock relations, the relationship between Mach number, shock angle, and deflection angle. Shockwave relations in terms of the hypersonic similarity parameter and hypersonic expansion-wave relations.	
Module-3 - Inviscid Hypersonic Flows	***9 Hour***
Newtonian flow model, Modified Newtonian theory, Mach-number independence principle, hypersonic small disturbance equation, hypersonic equivalence principle, blast-wave theory, Shock-shock interactions in hypersonic flow and different types of shock-shock interactions. CFD techniques for hypersonic inviscid flow.	
Module-4 - Viscous Hypersonic Flows	***9 Hour***
Governing differential equations, boundary layer and it's equation for hypersonic flow, Hypersonic transition, turbulent boundary layer. Hypersonic shock-wave/boundary-layer interactions. Computational methods for simulating hypersonic viscous flow.	
Module-5 – Aerodynamic Heating and Thermal Protection Systems	***9 Hour***
Aerodynamic heating: sources, mechanism. hypersonic aerodynamic heating and its effects on entropy layer. Types of thermal protection systems (TPS) and their design considerations, Materials used in TPS, Case studies of TPS in hypersonic vehicles.	

Learning Resources	1. *Anderson Jr, John D. Hypersonic and high-temperature gas dynamics. American Institute of Aeronautics and Astronautics, 2006.* 2. *Bertin, J. J. "Hypersonic Aerothermodynamics, AIAA, Education Series, Washington, D." (1994)* 3. *Anderson Jr, John D. Modern compressible flow: with historical perspective. McGraw-Hill, 2020.*	4. *Fletcher, Leroy S., ed. Aerodynamic heating and thermal protection systems. American Institute of Aeronautics and Astronautics, 1978.* 5. *Duffa, Georges. Ablative thermal protection systems modeling. American Institute of Aeronautics and Astronautics, Inc., 2013.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	20%	-	20%	-	20%	-
Level 2	*Understand*	30%	-	30%	-	30%	-
Level 3	*Apply*	50%	-	50%	-	50%	-
Level 4	*Analyze*	-	-	-	-	-	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Dr. Roshan Dinesh Kumar, GE Industry India Ltd., Bangalore*	1. *Dr. Lakshmana Dora C, IIT Hyderabad, Hyderabad*	1. *Dr. Malaikannan G, SRMIST*
2. *Dr. Saurav Kumar Ghosh, CSIR-NAL, Bangalore*	2. *Dr. T Chandra Sekar, IIT Bombay, Mumbai*	2. *Dr. Aravindh Kumar S M, SRMIST*

Course Code	21ASE613T	Course Name	CRYOGENIC SYSTEMS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Aerospace Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*explain the basics of cryogenic systems and it's applications*
CLR-2:	*predict the performance of Gas-Liquefaction Systems*
CLR-3:	*explain the various Cryo-coolers and gas Refrigeration Systems*
CLR-4:	*describe the different methods of gas separation and Cryo pumping*
CLR-5:	*apply the design aspects of cryogenic fluid storage and transfer lines and insulations*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*describe the Cryogenic systems*	-	-	3
CO-2:	*evaluate the performance of Gas-Liquefaction Systems*	2	1	3
CO-3:	*describe the various cryo-coolers and gas Refrigeration Systems performance*	1	-	3
CO-4:	*explain the various gas separation and cryopumping*	2	-	3
CO-5:	*examine the various cryogenic fluid transfer systems and insulation methods*	2	2	3

Module-1 - Cryogenic Fluids	***9 Hour***
Cryogenic fluids - Liquid hydrogen, liquid oxygen, liquid nitrogen, liquid helium- Properties of cryogenic fluids at cryogenic temperature - superfluidity -mechanical, thermal, electrical and magnetic properties-superconductivity	
Module-2 - Gas Liquefaction Systems	***9 Hour***
Gas Liquefaction systems- Thermodynamics of gas liquefaction- liquefaction cycles -Joule Thomson effect, Joule Thomson Coefficient, Linde –Hampson System, Claude Liquefaction System, Heylandt System	
Module-3 - Cryocoolers	***9 Hour***
Cryocoolers- Introduction, Classification of Cryocoolers, Stirling Cryo – cooler, Gifford-McMahon Cry cooler, Gas Cycle Refrigeration system- Classification of Gas Cycle refrigeration, Pulse tube refrigerator, Solvay cycle refrigerator, Vuilleumier refrigerator, Cryogenic regenerators	
Module-4 - Thermodynamic Ideal Gas Separation System and Vacuum Technology	***9 Hour***
Thermodynamic ideal Gas separation system, Principles of gas separation- various adsorbents, salient features – properties, determination of mass of absorbents for the adsorption of gases, Physical principles of adsorption- BET equation for single and multiple layer , Use of sorption process in cryogenics static and dynamic arrangement for the sorption processes , Adsorption columns Linde single column and double column gas separation- Vacuum Technology- Introduction, Production of high vacuum, Flow Regimes in Vacuum, Conductance in Vacuum, Pressure drop- Slip flow and mixed flow	
Module-5 - Cryogenic Fluid Transfer Systems and Cryogenic Insulation	***9 Hour***
Cryogenic fluid storage vessels, Cryogenic fluid transfer system Thermocouples, platinum resistance and semiconductor thermometry. Cool down of cryogenic transfer lines, frost phenomena, cryogenic insulation. in engineering -Cryogenic Insulation, Evacuated powder insulation, Opacified powder insulation, Gas filled powders Multilayer super-insulation, Fibrous materials Multilayer super-insulation, Cryogenic rockets, space simulation chamber	

Learning Resources	1. Randall F. Barron., "Cryogenic Systems", Oxford University, Second edition,1985 2. Walker.G, "Cryocoolers", Plenum Press, First edition, New York (1983) 3. Mamata Mukhopadhyay," Fundamentals of Cryogenic Engineering", PHI Learning Ltd, India, Fourth edition 2010	4. J. H. Bell," Cryogenic Engineering", Prentice Hall, Englewood Cliffs, First edition,1963. 5. Parner, S. F., "Propellant Chemistry", Reinhold Publishing Corpn., New York,1985. 6. R.B. Scott, "Cryogenic Engineering", Van Nostrand Co, New Jercy,1959

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	20%	-	20%	-
Level 2	Understand	20%	-	20%	-	20%	-
Level 3	Apply	60%	-	60%	-	60%	-
Level 4	Analyze	-	-	-	-	-	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. RS. Praveen, VSSC, ISRO,Thiruvananthapuram	1. Dr. Parthasarathi Ghosh, Head, Cryogenic Engineering Centre, IIT Kharagpur, Kharagpur	1. Dr. G. Saravanan, SRMIST
2. Dr .Lakshmi V M, VSSC, ISRO, Thiruvananthapuram	2. Dr. Rajesh Sadanandan, IIST, Thiruvananthapuram	2. Dr. A. Muthuram, SRMIST

Course Code	21ASE614T	Course Name	STRUCTURAL DYNAMICS AND AEROELASTICITY	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Aerospace Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the single degree of freedom and two-degree of freedom damped and undamped systems*
CLR-2:	*understand dynamic response of multi degree of freedom system and vibration of elastic bodies.*
CLR-3:	*understand static aeroelastic phenomena and its classification.*
CLR-4:	*understand dynamic aero elastic phenomena in detail*
CLR-5:	*understand flutter phenomena, prevention and control of aeroelastic instabilities.*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*solve equation of motion of single degree of freedom and two-degree of freedom of free and forced vibration of damped and undamped systems.*	1	1	3
CO-2:	*apply Lagrange and Hamilton principle to solve multi degree of freedom system problems.*	2	1	3
CO-3:	*formulate aero elastic equations to solve for steady state aeroelastic problems.*	2	2	3
CO-4:	*formulate aeroelastic equations to solve dynamic aeroelastic problems*	2	2	3
CO-5:	*explain flutter analysis and calculation of flutter using a suitable method.*	2	1	3

Module-1 - Single and Two Degree of Freedom Systems	***9 Hour***
Free and forced vibrations of undamped and damped SDOF systems. Free and forced vibrations of damped and undamped 2-DOF systems, Logarithmic decrement, support excitation, Numerical solving –solution of equation of motion	
Module-2 - Multi Degree of Freedom System	***9 Hour***
Multi degree of freedom system, co-ordinates coupling, coupled oscillations, orthogonality, Eigen value problems, Lagrange principle and its applications., Hamilton principle. Vibration of elastic bodies	
Module-3 – Introduction to Aeroelasticity	***9 Hour***
Introduction Aeroelastic Problems, Deformation of Structures and Influence Coefficients, Energy Method, Classification and Solution of Aeroelastic Problems-Case study.	
Module-4 - Static Aeroelasticity	***9 Hour***
Static Aeroelasticity. Divergence of 2-D airfoil and Straight Wing, Aileron Reversal. Control Effectiveness. Wing loading and deformations. Swept Wing	
Module-5 – Dynamic Aeroelasticity and Flutter Calculation	***9 Hour***
Dynamic Aero elasticity. Dynamic/Flutter model of 2-D Airfoil, Flutter Calculation, U-g Method. P-k Method. Exact Treatment of Bending - Torsion Flutter of Uniform Wing. Flutter Analysis by Assumed Mode Method, Panel Flutter-Case study.	

Learning Resources	*1.Timoshenko, S. "Vibration Problems in Engineering", John Wiley & Sons, Inc., 2018.* *2.Meirovitch, L. "Elements of Vibration Analysis", New Delhi, McGraw-Hill Education, 2014.* *3. Thomson W.T, Marie Dillon Dahleh, "Theory of Vibrations with Applications", Harlow, Essex Pearson 2014* *4. F.S. Tse., I.F. Morse and R.T. Hinkle, "Mechanical Vibrations", Prentice-Hall of India, 1985.* *5.Rao.J.S. and Gupta.K. "Theory and Practice of Mechanical Vibrations", New Delhi, New Age International, 1999..*	*6. E.H. Dowell et.al., "A Modern Course in Aero elasticity", Sijthoff & Noordhoff, 1980.* *7. R.L. Bisplinghoff, H. Ashley and R.L. Halfman, "Aero elasticity", Addison- Wesley, 1955.* *8. D.H. Hodges and G.A. Pierce, "Introduction to Structural Dynamics and Aeroelasticity" Cambridge Aerospace Series, 2002* *9. R.L. Bisplinghoff and H. Ashley, "Principles of Aeroelasticity", Dover, 1962* *10.Y.C. Fung, "An Introduction to the Theory of Aeroelasticity", John Wiley & sons, 1955.*

Learning Assessment							
	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr. V. Balamurugan, CVRDE, DRDO, Chennai	*1. Dr. Shankar Krishnapillai, IIT Madras, Chennai*	*1. Dr. S. Sivakumar, SRMIST*
2.Dr. D. Saji, National Aerospace Laboratories, Bangalore	*2. Dr. V. Aurumugam, MIT, Chennai*	*2. Dr. L. R. Ganapathy Subramanian, SRMIST*

Course Code	21ASE615T	Course Name	APPLIED FINITE ELEMENT METHOD	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Aerospace Engineering*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the concepts of finite element methods and the various solution schemes available.*
CLR-2:	*understand one-dimensional finite elements for structural analysis*
CLR-3:	*understand two dimensional finite elements for structural analysis.*
CLR-4:	*formulate mass and stiffness element matrices for solving vibration problems*
CLR-5:	*understand finite element method in obtaining solutions to heat transfer and fluid flow problems*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*derive governing equations involving different type of approximate methods*	2	1	3
CO-2:	*solve one-dimensional problems using finite element method.*	2	2	3
CO-3:	*solve simple 2-D problems using the finite element method*	2	3	3
CO-4:	*apply numerical integration techniques in solutions to vibration and buckling*	3	3	3
CO-5:	*formulate and solve heat transfer and fluid mechanics problems using the FE method*	2	3	3

Module-1 - Finite Element Method Concepts	***9 Hour***
Review of various approximate methods – Rayleigh-Ritz, Galerkin, Collocation and Finite Difference Methods – Problem Formulation – Application to Structural Elements & Practical Problems – Derivation of Stiffness and Flexibility Matrices, Matrix method of Analysis – Spring Systems – Role of Energy Principles – Interpolation, Nodes, Degrees of Freedom – Solution Schemes.	
Module-2 - Discrete Elements	***9 Hour***
Finite Element Structural Analysis Involving 1-D Bar and Beam Elements – Tapered Bar – Temperature Effects – Static Loading – Formulation of the Load Vector for 1-D Elements – Methods of Stiffness Matrix Formulation – Interpolation & Shape Functions – Boundary Conditions – Determination of Displacements & Reactions – Constitutive Relations – Determination of Nodal Loads & Stresses	
Module-3 - Continuum Elements	***9 Hour***
Plane Stress & Plane strain Loading – CST Element – LST Element – Element Characteristics – Problem Formulation & Solution Using Finite Elements – Axisymmetric Bodies & Axisymmetric Loading – Consistent and Lumped Load Vectors – Use of Local, Area and Volume Co-ordinates – Isoparametric Formulation – Shape Functions – Role of Numerical Integration – Load Consideration – Complete FE Solution	
Module-4 - Vibration and Buckling	***9 Hour***
Formulation of the Mass and Stiffness Element Matrices for Vibration Problems – Bar and Beam Elements – Derivation of the Governing Equation – Natural Frequencies and Modes – Damping Considerations – Harmonic Response – Response Calculation Using Numerical Integration – Buckling of Columns – Problem Formulation – Solution – Determination of Buckling Loads and Modes.	
Module-5 - Heat Transfer and Fluid Mechanics Problems	***9 Hour***
One Dimensional Heat Transfer Analysis – Formulation of the Governing Equations in Finite Element Form – Equivalent Load Vector – Solution & Temperature Distribution – Finite Element Formulation and Solution for Sample Problems Involving Fluid Mechanics.	

Learning Resources	*1. Bathe, K.J. and Wilson, E.L., Numerical Methods in Finite Elements Analysis, Prentice Hall of India Ltd., 1983.* *2. Dhanaraj, R., K. Prabhakaran and Nair, K., Finite Element Method, Oxford university press, India, 2015.* *3. Krishnamurthy, C.S., Finite Elements Analysis, Tata McGraw – Hill, 1987.* *4. Rao, S.S. Finite Element Method in Engineering, Butterworth, Heinemann Publishing, 3rd Edition, 1981*	*5. Robert D. Cook, David S. Malkus, Michael E. Plesha and Robert J. Witt, Concepts and Applications of Finite Element Analysis, John Wiley & Sons, 4th Edition, 2002.* *6. Segerlind, L.J., Applied Finite Element Analysis, John Wiley and Sons Inc., New York, 2nd Edition,1984.* *7. Tirupathi R. Chandrupatla and Ashok D. Belegundu, Introduction to Finite Elements in Engineering, Prentice Hall, 2002.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA) Formative CLA-1 Average of unit test (50%)		Continuous Learning Assessment (CLA) Life-Long Learning CLA-2 (10%)		Summative Final Examination (40% weightage)	
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	20%	-	20%	-
Level 2	Understand	20%	-	20%	-	20%	-
Level 3	Apply	30%	-	30%	-	30%	-
Level 4	Analyze	30%	-	30%	-	30%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. V. Balamurugan, CVRDE, DRDO, Chennai	1. Dr. Shankar Krishnapillai, IIT Madras, Chennai	1. Dr. S. Sivakumar, SRMIST
2.Dr. D. Saji, National Aerospace Laboratories, Bangalore	2. Dr. V. Aurumugam, MIT, Chennai	2. Dr. L. R. Ganapathy Subramanian, SRMIST

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