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

Computer Aided Design

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	21MEC501J	Course Name	MODELING AND SIMULATION	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							2	0	2	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the concepts of abstracting physical system and modelling concept*
CLR-2:	*understand the 3D model generation*
CLR-3:	*understand the simulation techniques for mechanical systems*
CLR-4:	*understand the modeling of biosystems*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*define the mathematical modeling of mechanical system*	*2*		
CO-2:	*develop geometric modeling of system*	*1*		
CO-3:	*simulate continues and discrete mechanical system*	*2*		*3*
CO-4:	*reconstruction the 3D solid models of biosystems*		*2*	*3*

Module-1 - Mathematical Modelling of Mechanical System	***15 Hour***
Fundamental Concepts in Mathematical Modelling - basic elements of Mechanical systems – Translational, rotational. Hydraulic systems - Modelling Electric Motor, Mass Pulley system- Translational mass element, Rotational mass element, translation spring element, Damper element- Modelling of First order and second order Systems: Governing equations for free and forced responses- system transfer functions- transfer functions first order and second order systems. *Practical: Mathematical modelling of mechanical system using simulation software.*	
Module-2 - Geometric Modelling	***15 Hour***
Wireframe Modelling, Surface Modelling-Analytical Surfaces Free-form Curved and sculptured Surface - Solid Modelling- Constructive Solid Geometry (CSG) - Boundary Representation (B-Rep) - Feature Based Modelling - Primitive Instancing, Cell decomposition, Spatial Enumeration – creation of Parametric Modelling techniques - Assembly modelling - Advanced assembly operations. *Practical: 3D modelling of mechanical system components using 3D modelling software*	
Module-3 - Mechanical System Simulation	***15 Hour***
Introduction of system and Models - System Study, System Simulation - Input Data Model - Continuous System Simulation - Discreet System Simulation- System Dynamics- Dynamic systems, Types of dynamic models, Frequency domain-based modelling, Time domain-based modelling, State space modelling of discrete time systems, Modelling examples of various practical systems. *Practical: modelling and simulation of continuous and discrete system using simulation tools*	
Module-4 - Modelling of Biosystems	***15 Hour***
Introduction to biomechanics - Anatomical morphology - History of anatomical models, digital 3D models - Creating a 3D Model using Graphics Software - Creating a 3D Model using Imaging and Scanning – steps involved, techniques- Image reconstruction – Creation of 3D Model using Segmentation- Digital 3D Anatomical Models to Create Physical Models- 3D printing – materials, resolution and accuracy and safety concerns. *Practical: Reconstruction of anatomical model using 3D laser scanner.*	

Learning Resources	1. *Kishore V. Pochiraju , "Modeling and Simulation for Mechanical Engineers", John Wiley & Sons* 2. *James McConville," Introduction to Mechanical System Simulation Using Adams" 2015* 3. *Kevin Russell, Qiong Shen, Rajpal S. Sodhi. "Kinematics and Dynamics of Mechanical Systems, Second Edition: Implementation in MATLAB® and SimMechanics", 2018, Taylor and Francis*	4. *Pushpa Singh, Narendra Singh, "Modelling and Simulation", S.K. Kataria & Sons, 2008* 5. *Ibrahim Zeid, CAD / CAM – Theory and Practice", 2009, McGraw Hill* 6. *Jun Ueda and Yuichi Kurta, "Human Modeling for bio-Inspired Robotics – Mechanical Engineering in Assistive Technologies", 2016, Science Direct*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
Mr. Parameswaran, Nokia, Chennai	*Dr. Raju Abraham, NIOT, Chennai.*	*1. Dr. S. Karuppudaiyan, SRMIST*
		2. Dr. V. Magesh, SRMIST

Course Code	21MEC502J	Course Name	THEORY OF VIBRATIONS	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	*Mechanical Engineering*	**Data Book / Codes / Standards**		*Nil*	

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the fundamentals of free and forced vibration analysis of single degree of freedom systems*
CLR-2:	*analyze the forced vibration response of single degree of freedom system under arbitrary forcing function*
CLR-3:	*perform the free and forced vibration analysis of multiple degrees of freedom system*
CLR-4:	*determine the natural frequencies and mode shapes of multiple degrees of freedom system using numerical techniques and know about various vibration measurement transducers and shakers*
CLR-5:	*analyze the free vibration of distributed mass systems with continuous system principles*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*solve a vibrating system problem for different free and forced vibration response*	3	2	
CO-2:	*solve vibrating systems subjected to arbitrary forces, including impulse, step, and ramp forces*	3	2	
CO-3:	*calculate natural frequencies and mode shape(s)and determine the free-vibration solution*	3	2	
CO-4:	*find the natural frequencies of vibration and the modal vectors by using various numerical techniques and to measure vibration characteristics and infer model parameters from the measured data.*	3	2	
CO-5:	*find the free-vibration solutions of string, bar, shaft, beam, membrane, and plate problems with continuous system principles*	3		2

Module-1: Single Degree of Freedom System	***15 Hour***
Basic concepts and Classifications of vibration, Equation of motion and natural frequency of free undamped vibrating system using Newtons second law and principle of energy conservation- Free vibration of torsional system with single rotor, center of percussion-types of damping – damped free vibrations- forced vibration response of a single degree of freedom subject to harmonic force – response due to rotating unbalance-force transmissibility – vibration isolation – support motion – base excitation -motion transmissibility using absolute and relative coordinates-whirling of shaft	
Module -2: Single Degree of Freedom System with General Excitation	***15 Hour***
Self- excitation system, dynamic stability of the system – Fourier series for general periodic function- Response under general periodic forcing - Response under general periodic force of irregular form- impulse response function – types of non-periodic inputs- convolution integral – response of single degree of freedom system subject to a general non-periodic force- Fourier transform and its applications - solution by Laplace transform – response spectrum	
Module -3: Multiple Degree of Freedom Systems	***15 Hour***
Examples for Multiple degree of freedom systems- Equation of motion by Newton's second law, Lagrange's equation- Free vibration analysis of undamped system with two DOF, pitch-bounce model-coordinate coupling-Principal coordinates-free vibration response of undamped two DOF system - Forced vibration response of undamped two DOF system- semi definite system – dynamic absorber-undamped absorber – torsional dynamic absorber – influence coefficients- stiffness and flexibility influence coefficients- Maxwell's reciprocal theorem	
Module -4: Natural Frequency and Modes of MDOF System and Vibration Measurement	***15 Hour***
Orthogonality of normal modes- Orthonormalization of Eigenvectors, modal matrix- Forced Vibration response of Undamped Systems Using Modal Analysis- Determination of natural frequency using Dunkerley's formula, Rayleigh's formula, Holzer's method and Matrix iteration method.	

Vibration measurement: Variable- Resistance transducers- Piezoelectric transducers, Electrodynamic Transducers and LVDT- Seismic instruments, vibration pickups, velometer, accelerometers- Frequency-Measuring Instruments- Vibration exciters, mechanical and electrodynamic shakers- Experimental modal analysis- machine condition monitoring techniques
Module -5: Continuous Systems and Balancing Machines ***15 Hour***
Basics of continuous systems, Transverse Vibration of a String or Cable-governing equation – frequency equation and solution – free vibration of axial vibration of bar- Normal functions, orthogonality of normal function- free torsional vibration of shaft-free transverse vibration of beams, membranes and plates. *Balancing of Rotating Machines, Single-Plane balancing- single plane balancing using vibration measurement- Two plane balancing using vibration measurement*

Learning Resources	1. *Singiresu S. Rao, Mechanical Vibration 6th edition in SI units, Pearson Education Inc., 2018.* 2. *Thomson. W. T., "Theory of Vibration with Applications", Chapman & Hall in 1993.* 3. *S. Graham Kelly, "Mechanical Vibrations", Cengage Learning. SI Edition. 2012.*	4. *William, W. Seto - "Mechanical Vibrations" Schaum Publishing company* 5. *C. Sujatha, Vibration and Acoustics Measurement and Signal Analysis, Tata Mc Graw Hill Education Pvt Ltd., 2010.* 6. *Leonard Meirovitch, "Fundamentals of vibrations", McGraw Hill International Edition. 2001.*

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*	*10%*	-	-	-	*10%*	-
Level 2	*Understand*	*10%*	-	-	-	*10%*	-
Level 3	*Apply*	*40%*	-	-	*40%*	*40%*	-
Level 4	*Analyze*	*40%*	-	-	*40%*	*40%*	-
Level 5	*Evaluate*	-	-	-	*20%*	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. Parameswaran, Nokia, Chennai	1. *Dr. Raju Abraham, NIOT, Chennai.*	1. *Dr. P. Nandakumar, SRMIST*

Course Code	21MEC503T	Course Name	ADVANCED MECHANICS OF SOLIDS	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	*Mechanical Engineering*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*equip the students in the 3D stress transformation and principal stress concepts in solid mechanics.*
CLR-2:	*quantify the failure of structural members and bending behavior of symmetrical beams.*
CLR-3:	*apply the concepts of energy techniques involved in structures, axial and transverse load on beams.*
CLR-4:	*obtain the knowledge on torsion of non-circular sections and unsymmetrical bending of beams*
CLR-5:	*improve the skill on theory of elasticity.*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*define the 3D stress transformation and principal stress*	*2*	*-*	*3*
CO-2:	*apply failure theories of structures*	*3*	*-*	*3*
CO-3:	*incorporate energy techniques on structures*	*3*	*-*	*3*
CO-4:	*evaluate torsion of non-circular sections and bending of unsymmetrical beams*	*3*	*-*	*3*
CO-5:	*analyze the bending of thin plates and thick cylinders*	*3*	*-*	*3*

Module-1 - Concepts of Force, Stress, Strain, Displacement and Transformations:	***12 Hour***
Introduction – force diagrams- free body diagrams- force Distributions- stress-strain relations. Displacements, Strain –Displacement relations – problems in 2D stress transformation. Coordinate systems - 3D Stress Transformation- Strain transformations- Generalized 3D stress –strain relations- the equilibrium equations – Compatibility – Principal stresses in 3D – maximum shear stress.	
Module-2 - Strength, Failure Modes and Design Considerations	***12 Hour***
Strength- Design Factor-Strength - failure theories – Basic- Tresca, Von Mises theories and comparison of theories - Plasticity and limit design concepts- Inelastic Behavior- Engineering Approximations used in Statically Indeterminate structure - axial loading of beams in bending-bending of symmetric beams in two planes	
Module-3 - Energy Techniques	***12 Hour***
Work- Strain Energy, total Strain Energy in bars with simple loading conditions- Castigliano's first Theorem- Castigliano's Second Theorem- Castigliano's Second Theorem applied to statically determinate problems - Deflections of Thick Curved Beams - Virtual Load Method, the Virtual Load Method applied to Statically Indeterminate Problems - Rayleigh's Method and Rayleigh-Ritz method applied to Beams in Bending - Straight Beams undergoing the combined effects of Axial and Transverse loading.	
Module-4 - Torsion and Bending of Structures	***12 Hour***
Torsion of non-circular sections, rectangular and steel rolled sections- Torsional strain energy – Closed thin - walled tubes-shear - open thin – walled beams shear flow - torsion of closed thin-walled tubes-single cell multiple cell sections – Bending of unsymmetrical Beams-Transverse shear stresses-Shear Center with one axis of symmetry- Shear center for open and unsymmetrical thin-walled beams – Curved beams - Circumferential stress in rectangular and square sections.	
Module-5 – Theory of Elasticity	***12 Hour***

Plane Elastic problems - Airy Stress Function Prandtl's stress function for torsion - Bending of thin –flat rectangular and circular plates- shell structures – Thick walled cylinders and rotating disks Contact stresses - stress concentrations.

Learning Resources	*1. Richard G. Budynas, "Advanced Strength and Applied Stress Analysis" (2nd Edition) by, McGraw-Hill International Editions, 1999.* *2. L.S. Srinath, "Advanced mechanics of solids", (2nd Edition) by Tata McGraw-Hill, 2003* *3. S.Timoshenko and SW Krieger ., "Theory of plates and shells" , by, McGraw – Hill International Edition 1999, Engineering mechanics series* *4. S.Timoshenko and D.H.Young , "Elements of strength of Materials", by. D Van Nostrand Co., 1968* *5. Arthur Boresi and Richardh Schmidt, "Advanced Mechanics of Materials," John Wiley & Sons, 6ed, 2009*	*6. Ansel C. Ugural and Saul K. Fenster, "Advanced Mechanics of Materials and Applied Elasticity," Prentice Hall; 5th ed.,2011* *7. G. T. Mase, R, E, Smelser, and G, E, Mase, "Continuum Mechanics for Engineers," 3rd edition, CRC Press, 2004* *8. Y. C. Fung, "Foundations of Solid Mechanics," Prentice Hall International, 1965* *9. Stephan H Crandal, Norman C Dahl, Thomas J Lardner," An Introduction to the Mechanics of Solids," McGraw Hill, 2nd edition,1978* *10. Robert Cook and Warren Young, "Advanced Mechanics of Materials," Pearson, 2nd edition, 1998*

Learning Assessment (@ Assessment by Open Book Examination)

	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*	*10%*	-	*10%*	-	*10%*	-
Level 2	*Understand*	*10%*	-	*10%*	-	*10%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	*20%*	-	*20%*	-	*20%*	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Mr. Parameswaran, Nokia, Chennai	*1. Dr. Raju Abraham, NIOT, Chennai.*	*1. Dr. V.Magesh, SRMIST*

Course Code	21MEC504J	Course Name	FINITE ELEMENT ANALYSIS	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	Mechanical Engineering	Data Book / Codes / Standards	Nil		

Course Learning Rationale (CLR):	The purpose of learning this course is to:
CLR-1:	find the approximate solution of boundary value problems
CLR-2:	develop basic finite element concepts and solution procedure for one dimensional problem
CLR-3:	find the finite element solution for two and three dimensional problems
CLR-4:	formulate and Solve Eigen value problems in Mechanical Engineering
CLR-5:	formulate and solve problems in heat transfer and Fluid dynamics problems using finite element method.

Course Outcomes (CO):	At the end of this course, learners will be able to:	Programme Outcomes (PO)		
		1	2	3
CO-1:	solve the differential equations using weighted residual and variational approaches	3		2
CO-2:	solve the structural analysis problems, such as bar, truss, beam using 1D element.	3		2
CO-3:	analysis of two-dimensional structural problems and three dimensional problems	3		2
CO-4:	solve Eigen Value and forced vibration problems using finite element method	3		2
CO-5:	solve one dimensional heat transfer and fluid flow problems using finite element method	3		2

Module-1: Solution of Differential Equations	15 Hour
FEM Applications, Commercial FEM software packages, Solution of differential equations by Weighted residual and variational methods – Collocation, Sub-domain, Least Squares, Galerkin methods - Variational formulation approach- Rayleigh-Ritz method, Principle of minimum potential energy. Solution of differential equations by Galerkin's finite element method	
Module-2: One Dimensional structural Analysis	**15 Hour**
Spring element- stiffness matrix, simple problems with spring element- Development of bar element-Governing equation - Minimum potential energy concept-higher order bar elements- application to trusses- Beam elements-natural coordinates- formulation of element stiffness matrix and load vectors, Gaussian quadrature integration	
Module-3: Finite Element Analysis of Two and Three-Dimensional Problems	**15 Hour**
Theory of elasticity-plane stress and strain conditions- derivation of shape function and element matrices of constant strain and linear strain triangle elements-Four node quadrilateral elements-isoparametric formulation-Lagrange and serendipity family elements-Higher order elements-Gauss quadrature for numerical integration-axis symmetric problems-bending of plates- Three dimension elements-Tetrahedron and Hexahedron elements- derivation of shape function and element matrices – Implementation of software packages for two and three dimensional problems.	
Module-4: Dynamic Analysis of Structures	**15 Hour**
Hamilton's Principle- lumped and consistent mass matrices for bar, beam and triangular elements-formulation of Eigen value problems in solid mechanics-natural frequency and normal modes for axial vibration of bar and transverse vibrations of beams - Forced vibration response by Numerical time integration – Finite Difference method, Runge-Kutta method, Newmark's method – Implementation of software packages for modal analysis of plates	

Module-5: Heat Transfer and Fluid Flow Problems	***15 Hour***
Basics of Heat Transfer-Governing equations and boundary conditions-Derivation of conductivity, convection and capacitance matrices and thermal load vectors for one dimensional element-steady state and transient heat conduction in one dimension-One dimensional potential fluid flow problems	

Learning Resources	1. *Hutton, D.V., "Fundamentals of Finite Element Analysis", McGraw Hill, International Edition, 2004.* 2. *Belegundu, Ashok D.; Chandrupatla, Tirupathi R, "Introduction to Finite Elements in Engineering", Pearson 2012* 3. *J.N Reddy, An introduction to the Finite Element Method, 2005, McGraw Hill*	4. *S.S. Rao, The Finite Element method in Engineering, Elsevier Science &Technology Books, 6th edition, 2018.* 5. *K.J. Bathe, Finite Element Procedures, Prentice Hall, Pearson Education, Inc, 2nd edition, 2014* 6. *Cook R.D., Malkus, D.S., Plesha, M.E., Witt, R.J., "Concepts and Applications of Finite Element Analysis", 4th Edition, John Wiley & Sons, 2001*

Learning Assessment (@ Assessment by Open Book Examination)

	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 –Practice (15%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*10%*	-	-	-	*10%*	-
Level 2	*Understand*	*10%*	-	-	-	*10%*	-
Level 3	*Apply*	*40%*	-	-	*40%*	*40%*	-
Level 4	*Analyze*	*40%*	-	-	*40%*	*40%*	-
Level 5	*Evaluate*	-	-	-	*20%*	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. Parameswaran, Nokia, Chennai	*1. Dr. Raju Abraham, NIOT, Chennai.*	*1. Dr.P. Nandakumar, SRMIST*

ACADEMIC CURRICULA

Computer Aided Design

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	21MEE501T	Course Name	INTEGRATED PRODUCT DESIGN AND DEVELOPMENT	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	*Mechanical Engineering*	**Data Book / Codes / Standards**		*Nil*	

Course Learning Rationale (CLR):	The purpose of learning this course is to:
CLR-1:	*understand the product design and development processes*
CLR-2:	*understand the phases of product development over the whole product design cycle*
CLR-3:	*understand the modules of architecture of a product*
CLR-4:	*understand the methodology for refining, enhancement and economics of design*
CLR-5:	*understand the forms and issues involved in protecting the rights of a designer*

Course Outcomes (CO):	At the end of this course, learners will be able to:	Programme Outcomes (PO)		
		1	2	3
CO-1:	*identify and analyze the product design and development processes in any industry.*	*1*	-	-
CO-2:	*define the phases of product development over the whole product design cycle*	*1*	-	-
CO-3:	*undertake a methodical approach to evolve the architecture of a product*	*1*	-	-
CO-4:	*carry out the process of refining and enhancing the design*	*2*	-	-
CO-5:	*be familiar with the forms and issues involved in protecting the rights of a designer*	*3*	*3*	-

Module-1 - Product Development Process	***9 Hour***
Stages in product development, Recognition of the need for product development, Product Development Process, Demand forecasting, understanding customer needs, Data collection and interpretation, Organizing the needs, Customer involvement in refining the requirements, Conjoint Analysis, Establish target specifications, Setting the Final Specifications	
Module-2 - Concept Generation, Evaluation and Selection	***9 Hour***
Problem decomposition, Search externally, Search internally, Systematic exploration, Evaluating the solutions, Hybridizing concepts, Concept selection, Concept Screening, Concept Scoring, Concept testing	
Module-3 - Product Architecture and Product Life Cycle Management	***9 Hour***
Implications of product architecture, Product change, Product variety, Component Standardization, product performance, manufacturability, Establishing the architecture – Creation and clustering, Geometric layout development, Fundamental and incidental interactions, Delayed Differentiation, Platform Planning, Related System-Level Design issues, Related system level design issues, secondary systems, Architecture of the chunks, Creating detailed interface specifications. Product Life Cycle Management (PLM), techniques and methods, PLM and project management, PLM in industry.	

Module-4 - Industrial Design and Design for X	***9 Hour***
Need for industrial design, impact of industrial design, Industrial Design Process - Investigation, conceptualization, refinement of customer needs, Management of the Industrial Design Process, Technology driven and User driven products, Assessing the Quality of Industrial Design, Design for Manufacture, Design for Assembly and Maintenance, Design for Economics, Design for Safety and reliability, Product development economics, Reducing the component costs and assembly costs, Minimize system complexity	
Module-5 – Patents And Intellectual Property Rights	***9 Hour***
Intellectual Property – types, Legislations coverings IPRs in India, Patent - Types of Patents, Patentability criteria - International Patenting, Copy rights – trademark and service marks, Trade secret-Geographical Indication, Industrial Designs – Plant varieties, Preparing a disclosure, Patents –- Product development, Elements of economic analysis, Managing projects- project planning,S Accelerating projects-project execution	

Learning Resources	1. *Karl Ulrich, Steven Eppinger, Maria C. Yang, "Product Design and Development", 7th Edition, Mc Graw Hill Education, 2020.* 2. *Foundation Skills in Integrated Product Development (FSIPD), Student Handbook NASSCOM, 2013.* 3. *Imad Moustapha, "Concurrent Engineering in Product Design and Development", New Age International publishers, 2006.* 4. *Stephen Rosenthal. "Effective Product Design and Development" Business One Orwin, Homewood 1992. ISBN.1-55632-603-4.*	5. *Staurt Pugh, "Tool Design — Integrated Methods for successful Product Engineering', Addison Wesley Publishing, New York, N.Y.1991. ISBN 0-202-41639-5.* 6. *Arunprasanth S, Krishna Sankar P, and Sriram Kumar K, "Foundation Skills in Integrated Product Development for Engineering Studies, First Edition", A.R. Publications, 2017.* 7. *John Stark, "Product Lifecycle Management (Volume 1): 21st Century Paradigm for Product Realisation" Springer, 5th edition, 2023*

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. Mr. Parameswaran, Nokia, Chennai	1. *Dr. Raju Abraham, NIOT, Chennai.*	*1. Dr. E Vijayaragavan, SRMIST*
		2. Dr. D Kumaran, SRMIST

Course Code	21MEE502T	Course Name	DESIGN FOR MANUFACTURE AND ASSEMBLY	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	*Mechanical Engineering*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	The purpose of learning this course is to:
CLR-1:	*familiarize various principles of DFMA for improving quality aspects of a product.*
CLR-2:	*have knowledge of different considerations for different manufacturing processes like casting, welding etc.*
CLR-3:	*have knowledge of different considerations for different manufacturing processes like forging, machining etc.*
CLR-4:	*have knowledge in design for assembly and environment consideration while design.*

Course Outcomes (CO):	At the end of this course, learners will be able to:	Programme Outcomes (PO)		
		1	2	3
CO-1:	*understand the principles of design for manufacturing processes, and material selection*	*2*		
CO-2:	*apply and analyse components using design features for casting and welding*	*2*		*3*
CO-3:	*apply and analyse components using design features for forging and machining*	*2*		*3*
CO-4:	*apply various techniques of design for manufacture for product design and assembly*		*2*	*3*

Module-1 - Introduction to Design for Manufacturing	***9 Hour***
Introduction to Design for Manufacturing (DFM), Advantages of Applying design for manufacturing and Assembly During Product Design, DFM - Definition Typical DFMA Case Studies, Overall Impact of DFMA on Industry. Development of the Systematic DFM Methodology and its applications, General design principles for manufacturability - strength and mechanical factors, mechanisms selection, evaluation method, Geometric Dimensioning & Tolerance (GD&T) Process capability- Tolerance stacks - Factors Influencing Form Design: Working principle, Material, Manufacture, Design- Feasible solutions.	
Module-2 - Design for Casting and Welding	***9 Hour***
Appraisal of various casting processes, selection of casting process, General design considerations for casting-casting tolerance-use of solidification, simulation in casting design-product design rules for sand casting, Case study comparison of cast iron, Steel and aluminium. Appraisal of various welding processes, factors in design of weldments – general design guidelines-pre and post treatment of welds-effects of thermal stresses in weld joints. Case studies in welding.	
Module-3 - Design for Forging and Machining	***9 Hour***
Forging: Design factors for forging – closed die forging design – parting lines of dies – drop forging die design – general design recommendations. Case studies in forging, Overview of various machining processes-general design rules for machining dimensional tolerance and surface roughness-Design for machining – ease –redesigning of components for machining ease with suitable examples. General design recommendations for machined parts, Case studies in machining	
Module-4 - Design for Assembly	***9 Hour***

Introduction, Design for Assembly: assembly process, Characteristics and applications, Example of common assembly, Economic significance of assembly, General taxonomies of assembly operation and systems, Assembling a product, Design considerations and recommendation for fasteners.
Module-5 Design for Assembly Tools and Design for the Environment ***9 Hour***
Application of tools like lean manufacturing, six sigma, poke-yoke, concurrent engineering in the perspective of DFA, Design for manufacture and Computer aided design. Environmental objectives, Global issues, Regional and local issues, Basic design for environment methods, Lifecycle assessment method, Techniques to reduce environmental impact, Design to minimize material usage, Design for Disassembly, Design for Failure.

Learning Resources	*1. Boothroyd, G, 2nd Edition 2002, Design for Assembly Automation and Product Design. New York, Marcel Dekker.* *2. Bralla, Design for Manufacture handbook, McGrawhill,1999* *3. Boothroyd, G, Heartz and Nike, Product Design for Manufacture, Marcel Dekker,1994* *4. Dickson, John. R, and Corroda Poly, Engineering Design and Design for Manufacture and Structural Approach, Field Stone Publisher, USA,1995*	*5. Fixel, J. Design for the Environment McGraw Hill., 2nd Edition 2009* *6.Harry Peck., Design for Manufacture, Pittman Publications,1983.2* *7.Alan Redford and chal, Design for Assembly-Principles and Procedures, McGraw Hill International Europe, London, 1994.* *8.Robert Matousek, Engineering Design-A Systematic Approach, Blackie&sons Ltd.,1963.*

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. Mr. Parameswaran, Nokia, Chennai	*1. Dr. Davidson Jebaseelan., VIT, Vellore*	*1. Dr.P.Susai Manickam, SRMIST*
	2. Dr. Raju Abraham, NIOT, Chennai.	

Course Code	21MEE503J	Course Name	OPTIMIZATION METHODS IN ENGINEERING DESIGN	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	*Mechanical Engineering*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to be:***
CLR-1:	*familiar with principles of optimization and its need*
CLR-2:	*familiar with various conventional optimization techniques*
CLR-3:	*familiar with solving multivariable problems techniques*
CLR-4:	*familiar with solving problems using unconventional optimization techniques*
CLR-5:	*familiar with modern methods of optimization and application of optimization to design of machine elements*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*understand optimization principles and its need*	*2*	*2*	*2*
CO-2:	*understand and apply the concept of conventional optimization techniques*	*3*	*3*	*3*
CO-3:	*understand and apply the concept of constrained in single variable as well as multivariable*	*3*	*3*	*3*
CO-4:	*understand and apply the concept unconventional optimization techniques*	*3*	*3*	*3*
CO-5:	*understand and apply Modern Methods of Optimization in real life situation*	*3*	*3*	*3*

Module -1: Introduction Optimization Techniques	***9 Hour***
Introduction to optimization - adequate and optimum design-Principles of optimization-design vector, design constraints-Statement of an optimization problem *Practical: Practical: Introduction to Optimization toolbox / Libraries* *Formulation of objective function -Design constraints -Single variable optimization techniques* *Practical: Solution method Choosing the Algorithms* *Classical optimization for multivariable-Basics of maxima and minima convex optimization -Important classes of convex optimization problems* *Practical: Solve a constrained problem using optimization variable – Graphical representation*	
Module -2: Classical Optimization Techniques	***9 Hour***
Techniques of unconstrained-Optimization -General Approach golden section Fibonacci method -Rate of convergence scaling of design variables - Direct search methods, Random jump method, Random walk method -Random walk method with direction exploitation – *Practical: Create optimization variable for each problem variable, formulate the problem with objective function and constraints.* *Grid search method -Univariate method -Pattern directions -Hooke and Jeeves method -Powells method* *Practical: Non-linear constraints with gradients* *Interpolation methods -Quadratic interpolation method -Cubic interpolation method* *Practical: Linear and quadratic programming problems – Numerical methods revision*	

Module -3: Multi Variable and Objective	***9 Hour***
Descent methods -Gradient of a function -Evaluation of the gradient -Conjugate gradient method -Fletcher -Reeves method -Quasi -newton methods *Practical: use of gradient evaluation function* *Transformation techniques -Penalty function -Multi objective optimization* *Practical: Multi-objective optimization Algorithms* *Utility function method -Inverted utility function method -Global criterion method -Goal attainment method -Bounded objective function method* *Practical: Multi-objective optimization algorithms - Minimization and maximization*	
Module -4: Non-Traditional Optimization Techniques	***9 Hour***
Genetic Algorithm introduction basic elements of natural genetics -reproduction crossover and mutation-The computational procedure involved in optimizing the fitness function in Genetic Algorithm - Tutorials on genetic Algorithm *Practical: Function GA tool at the command line, Fitness function, individuals, population and generations* *Simulated Annealing steps involved -Ant colony optimization -Graphical representation of ant colony optimization process* *Practical: Simulated Annealing solver Generating file* *Particle swarm optimization -Swarm size information links initialization equation of motion -Problems on particle swarm optimization* *Practical: Particle swarm optimization*	
Module -5: Optimization in Design of Machine Elements	***9 Hour***
Desirable and undesirable effects - Functional requirement - Material and geometrical parameters *Practical: Optimization of shafts and torsionally loaded members* *Design of simple axial transverse loaded members for minimum cost and minimum weight, Problems on minimum weight design of a prismatic beam - Design for linear and non-linear geometric problems helical springs* *Practical: Linear and non-linear geometric problems helical springs* *Integrating Simulation in optimization models: Multi-variable and Multi-objective optimization –Stochastic optimization Robustness and tolerance optimization.* *Practical: Case studies in engineering*	

Learning Resources	1. *Singaresu.S Rao, "Engineering Optimization – Theory & Practice", New Age International (P) Limited, New Delhi, 2009.* 2. *Kalyanamoy Deb, "Optimization for Engineering design algorithms and Examples", Prentice Hall ofIndia Pvt. Ltd., 2006.* 3. *Johnson Ray C, "Optimum design of mechanical elements", Wiley, John & Sons, Digitized 2007* 4. *Goldberg. D.E, "Genetic algorithms in search, optimization and machine", Barnen, AddisonWesley, New York, 1989.* 5. *William Orthwein, "Machine Component Design", Vol. I and II, Jaico Publishing house, New Edition,2006.*	6. *Rao.C.S, "Optimization Techniques", Dhanpat Rai& Sons, New Delhi* 7. *Fox.R.L, "Optimization methods for Engineering Design", Addison Wesley Pub, Digitized 2007.* 8. *Garret N. Vanderplaats, "Numerical optimization techniques for engineering", McGraw-Hill Ryerson,* 9. *Saravanan, R., "Manufacturing Optimization through intelligent techniques, Taylor & Francis (CRC Press), 2006* 10. *Arora, J., "Introduction to optimization Design" Elsevier Academic Press, New Delhi, 2004*

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 Practice (15%)*			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	*10%*	-	-	-	*10%*	-
Level 2	*Understand*	*10%*	-	-	-	*10%*	-
Level 3	*Apply*	*20%*	-	-	*20%*	*20%*	-
Level 4	*Analyze*	*20%*	-	-	*20%*	*20%*	-
Level 5	*Evaluate*	*20%*	-	-	*30%*	*20%*	-
Level 6	*Create*	*20%*	-	-	*30%*	*20%*	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. Parameswaran, Nokia, Chennai	*1. Dr. Raju Abraham, NIOT, Chennai.*	*1. Dr. D. Kinglsy Jeba Singh, SRMIST*
		2. Dr. M. R. Stalin John, SRMIST

Course Code	21MEE504T	Course Name	BIOMECHANICS	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	*Mechanical Engineering*	**Data Book / Codes / Standards**		*Nil*	

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*describe the fundamental of reference planes and positions*
CLR-2:	*interpret the structure, movements and loads on upper and lower extremity*
CLR-3:	*interpret the statics and dynamics of human body*
CLR-4:	*interpret mechanics of soft tissues*
CLR-5:	*describe the experimental testing and ergonomics in biomechanics*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*express the reference positions, planes, and axes associated with the human body*	*1*		
CO-2:	*identify and apply the anatomical structure and loads on the upper and lower extremity*	*2*		
CO-3:	*analyze the force and torque acting on the human body*	*2*		
CO-4:	*express the Muscle-Tendon function*	*1*		
CO-5:	*identify how to test the biological specimens and human body in a laboratory environment and also apply biomechanics knowledge to real-world problems*			*3*

Module-1 - Introduction	***8 Hour***
Biomechanics: definition and perspective, Standard reference terminology and anatomical reference position, Directional terms, anatomical reference planes and axes - Sagittal plane, frontal plane, transverse plane, joint movement terminology, and other movements and spatial reference systems	
Module-2 - Upper and Lower extremity	***9 Hour***
Structure, movement and loads on shoulder, elbow, wrist, spine, hip, knee and foot.	
Module-3 - Statics and Dynamics of Human Body	***8 Hour***
Forces, torques, and equilibrium, motion in one plane and levers (simple problems 2D). Kinematics and musculature, sports kinematics, collisions of the human body, common injuries in upper and lower extremity.	
Module-4 - Soft Tissue Mechanics	***8 Hour***
Structure of Cartilage, Tendon, Ligament and Muscle, Composition of tendons and ligaments, stress - strain curve for tendons and ligaments, Material Properties of Cartilage, Tendon, Ligament and Muscle. Cardiac Biomechanics, Cardiovascular biomechanics, Mechanics of Blood Vessels	
Module-5 – Experimental testing and Ergonomics in Biomechanics	***12 Hour***
Biomechanical testing instruments, Problems in testing, repeatability, reproducibility, reliability of results, Pit falls of biomechanical testing, movement-monitoring systems, Tools for Measuring Body Angles, Tools for measuring kinematic quantities video and film, Stride and Temporal Parameters, Motion Measurement, Ground Reaction Measurement Dynamic Electromyography (EMG), Challenges in – In-vitro, In-vivo and in-silico study.	

Biomechanics in work seating design - biomechanics during ladder and stair climbing and walking on ramps, Injury biomechanics and rehabilitation, Orthotics and prosthetics, Biomaterials for implant design.

Learning Resources	1. *Susan .J. Hall, —Basic biomechanics", Tata Mcgraw Hill, Sixth edition, 2011* 2. *Y. C. Fung, Biomechanics - Circulation Springer Verlang, 2nd Edition, 1997.* 3. *D. J. Schneck and J. D. Bronzino, —Biomechanics- Principles and Applications", CRC Press, Second Edition, 2000* 4. *Kreighbaum, E. and Barthels, K. (1996). Biomechanics: A Qualitative Approach for Studying Human Movement*	5. *Dr.Ajay Bahi and Dr.Sharad Ranga- Basics of Biomechanics, Jaypee brothers medical publication (P) Ltd.* 6. *Irving P. Herman, Physics of the Human Body, Springer, New York, NY, November 2006* 7. *Zatsiorsky, Vladimir M. Kinematics of Human Motion. Human Kinetics, 2002.* 8. *Zatsiorsky, Vladimir, and Boris Prilutsky. Biomechanics of skeletal muscles. Human Kinetics, 2012.*

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*	*10%*	-	*10%*	-	*10%*	-
Level 2	*Understand*	*30%*	-	*30%*	-	*30%*	-
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. Parameswaran, Nokia, Chennai	*1. Dr. Raju Abraham, NIOT, Chennai.*	*1. Dr. D. Raja, SRMIST*
		2. Dr. Sandipan Roy, SRMIST

Course Code	21MEE506P	Course Name	STRUCTURAL ASPECTS OF BIOMATERIALS	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	*Mechanical Engineering*	**Data Book / Codes / Standards**		*Nil*	

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*have the basic understanding of the structural biomaterials*
CLR-2:	*build the skills of test and characterize the various biomaterials*
CLR-3:	*have thorough knowledge on the clinical and regulatory issues of biomaterials in the different medical applications*
CLR-4:	*build the skills for modelling and analyze the biomaterials feasibility*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*define basics of structural biomaterials*	1	1	
CO-2:	*develop their skills in testing of biomaterials*	2	1	
CO-3:	*define the clinical and regulatory issues of biomaterials and demonstrate the application of biomaterials in various disciplines of medicine*	1		2
CO-4:	*apply the modeling and analysis skills in biomaterials*	2	2	

Module-1 – Introduction to Structural Biomaterials	***10 Hour***
Basics of structural materials: metals, ceramics, polymers, and composites – strengthening and toughening mechanism. Overview of Biomaterials – biomaterials used in medical devices - Nobel metal alloys-load bearing implant application – Biodegradable alloys - Tissues and Regulatory Issues -Review of structural tissues and constituents: bone, cartilage, vascular tissue, and dental tissues - Biocompatibility and Sterilization *Project 1: Role of design engineers in medical devices – Model an existing or new simple medical device*	
Module-2 – Biomaterials Testing	***10 Hour***
Constitutive Behavior and Biomechanical Design Issues-Elastic behavior, multiaxial loading, time-dependent behavior -Yield criteria and permanent deformation in devices -Fracture criteria and design concerns with brittle materials/stress concentrations -Fatigue: Total life and defect-tolerant philosophies -Friction, Wear and Lubrication. *Project 2: Medical device design including implants and clinical issues of any two currently used medical devices related to biomaterials and provide the solution.*	
Module-3 – Regulatory Issues and Applications of Biomaterials	***15 Hour***
Clinical Issues-Regulatory Issues: FDA testing and product development. Orthopedics: total joint replacement, soft tissue repair, and spinal implants. Cardiovascular: catheters, stents, grafts. Dental: implants, TMJ, restoration. Soft Tissues: reconstruction and augmentation- device development, legal and ethical issues	
Module-4 – Modelling and Analysis of Biomaterials	***10 Hour***
Stiff materials – Soggy skeletons and shock absorbers - Biological ceramics – functional design of bone- Experimenting with biomaterials – Tensile, compression, beam test, sundry fracture test-computer modeling. *Project 3: Structural analysis of polymer biomaterials using software.*	

Learning Resources	1. *L. Pruitt and A. Chakravartula. Mechanics of Biomaterials: Fundamental Principles for Implant Design, Cambridge University Press, Cambridge, UK, 2011* 2. *Julian Vincent, Structural biomaterials revised edition, Princeton University Press, New Jersey 1982.* 3. *Cuie Wen, Structural Biomaterials Properties, Characteristics, and selection, Woodhead publishing, 2021.*	*4. William R. Wagner, Shelly E. Sakiyama-Elbert, Guigen Zhang, Michael J. Yaszemski Biomaterials Science, An Introduction to materials in medicine, Fourth edition, Academic Press, 2020.* *5. Joon B. Park, Roderic S. Lakes, Biomaterials An Introduction, Springer, 2007.*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*						*Final Examination (0% weightage)*	
		Formative CLA-1 Average of unit test (20%)		*Project Based Learning CLA-2 (60%)*		*Report and Viva Voce (20%)*			
		Theory	*Practice*	*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. Parameswaran, Nokia, Chennai	*1. Dr. Raju Abraham, NIOT, Chennai.*	*1. Dr. V. Magesh, SRMIST*
		2. Dr. A. Vinoth, SRMIST

Course Code	21MEE507J	Course Name	COMPUTER GRAPHICS AND VIRTUAL REALITY	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	*Mechanical Engineering*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to be:***
CLR-1:	*familiar with the basics of computer graphics and its components*
CLR-2:	*familiar with the complete knowledge of 2D and 3D graphics*
CLR-3:	*familiar with the curves and surfaces*
CLR-4:	*familiar with the graphical kernel system and graphics exchanges standards*
CLR-5:	*familiar and conceive the knowledge on graphics and associated topics with introduction to VR and AR*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*understanding the history and development in the computer graphics, and solve 2D and 3D transformations*	*2*		
CO-2:	*understanding the 2D and 3D rendering pipeline*			*3*
CO-3:	*apply curves and surfaces to create surface modeling for various application.*			*3*
CO-4:	*create data exchange files to communicate between graphics system*		*3*	*3*
CO-5:	*understanding how virtual reality and augmented reality adds digital elements to a live view for better experience*		*3*	*3*

Module-1 - Introduction to Computer Graphics	***12 Hour***
History of Computer Graphics, Video Display Devices, Raster Scan and Random Scan Systems, Graphics monitors and Workstations, Input devices, Hard copy Devices, Graphics, Software Demo on Graphic Systems. Output primitives – points and lines, line function and line drawing a algorithms (DDA and Bresenham's algorithm), circle generating algorithms (mid-point circle algorithm), Loading the frame buffer Pixel addressing and object geometry, filled area primitives. 2D Transformation - Translation, Rotation, Scaling, composite transformations. 3D Transformation - Translation, Rotation, Scaling, composite transformations. Composite Transformations, Exercise on Line and circle drawing algorithms, Exercise on 2D & 3D transformation.	
Module-2 - Two and Three Dimensional Graphics	***12 Hour***
2D viewing – viewing pipeline, viewing coordinate reference frame, window-to-viewport coordinate transformation, two dimensional viewing functions, Clipping operations – point, line, Polygon clipping algorithms, Scan Conversion 3D viewing - viewing pipeline, viewing coordinates Projections, Clipping, Hidden line removal algorithms, Hidden surface removal algorithms, Algorithms for shading and rendering. Exercise on Clipping operations, Exercise on Projections, Exercise on Shading and Rendering	
Module-3 - Curves and Surfaces	***12 Hour***
Introduction to curve and its types, Hermite curves, Bezier curves, Exercise on curve generation, B-Spline, Rational , Surface Modeling techniques – Coons patch , Bi-cubic patch , Bezier surfaces ,B-spline surfaces, Exercise on curve generation, Exercise on Surface generation	
Module-4 Graphics Standards and Open GL	***12 Hour***

Introduction to Graphic Kernel System, Initial Graphics Exchange Specification (IGES), Standard for the Exchange of Product Model Data (STEP), Drawing Interchange Format, or Drawing Exchange Format (DXF), Continuous Acquisition and Life-cycle Support (CALS), Stereo Lithography (STL) • Communication Standards – LAN, Communication Standards – WAN. P2P - Open GL – Features in OpenGL, OpenGL operations, Abstractions in OpenGL – GL, GLU & GLUT Input and Interaction in OpenGL, D viewing pipeline in OpenGL, Viewing matrix (model-view matrix) specifications, Exercise on open GL programming - Error detection and Error recovery. Exercise on data exchange
Module-5 - Virtual and Augmented Reality ***12 Hour***
Virtual vs Interactive vs Immersive, Virtual Reality (VR) vs Augmented Reality (AR), Real vs Virtual. - Benefits of VR: 3D Visualization, Navigation, Interaction, Physical Simulation, Virtual environments. - VR Hardware: Computers, Tracking Devices, Input Devices, Output Devices, Glasses, Displays, Audio. - Head Mounted Display (HMD), Motion Trackers - BOOM, CAVE, Sensor Glove, Haptic Feedback devices. 5. Software: VR Software Features, Web Based VR, Division's Devise - VR and AR Applications: Industrial, Training Simulators, Entertainment - VR/AR Centres Exercise on VR/AR

Learning Resources	1. *Edward Angel and Dave Shreiner, —Interactive Computer Graphics – A Top-down Approach with Shader-Based OpenGL, 6th Edition, Addison Wesley.2012* 2. *Kunwoo Lee —Principles of CAD/CAM/CAE Systems, Addison Wesley. 1999.* 3. *Chris McMahon, Jimmie Browne, —CADCAM: Principles, Practice and Manufacturing Management, 2nd Edition, Addison Wesley, 2018.* 4. *Zeid, Ibrahim. CAD/CAM theory and practice. McGraw Hill, International Edition, 1998.*	5. *J. D. Foley, A. Van Dam, S. K. Feiner and J. F. Hughes, Computer Graphics – Principles and Practice, 2nd Edition in C, Pearson Education, 2003.* 6. *D. F. Rogers and J. A. Adams, Mathematical Elements for Computer Graphics, 2nd Edition, McGraw Hill, International Edition, 1990.* 7. *John Vince, —Introduction to Virtual Reality, Springer-Verlag London, 2004.* 8. *Gregory Kipper, Joseph Rampolla, —Augmented Reality – An Emerging Technologies Guide to AR, Syngress, 2012*

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*	*15%*	-		*15%*	*15%*	-
Level 2	*Understand*	*15%*	-		*15%*	*15%*	-
Level 3	*Apply*	*25%*	-		*25%*	*25%*	-
Level 4	*Analyze*	*25%*	-		*25%*	*25%*	-
Level 5	*Evaluate*	*10%*	-	-	*10%*	*10%*	-
Level 6	*Create*	*10%*	-	-	*10%*	*10%*	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. Parameswaran, Nokia, Chennai	*Dr. Raju Abraham, NIOT, Chennai.*	*Mr. S. Balamurugan, SRMIST*

Course Code	21MEE508J	Course Name	TRIBOLOGY IN DESIGN	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	*Mechanical Engineering*	**Data Book / Codes / Standards**		*Nil*	

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand and analyze the surfaces and friction*
CLR-2:	*understand and analyze the wear mechanisms*
CLR-3:	*understand and analyze the lubricants and lubrication phenomenon*
CLR-4:	*understand and analyze bearings surfaces and select suitable materials*
CLR-5:	*understand and analyze the surface engineering processes*

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 surface characteristics and friction*	2	1	1
CO-2:	*analyze the failure occurred due to various types of wear*	2	2	1
CO-3:	*apply the concept of lubrication to provide solutions*	2	2	2
CO-4:	*apply the knowledge of bearings surfaces to provide solutions*	2	2	2
CO-5:	*apply the concepts of friction and lubrication for various applications*	2	2	2

Module-1 - Friction	***8 Hour***
Engineering surfaces and surface topography, Measurement of surface topography and roughness parameters, Contact between surfaces, Sources of sliding Friction, Friction characteristics of metals and non-metals, Friction due to ploughing, Friction due to adhesion, Friction of ceramic materials, Friction of polymers.	
Module-2 - Wear	***14 Hour***
Types of Wear – Abrasive, Adhesive, Corrosive, Fatigue, Fretting. Wear of metals, Wear in polymers, Wear of ceramics.	
Module-3 - Lubrication and Lubricants	***14 Hour***
Stribeck Curve and its importance, Boundary and Mixed Lubrication regime, Hydrodynamic lubrication, Elasto hydrodynamic lubrication (EHL), Types of lubricants and their properties, Biodegradable lubricants and nano lubricants, Coatings, Self-lubricating coatings, Measurement of friction under dry and lubricated conditions.	
Module-4 - Surface Textures	***12 Hour***
Surface texturing methods, Influence of surface textures on bearing performance, Role of surface textures in reducing friction and wear in dry conditions, Role of surface textures in reducing friction and wear in wet conditions, Case study of surface textures in reducing friction and wear in pistons.	
Module-5 – Applications of Tribology	***12 Hour***
High temperature wear, Conventional surface treatments, Conventional coating techniques, Advanced coating techniques, Introduction to bio tribology, Wear of titanium alloys in bio tribology, Wear of biopolymers, Wear and lubrication in bearings.	

Learning Resources	1. *Hutchings.I.M and Shipway P, Tribology, Friction and Wear of Engineering Material, Elsevier Butterworth Heinemann , UK, 2017.* 2. *Bharat Bhushan, Introduction to tribology‖, Wiley Publication, 2013.* 3. *Williams.J.A, Engineering Tribology, Oxford University Press, 2005.* 4. *GwidonStachowiak, Andrew W Batchelor., Engineering tribology, Elsevier Butterworth –Heinemann, USA, 2005.*	5. *Stolarski.T.A, Tribology in Machine Design‖, Industrial Press Inc., 1990.* 6. *Cameron.A, Basic Lubrication Theory, Longman, U.K., 1981.* 7. *Neale.M.J., Tribology Handbook, Newnes Butter worth, Heinemann, U.K., 1975.* 8. *Dieter G.E., Mechanical Metallurgy‖, McGraw Hill Publication, India, Third Edition, 2013.*

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*	*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. Parameswaran, Nokia, Chennai	*1. Dr. Raju Abraham, NIOT, Chennai.*	*1. Dr. J. Daniel Glad Stephen, SRMIST*
		2. Dr. C. Shravan Kumar, SRMIST

Course Code	21MEE509J	Course Name	MECHANICS OF COMPOSITES	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	*Mechanical Engineering*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the constituents, classifications, applications, and of composites manufacturing techniques of various composite materials*
CLR-2:	*understand the mechanics of composite materials*
CLR-3:	*understand the analysis methods of laminated composites*
CLR-4:	*understand the failure and design the material for advanced engineering composites*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*familiarize the constituents, classifications, applications, and manufacturing techniques of various composite materials*	*1*		
CO-2:	*analyze the mechanics of composite materials*		*2*	
CO-3:	*apply the theory of composite mechanics for the analysis of laminated composites*			*3*
CO-4:	*implement failure theories for designing composite materials*			*3*

Module-1 - Introduction	***12 Hour***
Introduction to composite materials, matrix, and reinforcement - Matrix: polymers, metals, ceramics - Reinforcements: fibers, particles, whiskers – Advantages and limitations of composites – Properties and Applications of composites - Types of composites: Particulate-reinforced composite, Fiber-reinforced composites - Manufacturing of Composites - Hand lay-up technique, bag moulding, resin transfer moulding, filament winding, pultrusion, compression moulding. *Practice on incorporation of fillers in polymers and practice the fabrication of polymer matrix composites.*	
Module-2 - Mechanics and Classical Lamination Theory	***16 Hour***
Concepts of volume and mass fractions, density, void content, and Rule of mixtures - Characteristics of fiber-reinforced lamina: Elastic properties, stress-strain relationship, compliance, and stiffness matrices – Laminated structure: types of laminates - lamination theory, laminate strains, forces and moments, A, B, D Matrix, midplane strains and curvatures, thermal stresses and strains - Interlaminar stresses. Measurement of density of lamina, and Practice on mechanical testing of laminates.	
Module-3 - Analysis of Laminates	***16 Hour***
Bending, buckling, and vibration of laminated plates, and beams - Hygrothermal effects in Laminates – Laminate strength analysis - Analysis of sandwich structures - Finite element methods of analysis. Practice structural and vibration analysis of laminates using software.	
Module-4 - Failures Prediction and Laminate Design	***16 Hour***
Failure theories for fiber-reinforced composites: Maximum stress theory, Maximum strain theory, Azzi–Tsai–Hill theory, Tsai–Wu failure theory - Failure prediction in unnotched and notched laminates - Introduction to laminate design consideration - Design and analysis of adhesive and mechanically fastened joints. Case studies: Design of an automotive drive shaft, corvette leaf springs, and thin pressure vessels.	

Learning Resources	*1. Mallick, P.K., "Fibre Reinforced composites: Materials, Manufacturing and Design", CRC Press, 2007* *2. Agarwal, B.D, and Broutman L.J, "Analysis and Performance of Fibre Composites", John Wiley and Sons, New York, 1990* *3. Autar K. Kaw, "Mechanics of Composite Materials", CRC Press, New York, 2006* *4. Gibson, R.F., "Principles of Composite Material Mechanics", McGraw-Hill, 2007*	*5. Halpin, J.C., "Primer on Composite Materials, Analysis", Technomic Publishing Co., 1984* *6. Hyer MW and Scott R White, "Stress Analysis of Fiber–Reinforced Composite Materials", McGraw-Hill,1998* *7. Robert M. Jones, "Mechanics of Composite Materials", Second Edition, Taylor and Francis, 1999*

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*	*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
Mr. Parameswaran, Nokia, Chennai	*Dr. Raju Abraham, NIOT, Chennai.*	*Dr. M. Kamaraj, SRMIST*

Course Code	21MEE510J	Course Name	DESIGN OF HYDRAULIC AND PNEUMATIC SYSTEMS	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	*Mechanical Engineering*	**Data Book / Codes / Standards**		*Nil*	

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*be familiar with the principles of hydraulic pumps and actuators*
CLR-2:	*be familiar with the different valves and accessories used in hydraulic systems*
CLR-3:	*able to devise hydraulic circuit for given applications*
CLR-4:	*be familiar with principles and characteristics of pneumatic components*
CLR-5:	*apply knowledge to Design the fluid power system and trouble shoot fluid power systems*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*understand the principles and characteristics of hydraulic pumps and actuators*	*3*		
CO-2:	*understand the different valves and accessories used in hydraulic systems*	*3*		
CO-3:	*design the hydraulic circuit for given applications.*	*3*		1
CO-4:	*familiarize the principles and characteristics of pneumatic components.*	*3*		
CO-5:	*design the fluid power system and conduct maintenance and troubleshooting of fluid power systems*		3	1

Module-1 - Hydraulic Pumps and Actuators	***14 Hour***
Introduction to fluid power controls, Properties of Hydraulic fluid, Pumps: Gear Pumps, Vane Pumps - Radial & Axial Pumps - Piston pumps, Capacity rating, Selection of Pumps, Pump characteristics. Linear Actuators-Cylinders: Different types of cylinders, Types of mounting, Computations of force. Rotary actuators- Motors: Motors - fixed &Variable displacement motors, Hydraulic Motor Performance, Electrohydraulic Stepping motors	
Module-2 - Control Valves and Accessories	***10 Hour***
Control Valves: Pressure control-, Direction Control, and Flow control valves- Types, Construction and Operation. Servo and Proportional Valves-Applications. Accessories- Reservoirs, Pressure intensifier, Fluid Power ANSI Symbols	
Module-3 - Hydraulic Circuits	***12 Hour***
Circuit for speed control - meter in, meter out and bleed off. Circuits for – continuous reciprocation, cylinder Synchronization and sequencing. Hydraulic press, Pump unloading Circuit, Locked cylinder using pilot check valves. Accumulators: Accumulator types& its circuits	
Module-4 - Pneumatic Systems	***12 Hour***
Pneumatic systems- Fundamentals, Merits and Demerits Over Hydraulic systems, Compressor-types and working principle. Filters, Regulators, Lubricators, Mufflers and Air dryers for conditioning the pressurized air. Pneumatic Actuators, Design of Pneumatic Circuits- reciprocation, sequencing circuits, Low-cost automation. Fluid Logic Controls Systems: Principles of Fluid Logic Control, Basic Fluidic Devices Fluidic Sensors, Fluidic Logic Circuits	
Module-5 – Fluid Power System Design and Maintenance	***12 Hour***

Speed, force and time calculations, Sizing of actuators and pumps. Sizing of reservoirs and accumulators. Electrical controls for fluid power Circuits, Design of hydraulic and Pneumatic circuit for specific application – Cascading- for - Ladder diagram (Electrical controls), Maintenance procedures, Trouble shooting of fluid power systems fault finding process, causes and remedial actions Circuit Failures:

Learning Resources	1. *Anthony Esposito, "Fluid Power with applications", Pearson India education services PVT Ltd, 7th edition, 2015.* 2. *Andrew Parr, "Hydraulics and Pneumatics: A technician's and engineer's guide", Elsevier Ltd, 2011.* 3. *Majumdar.S.R, "Pneumatic systems – principles and maintenance", Tata McGraw-Hill, New Delhi, 2006.* 4. *Werner Deppert / Kurt Stoll, "Pneumatic Application: Mechanization and Automation by Pneumatic Control, Vogel verlag, 1986.* 5. *John Pippenger, Tyler Hicks, "Industrial Hydraulics", McGraw Hill International Edition, 1980.*	6. *Majumdar.S.R, "Oil Hydraulic Systems: Principles and Maintenance", Tata McGraw Hill, 2006.* 7. *FESTO, "Fundamentals of Pneumatics", Vol I, II and III.* 8. *Hehn Anton, H., "Fluid Power Trouble Shooting", Marcel Dekker Inc., NewYork, 1995.* 9. *Thomson, "Introduction to Fluid power", Prentice Hall, 2004.*

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 Practice (15%)*			
		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. *Mr. G.M. Kumaravel/ Brakes India Ltd*	*Dr. Raju Abraham, NIOT, Chennai.*	1. *Dr. R. Murugesan, SRM IST*
2. *Mr. Parameswaran, Nokia, Chennai*		

Course Code	21MEE601T	Course Name	ADVANCED FINITE ELEMENT ANALYSIS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	1	0	3

Pre-requisite Courses	*21MEC504J*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*study the basics of bending of plates and shells*
CLR-2:	*study the basics of non – linear static analysis of bars and beams*
CLR-3:	*apply knowledge on numerical methods for dynamic analysis*
CLR-4:	*impart adequate knowledge on fluid mechanics and heat transfer analysis*
CLR-5:	*learn about error estimation, convergence, zero- energy mode and adaptive refinement*

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 plate bending and shell theory*	*3*		*2*
CO-2:	*solve non-linear problems in bars and beams*	*3*		
CO-3:	*apply different types of numerical methods for dynamic analysis*	*3*		*2*
CO-4:	*solve the fluid mechanics and heat transfer problems*	*3*		*2*
CO-5:	*validate the analysis using error estimation, convergence, zero- energy mode and adaptive refinement*	*3*		*1*

Module-1 - Bending of Plates and Shells	***12 Hour***
Basic concept of Finite Element Method, Basic concept of Classical plate and Shear deformable plate theory Confirming and non-Confirming Elements, Bending of plate model-Displacement model and Finite Element model- Co and C1 Continuity –Elements, plate model, Introduction to shells-Circular Arches and Arch Elements, Shells of Revolution-Thin shell-Mindlin shell formulation, General Isoparametric Formulation-Three and four node shell elements.	
Module-2 - Non – Linear Static Analysis of Bars and Beams	***10 Hour***
Nonlinear Problems- Introduction-Types of Nonlinearities, Formulation of the Continuum Mechanics Incremental Equations of Motion - The Deformation Gradient, Strain, and Stress Tensors, Displacement based Isoparametric Continuum Finite Elements-Truss and bar elements, Basic concept of Inelastic material -Visco Plasticity-Formulation, Large deflection bending of bars and beams, Basic concept of Geometric Non linearity - large displacement Formulation.	
Module-3 - Dynamic Analysis	***9 Hour***
Dynamic equations-Mass and Damping matrices, Direct Integration methods-Central difference method-Houbolt method-Newmark Methods, Mode superposition- Change of basis to modal generalized displacement-with damping and without damping, Basic concepts and Solution to Nonlinear equations in dynamic analysis, Basic concept of Explicit integration-Implicit Integration-mode superposition method	
Module-4 - Fluid Mechanics and Heat Transfer Analysis	***9 Hour***
Heat Transfer Analysis -Governing Heat Transfer Equations- Incremental Equations- Finite Element Discretization of Heat Transfer Equations, Analysis of incompressible fluid flow-Finite element Governing equations	

Module-5 – Error Estimates, Convergence, Zero- Energy Mode and Adaptive Refinement	***5 Hour***
Shear locking- Patch test, Rate of convergence, zero- energy mode and types of error norms for triangular and quadrilateral elements, Assembly of elements and load calculation for non-linear FEM USING direct iteration and Newton's Methods using Computer code/Existing software	

Learning Resources	*1. Rao, S.S., 2017. The finite element method in engineering. Butterworth-heinemann.* *2. Bathe K.J. "Finite Element Procedures in Engineering Analysis", Prentice Hall, 2016.* *3. J N Reddy "Introduction to Non-Linear Finite Element Analysis" McGraw Hill Book Company New York; 2016* *4. Cook R.D., "Concepts and Applications of Finite Element Analysis", John Wiley and Sons Inc., New York, 1989.*	*5. Cook R.D., Malkus, D.S., Plesha, M.E., Witt, R.J., "Concepts and Applications of Finite Element Analysis", 4th Edition, John Wiley & Sons, 2001.* *6. J.N Reddy, An introduction to the Finite Element Method, 2005, McGraw Hill* *7. Jacob Fish & Ted Belytschko, "A first course in Finite Elements" , 2007, Wiley*

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.Jeyabalan, R&D Head . GE Renewable Energy. Hosur.	*1. Dr.Sundararajan Natarajan, Department of Mechanical Engineering, IIT Madras, snatarajan@iitm.ac.in*	*1. Dr.P.V.Jeyakarthikeyan, SRMIST*
2.Mr. Karthic Sethuraman, Intuitive, Connected and Autonomous Driving Technologies, Valeo India	*2. Dr. Raguraman Munusamy, IIITDM Kancheepuram, Chennai raguraman.munusamy@iiitdm.ac.in*	*2. Dr.P.Nandakumar, SRMIST*

Course Code	21MEE604T	Course Name	ADVANCED MECHANISM DESIGN AND SYNTHESIS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	1	0	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*perform the kinematic analysis of a mechanism*
CLR-2:	*design a mechanism based on the customer requirement*
CLR-3:	*locate a conjugate point and radius of curvature of the point on coupler*
CLR-4:	*perform force analysis of a mechanism*
CLR-5:	*perform the kinematic analysis of a spatial and robot mechanism*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	**Programme Outcomes (PO)**		
		1	***2***	***3***
CO-1:	*perform kinematic analysis of various planar mechanisms.*	*3*		*2*
CO-2:	*synthesis a planar mechanism based on the design requirement and constraints*	*3*		*2*
CO-3:	*determine the radius of curvature and conjugate point for any point on the coupler*	*3*		*2*
CO-4:	*perform static and dynamic analysis of a planar mechanism.*	*3*		*2*
CO-5:	*perform kinematic analysis of various spatial mechanisms and robotic arm.*	*3*		*2*

Module 1: Kinematics Analysis of Mechanisms	***9 Hour***
Fundamentals of Kinematics, Mobility Analysis, Classifications of Mechanisms - Kinematic Inversion - Grashof's law - Mechanical Advantage - Transmission Angle - Position Analysis - Vector loop closure equations for four bar, Slider Crank, Six bar linkages, Analytical and Graphical methods for velocity and acceleration Analysis - Four bar linkage jerk analysis. Plane complex mechanisms	
Module-2: Kinematic Synthesis of Linkages	***9 Hour***
Type, Number and Dimensional Synthesis, Function Generation, Path Generation and Motion Generation, Graphical Methods Two Position, Three Position and Four Position Synthesis of four bar Mechanism, Slider crank Mechanism, Precision positions Over lay Method, Analytical Methods - Blotch's Synthesis, Freudenstein's Method, Coupler curve Synthesis, Cognate linkages - The Robert - Chebyshev theorem.	
Module-3: Path Curvature Theory	***9 Hour***
Centrodes, Fixed and moving Centrodes, Hartmann's Construction, Inflection Points, The Inflection Circle, The Euler - Savary Equation, The collineation axis and Bobillier theorem, Conjugate points and inverse motion, the cubic Stationary curvature, Ball's Point.	
Module-4: Dynamic Analysis of Mechanisms	***9 Hour***
Static force analysis -two, three and four force member-static force analysis including friction - inertia force analysis - Combined static and inertia force Analysis, Shaking force and moment- principle of super position- Introduction to force and moment balancing of linkages.	
Module-5: Spatial Mechanisms and Robotics	***9 Hour***
Introduction Mobility of mechanisms, Describing spatial motions, Kinematic analysis of spatial mechanism, Kinematic synthesis of spatial mechanisms, position, Velocity and acceleration analysis,	

Eulerian Angles - Introduction to Robotic Manipulators - topological arrangements of Robotic arms, Kinematic analysis of spatial Mechanism - Devavit - Hartenberg Parameters, Forward and inverse Kinematics of Robotic Manipulators, Inverse Velocity and Acceleration Analyses, Robot Actuator Force Analysis.

Learning Resources	1. *Erdman , A. G, Sandor ,G. N. and S Kota" Mechanism Design: Analysis and Synthesis " Vol - I , Vol - II , Fourth edition, Prentice Hall, 2001.* 2. *Shigley, J.E., and Vicker , J.J. , " Theory of Machines and Mechanisms" fifth edition, Oxford University Press, 2017.* 3. *David.H.Myszka, "Machines and Mechanisms", fourth edition, Pearson Education, Inc, 2012.* 4. *Norton R.L. "Design of Machinery" sixth edition, McGraw Hill, 2018.*	5. *Hamilton H Mabie , Charles F. Reinhofz , " Mechanisms and Dynamics of Machinery " fourth edition, John Wiley & Sons !987.* 6. *Amitabha Ghose and Ashok Kumar Malik , " Theory of Mechanisms and Machines ", EWLP ,Delhi ,2008.* 7. *Rao J.S., Dukkipathi R.V., "Mechanisms and Machine Theory", Second Edition - New Age international (P) Ltd., 2007.* 8. *J.J. Craig, "Introduction to Robotics", third edition, Pearson Education, Inc., 2005.*

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	10%	-	10%	-	10%	-
Level 2	Understand	10%	-	10%	-	10%	-
Level 3	Apply	40%	-	40%	-	40%	-
Level 4	Analyze	40%	-	40%	-	40%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. Parameswaran, Nokia, Chennai	Dr. Raju Abraham, NIOT, Chennai.	1. Dr.P. Nandakumar, SRMIST

ACADEMIC CURRICULA

Computer Aided Design & Robotics

Common Professional Elective 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	21MEE602J	Course Name	ADDITIVE MANUFACTURING TECHNOLOGY	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	*Mechanical Engineering*	Data Book / Codes / Standards		*Nil*	

Course Learning Rationale (CLR):	The purpose of learning this course is to:
CLR-1:	*understand the need of design for AM*
CLR-2:	*understand additive manufacturing systems and its process*
CLR-3:	*understand need of post processing for AM*
CLR-4:	*understand rapid tooling and its applications*
CLR-5:	*understand future development of Additive Manufacturing*

Course Outcomes (CO):	At the end of this course, learners will be able to:	Programme Outcomes (PO)		
		1	2	3
CO-1:	*design for additive manufacturing processes*	*2*		
CO-2:	*identify the working principles and process parameters of additive manufacturing*	*3*		
CO-3:	*apply suitable post processing operation based on product and materials*	*2*		*1*
CO-4:	*apply the suitable tooling methods for any given industrial application*	*1*		*2*
CO-5:	*realize the future development of additive manufacturing*	*2*		*3*

Module-1 – Design for Additive Manufacturing (DFAM)	***15 Hour***
Introduction to geometric modelling, Modelling of Synthetic curves like Hermite, Bezier and B-spline, Parametric Representation of freeform surfaces, Need for Design for Additive Manufacturing (DFAM), CAD tools, General Guidelines for DFAM, The Economics of Additive Manufacturing, Design to Minimize Print Time, Design to Minimize Post-processing. Multi scale design for Additive manufacturing, Mass customization, Biomimetic design, Design of multi-materials and functionally graded materials. *Practical: Design of complex geometry and multi-scale model using modelling software*	
Module-2 – Additive Manufacturing Processes	***10 Hour***
Liquid based process: Selective Laser Apparatus (SLA)- Solid Ground Curing (SGC) – Principles, process, materials, and applications - Extrusion-Based Processes: Fused Deposition Modelling (FDM) - Bio-Extrusion- Principles, process, materials, and applications- Sheet Lamination Processes: Laminated Object Manufacturing (LOM) - Bonding Mechanisms, process, Materials, applications. Powder Bed Fusion Processes: Selective laser Sintering (SLS)- Selective laser metal (SLM) - Electron Beam melting (EBM) Powder fusion mechanism and powder handling- process material and Applications - Directed Energy Deposition Processes- Laser Engineered Net Shaping (LENS), Direct Metal Deposition (DMD) Processing-structure properties, relationships, materials, and applications.	
Module-3 – Post Processing of Additive Manufacturing Parts	***10 Hour***
Removal of 3D – printed parts from bed- Support Removal - improvement of Surface Texture – Accuracy- Aesthetic- Preparation for use as a Pattern-Property Enhancements using Non-thermal and Thermal Techniques- case studies. Guidelines for Selection of process – method for parts and Challenges. Post processing tools and devices.	
Module-4 – Rapid Tooling and Applications	***10 Hour***

Conventional Tooling, Rapid Tooling, Differences between Conventional and Rapid Tooling, Classification of Rapid Tooling: Direct and Indirect Tooling methods- Soft and Hard Tooling methods – case study with Rapid Tooling applications for investment Casting - silicon rubber mould – epoxy tools- Sand-Casting - Automotive Industry and jewellery industry components *Practical: Case study – Hard tooling-soft tooling application of automobile and aerospace components*
Module-5 –Future development in Additive Manufacturing ***15 Hour***
Computed Tomography (CT), Basic Components of CT, Different Types of CT Scanners, Magnetic Resonance Imaging (MRI), Ultrasound imaging, 3-D laser scanners, Industrial CT Scanners, 3D reconstruction and Reverse Engineering (RE), Image Reconstruction Procedure - Additive Manufacturing Related Technology in Sports, Rehabilitation, Device for Elderly, Forensic Science and Anthropology, Tissue Engineering and Organ Printing. *Practical: case study - 3D reconstruction of prosthetics using Reverse engineering tools*

Learning Resources	1. *Chua. C.K, "Rapid Prototyping", Wiley, 1997.* 2. *Hilton. P.D. et all, "Rapid Tooling", Marcel, Dekker 2000.* 3. *Jacohs P.F., "Stereolithography and other Rapid Prototyping and Manufacturing Technologies", ASME, 1996.* 4. *Pham D.T. and Dimov S.S., "Rapid Manufacturing; the technologies and application of RPT and Rapid tooling", Springer, London 2001.*	5. *Additive Manufacturing, Second Edition, Amit Bandyopadhyay Susmita Bose, CRC Press Taylor & Francis Group, 2020.* 6. *Bio-Printing: Principles and Applications, Chua Chee Kai and Yeong Wai Yee, World Scientific Publishing, 2015.* 7. *Additive Manufacturing: Principles, Technologies and Applications, C.P Paul, A.N Junoop, McGraw Hill, 2021.*

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%*	*-*
Level 2	*Understand*	*20%*	*-*	*-*	*20%*	*20%*	*-*
Level 3	*Apply*	*30%*	*-*	*-*	*20%*	*30%*	*-*
Level 4	*Analyze*	*30%*	*-*	*-*	*30%*	*30%*	*-*
Level 5	*Evaluate*	*-*	*-*		*30%*	*-*	*-*
Level 6	*Create*	*-*	*-*		*-*	*-*	*-*
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
Mr. Parameswaran, Nokia, Chennai	*Dr. Raju Abraham, NIOT, Chennai.*	*1. Dr. S. Karuppudaiyan, SRMIST*
		2. Dr. D. Raja, SRMIST

ACADEMIC CURRICULA

Computer Aided Design & Solar Energy

Common Professional Elective 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	21MEE505T	Course Name	MECHANICAL BEHAVIOR OF ENGINEERING MATERIALS	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	*Mechanical Engineering*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	The purpose of learning this course is to:
CLR-1:	*familiarize the structure and properties of materials*
CLR-2:	*familiarize tension and torsion loading*
CLR-3:	*understand about fatigue and creep behaviors*
CLR-4:	*familiarize fracture mechanics concepts and theory*
CLR-5:	*understand mechanical properties of non-metallic and composite materials*

Course Outcomes (CO):	At the end of this course, learners will be able to:	Programme Outcomes (PO)		
		1	2	3
CO-1:	*recognize and analyze the structure and properties*	*2*		
CO-2:	*acquire knowledge on tension and torsion load responses*	*1*	*2*	
CO-3:	*acquire knowledge on fatigue and creep*	*1*		
CO-4:	*acquire knowledge on fracture mechanics*	*2*		
CO-5:	*understand mechanical properties of non-metallic and composite materials*	*2*	*2*	

Module-1 - Structure and Properties	***7 Hour***
Crystal Structures, planes and directions; Defects in crystals, Crystal anisotropy; Microstructure, Dislocation and Twining; Strengthening mechanisms.	
Module-2 - Tension and Torsion	***8 Hour***
Stress - Strain curve, Complex stress/strain states, Elasticity, Isotropic and Anisotropic; Elastic-Plastic Deformation, Yielding, Ductility; Residual Stresses; Strain hardening exponent; Strain rate sensitivity; Mechanical properties in torsion, Tensile test, Compression test; Types of torsion failures, Torsion test, Measuring shear stress, Hardness, micro-hardness and nano-indentation.	
Module-3 - Fatigue and Creep	***10 Hour***
Fatigue phenomena; Theories of fatigue failure; Evaluation of fatigue resistance; Parameters influencing fatigue; Cyclic stress strain behavior; Design against fatigue; Description of creep, Creep curve, Stress-rupture test, Creep mechanisms, Creep in two phase alloys; Materials aspects creep design; Creep fracture.	
Module-4 - Fracture Mechanics	***10 Hour***
Types of fracture; Griffith's Theory; Irwin - Orowan Theory - crack propagation Modes; Ductile fracture; Analysis of crack propagation; Stress intensity factor; Crack opening displacement; J integrals; Measuring elastic-plastic fracture mechanics parameters.	
Module-5 – Properties of Non-Metallic Materials and Composites	***10 Hour***
Rheological behavior: Viscoelasticity and hyperelasticity in polymers; Flow and deformation behavior of polymer, ceramics and glasses; Deformation behavior of metal sandwich plate and metal-matrix composite material; Failure in Polymers; Failure fiber reinforced composites; Failure in Ceramics, Toughening mechanisms.	

Learning Resources	*1. George E. Dieter, "Mechanical Metallurgy", McGraw Hill,1986.* *2. Thomas H. Courtney, "Mechanical Behaviour of Materials", McGraw Hill 2017*	*3.. Joachim Roesler, Harald Harders, Martin Baeker, Mechanical Behaviour of Engineering Materials, Springer, 2007* *4. Joseph Marin, "Mechanical Behaviour of Engineering Materials", Prentice-Hall of India Pvt. Ltd., 1966*

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. Sandip Ghosh Chowdhury, CSIR-NML Jamshedpur, sgc@nmlindia.org	*1. Prof. Debdulal Das, IIEST Shibpur, debdulal_das@metal.iiests.ac.in*	*1. Dr. Shubhabrata Datta, SRMIST*
2. Dr. Srinivas Gunti, Tata Motors, Pune, rsg770075@tatamotors.com	*2. Prof. Pijush Ghosh, IIT Madras, pijush@iitm.ac.in*	*2. Dr. Kumaran D, SRMIST*

Course Code	21MEE605J	Course Name	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	*Mechanical Engineering*	**Data Book / Codes / Standards**		*Nil*	

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*get familiarity with governing equations of fluid mechanics and their mathematical behavior*
CLR-2:	*understand the intricate details of discretization techniques and stability analysis of difference equations*
CLR-3:	*know various numerical methods to solve equations and solution technique for compressible flows*
CLR-4:	*grasp techniques for coupling continuity and momentum equations for incompressible flows, SIMPLE algorithm and its application to Couette flow*
CLR-5:	*be familiar with concepts of turbulence and its modelling*

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 to a fluid system and classify governing equations mathematically*	*2*	*2*	-
CO-2:	*implement different discretization techniques to solve simple PDEs, and perform stability analysis*	*3*	*3*	-
CO-3:	*analyze the solution techniques for algebraic, ordinary differential and partial differential equations and applying to solve compressible flows*	*3*	*3*	-
CO-4:	*evaluate the solution techniques for elliptic equations and apply them to potential flows, incompressible flows and specifically to Couette flow*	*3*	*3*	-
CO-5:	*evaluate the concept of turbulence and Reynold's averaging and* examine the *turbulence modelling approaches*	*3*	*3*	-

Module-1 - Governing Equations	***12 Hour***
Equations Introduction, Various applications of computational fluid dynamics, Models of fluid flow, Continuity equation derivation in all forms, Momentum, Energy and Scalar transport equations derivation, Conservation and Non-conservation form of governing equations, Different types of boundary conditions –Dirichlet, Neumann, Cauchy and Robbins boundary conditions with examples, Classification and Mathematical behaviour of Partial differential equations – elliptic, parabolic and hyperbolic, well-posed problems. Practical- Introduction to commercial CFD software, Simulation of flow over a flat plate for laminar conditions	
Module-2-Discretization Techniques	***12Hour***
Discretization concept and principles, Finite difference approximations of partial derivatives – Forward, Backward and Central difference methods, Discretization of one-dimensional un-steady state heat conduction, Explicit and Implicit method, Discretization of one-dimensional wave equation, Tutorials on discretization of equations, Stability analysis of different equations, consistency and convergence, Discussion on CFL condition, Short discussion on shock capturing methods: Godunov, TVD, flux-limiter schemes. Practical: Coding on explicit and implicit schemes and simulation of flow over circular pipe for laminar conditions with commercial CFD software conditions.	
Module-3 - Solution Techniques and Numerical Methods for Compressible Flows	***12 Hour***
Direct methods for system of linear equations: Gauss elimination method and Tri-diagonal matrix algorithm (TDMA), Iterative methods: Gauss-Siedel, Jacobi and relaxation techniques, Solution techniques for ordinary differential equations: Euler, predictor-corrector, Runge-Kutta (4 stages) methods, Linear multi-step methods: Adams-Bashforth method, Short discussion on algebraic multi-grid method, Application of McCormack technique to compressible flows: case study- Supersonic flow through convergent-divergent nozzle: Governing equations, numerical method, boundary conditions, case set-up and results, Tutorials on McCormack method, Coding practice for Jacobi method. Practical: Coding on TDMA, and relaxation techniques, Supersonic flow simulation in a convergent-divergent nozzle with commercial CFD software	
Module-4 Solution Techniques for Elliptic and Parabolic Equations	***12 Hour***

Application of relaxation techniques to potential flow equation, Application of Alternating Direction Implicit (ADI) method to unsteady two-dimensional heat conduction, Techniques for incompressible Navier-Stokes equations: Concept of staggered grid., Pressure correction method, SIMPLE algorithm and boundary conditions, Solution of Couette flow using SIMPLE algorithm. Practical: Coding on ADI method, Grid convergence study on flat plate flow with Fluent
Module-5 – Introduction to Turbulence Modelling ***12 Hour***
Concept of Turbulent boundary layer over a flat plate: Laminar sub, logarithmic and outer layers, Concept of turbulence, Reynolds averaging, Time-averaged equations for turbulent flow, Boussinesq approximation, Types of turbulence models: Prandtl mixing length, One-equation, Two-equation models, Comparison of different turbulent models, Energy cascade mechanism in turbulent flows, Advanced methods: Large Eddy Simulations, Direct Numerical Simulations, Detached Eddy Simulations. Practical: Turbulent simulation of flow in a circular pipe, flat plate, mixing layer with k-ε model with commercial CFD software.

Learning Resources	1. *Anderson J.D., "Computational Fluid dynamics: The basics with Applications", McGraw Hill Education, July 2017.* 2. *Versteeg H.K., and Malalasekera W., "An introduction to computational fluid dynamics"The finite volume method", Pearson India Publisher, January 2010* 3. *3. Muralidhar.K, and Sundararajan.T, "Computational Fluid Flow and Heat Transfer", Narosa Publishing House, New Delhi, Second Edition, 2008.*	4. *Erwin Kreyszig, "Advanced Engineering Mathematics", John Wiley & Sons, 2011.* 5. *5. R. Byron Bird, Warren E. Stewart, Edwin N. Lightfoot, "Transport Phenomena", 3rd Edition, John Wiley and Sons, 2013.* 6. *6. Piyush K. Kundu and Ira M. Cohen, "Fluid Mechanics", 4th Edition, Elsevier, 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*	*15%*	*10%*	*15%*	*10%*	*15%*	*10%*
Level 3	*Apply*	*10%*	*10%*	*10%*	*10%*	*10%*	*10%*
Level 4	*Analyze*	*10%*	*10%*	*10%*	*10%*	*10%*	*10%*
Level 5	*Evaluate*	*10%*	*10%*	*10%*	*10%*	*10%*	*10%*
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. Anil Kumar, Fluidyn Consultancy Private Limited, Bengaluru.	*1. Dr. Arul Prakash, Professor, IIT Madras*	*1. Dr. D. Siva Krishna Reddy, SRMIST*
2. P. S. G. Kumar, Siemens Industry Software (India) Pvt Ltd, Bengaluru	*2. Dr. G. Kumaresan, Anna University Chennai*	*2. Dr. P.Sudhakar, SRMIST*