ACADEMIC CURRICULA

Professional Elective Courses

MECHANICAL ENGINEERING

Regulations - 2018

Volume – 4 (7)

(Detailed Syllabus for Third & Fourth Year Courses)

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

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

Kattankulathur, Kancheepuram, Tamil Nadu, India

Course Code	18MEE301T	Course Name	FUNDAMENTALS OF VIBRATION AND NOISE	Course Category	E	Professional Elective	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*18MEC201T Machines and Mechanisms*	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:*	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected roficiency (%)	Expected Attainment (%)
CLR-1 :	*Be familiar with the vibrations of two degree of freedom systems*			
CLR-2 :	*Be familiar with the vibrations of multi degree of freedom systems*			
CLR-3 :	*Be familiar with the vibrations of continuous systems*			
CLR-4 :	*Be familiar with the Numerical Integration methods in Vibration analysis*			
CLR-5 :	*Be familiar with the vibration measurement devices*			
CLR-6	*Be familiar with the vibrations of multi degree of freedom systems & Continuous systems, numerical integration methods in vibration analysis and vibration measuring devices*			

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected roficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Able to learn the concepts of vibration analysis of two degree of freedom systems and vibration absorbers*	*1& 2*	*75*	*70*	*H*	*M*	*M*	*H*	*L*	*L*	*M*	*L*	*L*	*L*	*L*	*M*			
CLO-2 :	*Able to Understand and apply the various numerical methods for vibration analysis of three degree of freedom systems*	*1*	*75*	*70*	*H*	*M*	*M*	*H*	*L*	*L*	*M*	*L*	*L*	*L*	*L*	*L*			
CLO-3 :	*Able to learn the concepts of vibration analysis of continuous systems*	*1*	*75*	*70*	*H*	*M*	*M*	*L*	*M*	*L*	*M*	*L*	*L*	*L*	*L*	*L*			
CLO-4 :	*Able to apply the knowledge of numerical integration methods in vibration analysis*	*1*	*75*	*70*	*H*	*M*	*M*	*L*	*M*	*L*	*M*	*L*	*L*	*L*	*L*	*L*			
CLO-5 :	*Able to Understand the vibration measurement devices and condition monitoring techniques*	*1&2*	*75*	*70*	*H*	*H*	*M*	*M*	*H*	*L*	*H*	*L*	*L*	*M*	*L*	*M*			
CLO-6:	*Able to understand the vibrations of two, multi degree of freedom systems and continuous sytems and apply the knowledge of numerical integration methods in vibration analysis and vibration measuring devices in field measurement.*	*1&2*	*75*	*70*	*H*	*H*	*M*	*M*	*H*	*L*	*H*	*L*	*L*	*M*	*L*	*L*			

		Vibrations of Two degree of freedom systems / Module 1	Vibrations of Three Degree of freedom systems / Module 2	Vibrations of Continuous systems Numerical Integration Methods in Vibration Analysis / Module 3	Numerical Integration Methods in Vibration Analysis / Module 4	Vibration Measuring Instruments / Module 5
Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Introduction to vibration terminologies and multidegree of freedom systems*	*Equation of Motion for free undamped three degrees of freedom systems using Newton's Method, Orthogonality Condition*	*Transverse Vibrations of String or a cable*	*Introduction to Finite Difference method*	*Vibration Measuring Devices – Transducer, Vibrometer*
S-2	SLO-1	*Equation of Motion for free undamped two degrees of freedom systems using Newton's method*	*Multidegree of freedom systems – Matrix method , Eigen Value Method – Eigen values and Eigen vector*	*Longitudinal vibrations of a Bar or a Rod*	*Central difference method for single degree of freedom systems*	*Vibration Measuring Devices – Accelerometer and Seismometer.*
S-3	SLO-1	*Equation of Motion for free undamped two degrees of freedom systems using Lagrangian energy method*	*Tutorials on Multidegree of freedom systems – Newton's Method, Matrix method , Eigen Value Method*	*Tutorials on Transverse Vibrations of Strings and Longitudinal vibrations of Rods*	*Central difference method for multi degree of freedom systems*	*Tutorials on vibrometer, Accelerometer and Seismometer.*
S-4	SLO-1	*Tutorials on free undamped two degrees of freedom systems using Newton's method and Lagrangian method*	*Influence Coefficients Method – Stiffness and Flexibility matrix – spring mass system*	*Torsional vibrations of rods*	*Tutorials on central difference method*	*Frequency Measuring devices – Single Reed, Multi reed and stroboscope.*

S-5	SLO-1	*Determine the natural frequencies and mode shapes for coordinate coupling*	*Dunkerly's Method for closed coupled system , Rayleigh's Method for spring mass system*	*Lateral Vibrations of a Beam*	*Runge-Kutta Method for single degree of freedom systems*	*Vibration exciters*
S-6	SLO-1	*Concept of Linear undamped vibration absorber*	*Tutorials on Influence Coefficients Method, Dunkerly's Method and Rayleigh's Method*	*Tutorials on Torsional vibration of rods and lateral vibration of a Beams*	*Runge-Kutta Method for multi degree of freedom systems*	*Tutorials on vibration exciters.*
S-7	SLO-1	*Tutorials on coordinate coupling and Linear undamped vibration absorber*	*Concept of Holzer's Method for Far Coupled systems and Close Coupled Sytems*	*Rayleigh's method for continuous system*	*Tutorials on Runge-Kutta Method*	*Experimental Modal Analysis, Condition Monitoring techniques*
S-8	SLO-1	*Torsional Vibration of Two rotor systems.*	*Torsional Vibration of Three rotor systems- Equivalent Length Determination*	*Rayleigh's Ritz method for continuous system*	*Finite Difference Methods for Longitudinal vibration of bars*	*Balancing Machines – Single plane and two plane balancing*
S-9	SLO-1	*Torsional Vibration of Geared Systems with Two rotor System*	*Tutorials on Hozler's method and Three rotor systems.*	*Tutorials on Rayleigh's method and Rayleigh's Ritz method*	*Finite Difference Methods for transverse vibration of beams*	*Tutorials on Modal analysis*

Learning Resources	*1. Rao.S.S, "Mechanical Vibrations", 5th Edition, Pearson Education Inc. Delhi 2009.* *2. Ambekar.A.G, "Mechanical Vibrations and Noise engineering", PHI New Delhi, 2015.* *3. Thomson.W.T, "Theory of Vibration and its Applications", 5th Edition, Prentice Hall, New Delhi, 2001.* *4. Meirovitch, L., "Elements of Vibration Analysis", Mc Graw – Hill Book Co., New York, 1986.*	*5. Rao.J.S and Gupta.K, "Introductory course on theory and practice of mechanical vibrations", 2nd Edition, New Age International, New Delhi, 2014.* *6. Ramamurthi.V, "Mechanical Vibration Practice with Basic Theory", 1st edition, Narosa Publishing House, Chennai, 2000.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Understand										
Level 2	Apply	*40%*	-	*40%*	-	*40%*	-	*40%*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc,

INDUSTRIAL EXPERT	ACADEMIC EXPERT	INTERNAL EXPERT
1. Dr. R. Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in, rkpearls@yahoo.com	*Dr. Rajendra Machavaram, IIT Kharagpur*	*V.N.B Prasad Sodisetty, SRMIST*
2. Dr. A. Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*Raghavendra bejgam engineering project lead, pentair, noida.*	*Dr. P. Nandakumar, SRMIST*

Course Code	18MEE302T	Course Name	INDUSTRIAL TRIBOLOGY	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	PSG Design Data book		

Course Learning Rationale (CLR):	The purpose of learning this course is to:	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	Understand and analyze thesurfaces and friction			
CLR-2 :	Understand and analyze the wear mechanisms			
CLR-3 :	Understand and analyze the film theory			
CLR-4 :	Understand and analyze the lubricants and lubrication phenomenon			
CLR-5:	Understand and analyze the surface engineering processes and select suitable materials for bearing			
CLR-6:	Understand and solve various engineering problems			

Course Learning Outcomes (CLO):	At the end of the course, student will be able to:	Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Program Learning Outcomes (PLO)														
					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
					Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	Understand friction and engineering surfaces	1,&2	100	85	H	H			H		H					H	H		
CLO-2 :	Apply the knowledge and analyze the failure occurred due to various types of wear	3&4	100	85	H	H	H	H	H		H					H	H		
CLO-3 :	Apply the knowledge of lubrication to provide solutions	3&4	100	85	H	H	H	H	H							H	H		
CLO-4 :	Analyze various surface conditions and provide new ideas of surface protection techniques	3&4	100	85	H	H	H	H	H							H	H		
CLO-5:	Formulate new materials	5	100	85	H	H										H	H	H	H
CLO-6:	Investigate the failure of a system	5	100	85	H	H			H	H						H	H	H	H

		Surfaces and friction	Wear	Film lubrication theory	Lubricants and lubrication	Surface engineering and materials for bearings
Duration (hour)		9	9	9	9	9
S-1	SLO-1	Introduction to the concept of tribology, Tribological problems	Introduction, background of Wear and Types of Wear with applications.	Introduction to Viscosity and its importance in lubrication.	Types of lubricants and their properties	Introduction to surface engineering
S-2	SLO-1	Nature of engineering surfaces, Surface topography	Abrasive wear	Influence of various particles on viscosity of a lubricant.	Stribeck Curve and its importance	Surface treatments
S-3	SLO-1	Surface profilometer, measurement of surface topography; importance of roughness parameters	Adhesive wear	Fluid film in simple shear, Viscous flow between very close parallel plates.	Boundary and Mixed Lubrication regime	Coatings and cladded plates
S-4	SLO-1	Contact between surfaces, Sources of sliding Friction, Friction characteristics of metals and non-metals	Wear due to corrosion	Shear variation within the film, Lubricant supply, lubricant low rate.	Hydrodynamic lubrication	In situ formed tribo films
S-5	SLO-1	Friction due to ploughing, Friction due to adhesion	Fatigue and fretting wear	Cold jacking, Couette flow,	Elasto hydrodynamic lubrication(EHL); Problems on EHL	Surface Texturing
S-6	SLO-1	Sources of rolling friction, Stick slip motion	Wear in metals	Cavitations, film rupture and oil whirl	Importance of film thickness, Lambda ratio	Tribo corrosion
S-7	SLO-1	Friction of ceramic materials	Wear in polymers	Petroff's equation	Bio degradable lubricants	Surface analysis techniques
S-8	SLO-1	Friction of polymers	Wear of ceramics	Reynolds equation	Nano lubricants	Materials for bearings
S-9	SLO-1	Measurement of friction	Measurement of wear, Ferrography and oil analysis	Sommerfield Number	Hertzian contact and problems on Hertizian contacts	Condition monitoring

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. *7. Neale.M.J., "Tribology Handbook", Newnes Butter worth, Heinemann, U.K., 1975.*

Learning Assessment											
	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*40%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
Level 2	Apply Analyze	*40%*	-	*40%*	-	*40%*	-	*40%*	-	*40%*	-
Level 3	Evaluate Create	*20%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. R. Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in, rkpearls@yahoo.com	*Dr.P. Ramkumar, IITM, ramkumar@iitm.ac.in*	*Mr. ShubrajitBhaumik, SRM IST ,*
2. Dr. A. Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*Dr.Chiradeep Ghosh , chiradeep.ghosh@tatasteel.com, Tata Steel*	*Dr. TVVNL Rao, SRMIST*

Course Code	18MEE303T	Course Name	MECHANISM DESIGN, ANALYSIS AND SYNTHESIS	Course Category	E	Professional Elective	L	T	P	C
							3	0	0	3

Pre-requisite Courses	18MEC201T Machines and Mechanisms	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:	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	Performthe kinematic analysis of various mechanisms and linkages			
CLR-2 :	Synthesis a linkage or mechanism for the given requirements			
CLR-3 :	Determine the acceleration at any point on the coupler			
CLR-4 :	Perform static and dynamic force analysis of linkages			
CLR-5 :	Perform kinematic analysis and synthesis of spatial mechanisms and Robot linkages			
CLR-6 :	Design a mechanism according to the need and analyze it.			

Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	1	2	3	Program Learning Outcomes (PLO)														
					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	Determine the position, velocity and acceleration of simple and complex linkages.	1,2 &3	75	65	H	H	M	M	H	-	-	-	-	-	-	L			
CLO-2 :	Synthesize a linkage based on the given working conditions	1,2 &3	75	65	H	H	H	H	H	-	-	-	-	-	-	L			
CLO-3 :	Find the conjugate points, radius of curvature and acceleration at any point on the coupler link.	1,2 &3	75	65	H	H	M	H	H	-	-	-	-	-	-	L			
CLO-4 :	Find forces/moments in various links with or without considering inertia of links	1,2 &3	75	65	H	H	H	M	H	-	-	-	-	-	-	L			
CLO-5 :	Determine the position, velocity and acceleration of spatial linkages and robot linkages	1,2 &3	75	65	H	H	H	H	H	-	-	-	-	-	-	L			
CLO-6 :	Do the kinematic and dynamic analysis of mechanisms in addition to its synthesis.	1,2 &3	75	65	H	H	H	H	H	-	-	-	-	-	-	L			

		Kinematic Analysis of Mechanisms	Kinematic Synthesis of Linkages	Path Curvature Theory	Force Analysis of Mechanisms	Kinematics of Spatial Mechanisms And Robotics
Duration (hour)		9	9	9	9	9
S-1	SLO-1	Review of fundamentals of kinematics, mobility analysis and classifications of mechanisms	Introduction to synthesis, type, number and dimensional synthesis	Fixed and moving centrodes	Static force analysis of linkages	Mobility and description of spatial mechanisms
S-2	SLO-1	Kinematic Inversions, Grashoff's law	Two position synthesis of four bar and slider crank mechanisms by extreme position and inversion methods	Determination of radius of curvature of coupler points by Hartmann's Construction	Static force analysis of linkages by graphical method, principle of super position	Position, velocity and acceleration analysis of spatial mechanisms by vector algebra method
S-3	SLO-1	Mechanical advantage and Transmission angle	Three position synthesis of four bar by inversion method	Determination of radius of curvature of coupler points by the Euler- Savary equation		
S-4	SLO-1	Position analysis of four bar, Slider Crank by complex and vector algebra methods	Three position synthesis of slider crank mechanisms by inversion method	Inflection Points, The Inflection Circle	Dynamics force analysis- D'Alembert's principle	Problems on kinematic analysis of spatial mechanisms
S-5	SLO-1	Velocity, acceleration and jerk analysis of four bar by complex and vector algebra methods	Four position synthesis by point position reduction method and Overlay method.	The collineation axis and Bobiller's theorem	Combined static and dynamics analysis of four bar linkage, Graphical and analytical methods	Kinematic synthesis of spatial mechanisms
S-6	SLO-1	Velocity, acceleration and jerk analysis of Slider Crank by complex and vector	Coupler curve synthesis	Determination of radius of curvature of coupler points by Bobiller's Construction	Problems on combined static and dynamic analysis	Introduction to Robot kinematics, Topological arrangements of robotic

		algebra methods				*arms, Eulerian angles, DH parameters*
S-7	SLO-1	*Velocity analysis of complex and six bar linkages by relative velocity method (Graphical method)*	*Analytical Methods of synthesis by Blotch's Synthesis*	*Problems on Bobiller's Construction*	*Shaking force and shaking couple*	*Kinematic analysis of robot manipulators using transformation matrices*
S-8	SLO-1	*Acceleration analysis of complex and six bar linkages by relative velocity method (Graphical method)*	*Analytical Methods of synthesis by Freudestien's Method*	*Problems on Bobiller's Construction*	*Introduction to force and moment balancing of linkages*	*Inverse kinematics of robot manipulators*
S-9	SLO-1	*Problems on velocity and acceleration of mechanisms by Graphical method*	*Cognate linkages by the Roberts – Chebyshev theorem*	*The cubic Stationary curvature - Ball's Point*	*Problems on Balancing of linkages*	*Robot actuator force analysis*

Learning Resources	1. *Uicker J. J.,Gordon R. Pennock & Joseph E. Shigley John J. Uicker "Theory of Machines and Mechanisms", Oxford Higher education, 2014.* 2. *Rao, J. S., and Dukkipatti, R.V., "Mechanisms and Machine Theory", 2nd Edition, New Age international (P) Ltd., 1995* 3. *Sandor, G. N. and Erdman A. G., Mechanism Design, Analysis and Synthesis Vol: I and Vol: II, Prentice Hall, 1990.* 4. *Norton, R. L., Design of Machinery, McGraw Hill, 1999.*	5. *Hamilton H Mabie and Charles F. Reinhofz, Mechanisms and Dynamics of Machinery, John Wiley & Sons, 1987.* 6. *Amitabha Ghose and Ashok Kumar Malik, Theory of Mechanisms and Machines, EWLP, Delhi, 1999.* 7. *R.S.Hartenberg and J. Denavit, "Kinematic Synthesis of Linkages", Mc. GrawHill Book Company, 1964*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Understand										
Level 2	Apply	*40%*	-	*40%*	-	*40%*	-	*40%*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr.R.Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*1. Dr. Shankar Krishnapillai, skris@iitm.ac.in, IIT Madras*	*1. Dr P. Nandakumar, SRMIST*
2. Dr.A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*2. Dr.R.Prabhu sekar, rprabhusekar@mnnit.ac.in, MNNIT Allahabad*	*2. Mr. K.R. Arunprasath, SRMIST*

Course Code	18MEE304T	Course Name	DESIGN FOR MANUFACTURING 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	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	To study how a design can be made suitable for various manufacturing and assembly process requirements			
CLR-2 :	Application of this study to various Casting and welding.			
CLR-3 :	Application of this study to various forging, and machining processes			
CLR-4 :	To study about the various assembly methods and processes			
CLR-5 :	Know the effect of manufacturing process and assembly operations.			

Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Program Learning Outcomes (PLO)													
					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
					Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	Students will demonstrate the ability to identify needs of the customer and convert them in to technical specifications of a product.	1& 2	90	85	H	--	H	--	--	--	--	--	--	--	--	--	--	--	--
CLO-2 :	Know the manufacturing issues that must be considered in the Casting and welding	1	85	80	H	H	H	H	--	--	--	--	--	--	--	--	--	--	--
CLO-3 :	Know the manufacturing issues that must be considered in the forging and machining processes.	1	85	80	H	H	H	H	--	--	--	--	--	--	--	--	--	--	--
CLO-4 :	Students will understand the principals used while designing for manufacture, assembly.	1&2	85	80	H	H	H	H	--	--	--	--	--	--	--	--	--	--	--
CLO-5 :	Students will understand principles of assembly to minimize the assembly time.	1&2	85	80	H	H	H		--	--	--	--	--	--	--	--	--	--	--

		Learning Unit / Module 1	Learning Unit / Module 2	Learning Unit / Module 3	Learning Unit / Module 4	Learning Unit / Module 5
Duration (hour)		9	9	9	9	9
S-1	SLO-1	Significance of design- Systematic working plan-The engineering problem to be solved-The basic design	Influence of loading, Materials, Production methods on form design	Forging Considerations-Hammer forging-Drop forging	DFA-Introduction-Distinction between assembly methods and processes	Approaches to design for assembly-Introduction
S-2	SLO-1	Factors influencing choice of materials-The factors influencing manufacturing	Casting considerations-Grey iron castings	Requirements and rules for forging.	Factors Determining assembly methods and processes-Success and failure-Causes of failure	Approaches based on design principles and rules-Example DFA method using Design Principles
S-3	SLO-1	Process Capability-Mean, Median, Variance, Mode, Standard Deviation, Normal Distribution- Process capability metrics-	Steel castings -Aluminum Casting-Requirements and rules for casting	Redesign of components for forging.	Product Design factors independent of methods and processes-Introduction-Number of operations in the product	DFA Systems employing Quantitative evaluation procedures-IPA Stuttgart Method
S-4	SLO-1	Process Capability and Defect Rate, Assumptions, Conditions and Precautions in process capability	Form design of pressure die castings	Choice between casting, forging and welding.	Assembly Precedence-Standardization. Case studies in assembly precedence.	DFA Methods employing a Knowledge-based approach-Knowledge Representation
S-5	SLO-1	Process Capability-Simple problems	Redesign of components for casting-Pattern-Mould-Parting Line	Machining Considerations-Drills-Milling-Keyways-Dwells and Dwelling Procedure-Countersunk Head screws	Design factors dependent on Assembly methods-Introduction-Single Station Assembly	Computer Aided DFA methods-Part model-Feature Processing
S-6	SLO-1	Tolerances-symbols and Definition	Welding considerations-Welding	Requirements and rules for Machining	Line Assembly-Hybrid Systems-Manual	Assembly measures-Qualitative and

			Processes	*considerations-Reduction of machined areas*	*Assembly Lines-Flexible Assembly Lines*	*Quantitative measures*
S-7	SLO-1	*Tolerances relevant to manufacturing, Assembly- Material condition*	*Requirements and rules for welding*	*Redesign of components for Machining.*	*Design factors dependent on Assembly processes-Factors Influencing Production rate to Facility Ratio-Parts Presentation-Manual Assembly*	*Boothroyd and Dewhurst DFA method-Objectives of the method*
S-8	SLO-1	*Tolerance stack- effects on assembly-Examples*	*Redesign of components for welding*	*Simplification by separation-Simplification by Amalgamation*	*Dedicated Assembly-Transportation-Separation-Orientation-Flexible Assembly*	*Redesign of a simple product-Small consumer product-Fastener solution-Redesign using symmetry*
S-9	SLO-1	*Methods of eliminating tolerance stack-Examples*	*Case studies in Form Design-simple problems in form design*	*Case studies- forging and Machining*	*Gripping-Transferring-Part Insertion-Failures-Error Recovery*	*Case Studies-Designing of a disposal valve-Design of a lever-arch file mechanism*

Learning Resources	1. *Harry Peck., Design for Manufacture, Pittman Publications,1983.* 2. *Alan Redford and chal, Design for Assembly-Principles and Procedures, McGraw Hill International Europe, London, 1994.* 3. *Robert Matousek,Engineering Design-A Systematic Approach,Blackie&sons Ltd.,1963.*	4. *James G.Bralla,Hand Book of Product design for Manufacturing,McGraw Hill Co.,1986.* 5. *Swift,K.G.,Knowledge Based Design for Manufacture,Kogan Page Ltd.,1987.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Understand										
Level 2	Apply	*40%*	-	*40%*	-	*40%*	-	*40%*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr.R.Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*Dr. Davidson Jebaseelan, davidson.jd@vit.ac.in VIT Chennai.*	*Mr. P.Susai Manickam, SRM IST, Chennai*
2. Dr.A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*Mr. Vignesh Shanmugam.s Hyundai Motors Limited, Chennai E mail – 273357@hmil.net*	*Dr. P. Nandakumar, SRM IST, Chennai*

Course Code	18MEE305T	Course Name	FINITE ELEMENT METHOD	Course Category	E	Professional Elective	L	T	P	C
							3	0	0	3

Pre-requisite Courses	18MEC106T Mechanics of Solids, 18MAB202T Numerical methods	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:	Learning		
		1	2	3
CLR-1 :	Find the approximate solution of boundary value problems	Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-2 :	Know the variationaland Weighted residual approaches to solve differential equations			
CLR-3 :	Develop basic finite element concepts and solution procedure			
CLR-4 :	Formulatetheelement stiffness and mass matrices for various one and two dimensional elements			
CLR-5 :	Formulate the element heat conductance and convection matrices one dimensional element			
CLR-6 :	To formulate and solve problems in solid mechanics, Eigen Value and heat transfer using finite element method.			

Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	Solve the differential equations using weighted residual and variational approaches.	1,2&3	75	65	H	H	L	H	M	-	-	L	L	-	-	M			
CLO-2 :	Solve the structural analysis problems, such as bar, truss and beam using 1D element.	1,2 &3	70	65	H	H	L	H	M	-	-	L	L	-	-	M			
CLO-3 :	Analysis of two-dimensional structural problems on plane triangular and quadrilateral elements.	1,2 &3	70	65	H	H	L	H	M	-	-	L	L	-	-	M			
CLO-4 :	Be able to solve Eigen Value problems in solid mechanics using finite element method.	1,2 &3	65	65	H	H	L	H	M	-	-	L	L	-	-	M			
CLO-5 :	Be able to solve one dimensional heat transfer problems using finite element method	1,2 &3	70	65	H	H	H	H	H	-	-	L	L	-	-	M			
CLO-6	Analyze structural and heat transfer problems using Finite Element	1,2 &3	65	60	H	H	M	M	M	-	-	L	L	-	-	M			

		Introduction to FEA	1D Linear Static Analysis	2D Linear Static Analysis	Dynamic Analysis of Structures	1D Heat Transfer Problems
Duration (hour)		9	9	9	9	9
S-1	SLO-1	Basics of FEA, Historical background, applications of FEA in engineering, modelling of discrete and continuum models	Finite element procedure for a continuum problem, discretization, types of elements	Introduction to twodimension elasticity, plane stress and strain conditions	Dynamic analysis, Formulation- Hamilton's Principle, lumped and consistent mass models	Review of fundamentals of heat Transfer
S-2	SLO-1	Variational problems, Euler'sequation	Selection of interpolation function, shape function, derivation of element stiffness matrix for a one dimensional bar element	Constant strain triangular element, Area coordinate system, shape function, strain displacement matrix	Derivation of lumped and consistent mass matrices for axial bar element, formulation of eigen value problem	Governing equations and boundary conditions for Heat transfer
S-3	SLO-1	Rayleigh-Ritz method, minimum potential energy,Example problem, solving differential equation	assembly of elements, imposing boundary conditions, calculation of element stress, example problems		Determination of natural frequencies and normal mode shapes of axial vibration	Derivation of conductance matrix for steady state 1D heat conduction
S-4	SLO-1	Weighted residual approaches, collocation method, subdomain method, Galerkinmethod and least square method	Tutorial Problems on axial loading of bars	Derivation of element stiffness matrix for a CST element	Problems onnatural frequencies and normal mode shapes of axial vibration	Tutorial on Steady state 1D heat conduction
S-5	SLO-1	Example problem, solving differential equations using weighted residual approaches	Local and global coordinate systems	Tutorial on two dimensional plate problems with CST elements	Derivation of lumped and consistent mass matrices for beam element	
S-6	SLO-1	Galerkin's Finite Element method for solving differential equations, example problems,	Analysis of truss, coordinate transformations, Derivation of the stiffness matrix	LST and four noded quadrilateral elements, isoparametric	Determination of natural frequencies and normal mode shapes of beam	Derivation of element matrix for steady state 1D heat conduction including

		comparison of results with different methods		*formulation*		*convection*
S-7	SLO-1	*Spring element, formulation of stiffness matrix, assembly procedure for global stiffness matrix, applying boundary conditions*	*Assembly of stiffness matrix for a truss, Tutorial Problems on Trusses*	*Gaussian quadrature Integration-Derivation of one point and two point formula*	*Determination of natural frequencies and normal mode shapes of beam*	*Tutorial on Steady state 1D heat conduction with convection*
S-8	SLO-1	*Solution of linear algebraic equations, Gauss elimination method, Cholesky decomposition, example problems*	*Beam element, Hermite shape functions, derivation of element stiffness matrix of a beam element.*	*Problems using Gaussian quadrature with one and two points*	*Problemson eigen value problems on beams*	*Solution of simple Heat Transfer 1-D and 2-D steady state problems using a FEA software*
S-9	SLO-1	*Tutorial problems on springs with series and parallel combinations*	*Calculation of load vector for point, uniform distributed and varying loads on beams*	*Lagrange interpolation functions for serendipity family elements*	*Derivation of lumped and consistent mass matrices for a CST element*	*Introduction to transient heat transfer problems*

Learning Resources	1. *Hutton, D.V., "Fundamentals of Finite Element Analysis", McGraw Hill, International Edition, 2004.* 2. *Chandrupatla, T.R., Belegundu, A.D., "Introduction to Finite Elements in Engineering", Prentice Hall of India, 1997.* 3. *P.Seshu, "Text book of Finite Element Analysis", PHI learning Private Ltd., 2012.*	4. *S,S,Rao, "The Finite Element method in Engineering", Elsevier Science &Technology Books, 2004* 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*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Understand										
Level 2	Apply	*40%*	-	*40%*	-	*40%*	-	*40%*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr.R.Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*1. Dr. Atanu Banerjee, atanub@iitg.ac.in, IIT Guwahati*	*1. Dr P. Nandakumar, SRMIST*
2. Dr.A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*2. Dr.R.Prabhusekar, rprabhusekar@mnnit.ac.in, MNNIT Allahabad*	*2. Mr.P. SusaiManikam, SRMIST*

Course Code	18MEE306T	Course Name	ADVANCED STRENGTH OF MATERIALS	Course Category	E	Professional Elective	L	T	P	C
							3	0	0	3

Pre-requisite Courses	18MEC106T Mechanics of Solids	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:	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CLR-1 :	Be able to Compute the combined effect of deformation/loading arising out of different causes as applied to structural members made of linear, homogeneous, isotropic material so as to be able to predict (as part of a different course) failure of components/sub-systems of a product	Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO – 3
CLR-2 :	Be able to Compute the effect of deformation/loading in straight and curved beams (a class of primary structural member) subjected to bending (a type of primary loading)																		
CLR-3 :	Be able to Study the effect of bending (a type of primary loading) deformation/load as applied to flat thin plates (a class of primary structural member)																		
CLR-4 :	Be able to Study the use of energy methods in structural analysis as an alternative means of solving a structural mechanics problem																		
CLR-5 :	Be equipped with analytical skills the learning process of which has a bearing in professional practice in understanding difference(s) between exact and approximate solution procedures																		
CLR-6 :	Be able to analyze effects of typical loadings on primary structural members using approximate or exact methods as applicable																		
Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:																		
CLO-1 :	Perform 2D & 3d stress and strain transformation and arrive at maximum values for normal and shear stresses and find the planes on which these stresses act	1, 2	90	75	H	H													
CLO-2 :	Determine i)bending stress in straight beams (due to unsymmetrical bending), ii) transverse shear stresses in straight beams and locate shear center for specified cross-sections, and iii) circumferential (bending) stresses in curved beams	1, 2	90	75	H	H													
CLO-3 :	i)Derive expressions for displacement/strains, stresses, and moments, ii) derive (using these expressions) the governing equation for bending of flat rectangular and axi-symmetric circular plates. Use the expressions for computing these parameters in specified cases	1,2	90	75	H	H													
CLO-4 :	Compute strain energy due to various loadings and using it to determine deflection	1,2	90	75	H	H													
CLO-5 :	Understand the primary difference between theory of elasticity and mechanics of materials approaches and solve plane stress, torsional, and rotating disk problems	1,2	90	75	H	H													
CLO-6 :	Determine displacements, strains, and stresses related to primary structural members	1,2	90	75															

		Stress & Strain Theory	Bending of Straight & Curved Beams	Bending of flat thin plates	Energy Methods	Theory of Elasticity & Its Applications
Duration (hour)		9	9	9	9	9
S-1	SLO-1	Introduction – course overview, Equilibrium, compatibility, and constitutive relations in macroscopic form, Definition of stress at a point in 3D, representation on an element and sign convention	BendingStresses in beams (initially straight) due to symmetrical loading – review and definition of un-symmetrical bending	Introduction to flat plates – definition of a plate, rectangular and axi-symmetric circular plates, thin vs thick plates, comparison with beams (1D) as a structural member (2D), typical real-world	Work, Strain energy definition for linear, perfectly elastic materials; strain energy due to - uniaxial stress, additional normal stresses in other perpendicular directions, shear stress	Introduction to and comparison with mechanics of materials approach, definition of Plane stress and plane strain linear elastic problems

				applications. Linear vs non-linear bending – definition. Derivation of governing equation for bending of a flat, thin, rectangular plate – outline of procedure		
S-2	SLO-1	concept of a tensor (in relation to a scalar and a vector), 2D stress transformation in Cartesian coordinate system using direction cosines	Bending stresses in beams due to un-symmetrical bending (plane of loading not coinciding with plane of symmetry, even if it exists) – explanation of theory in decoupling the problem into sub-problems using the concept of principal axes and moments of inertia	definition of strains, stresses, and moments and use of these parameters in derivation of governing equation for plate bending (based on Kirchhoff theory) – use of strain-displacement, and stress-strain relations	strain energy due to - general state (3D) of stress, plane stress	Plane stress and plane strain linear elastic problems - Airy's stress function in rectangular coordinates – derivation of the biharmonic equation
S-3	SLO-1	3D stress transformation in Cartesian coordinate system using direction cosines	Application of theory in computing bending stresses and determination and location of neutral axis	Use of equilibrium equations and completion of derivation of governing equation; specification of different boundary conditions generally used – simply supported, clamped, free	Total strain energy in bars with simple loading conditions – axial loading, torsional loading of a solid circular bar, and transverse loading	simple problems related to bending of beams using Airy's stress function in rectangular coordinates
S-4	SLO-1	principal stresses in 3D (after a quick review in 2D)	Deflection due to unsymmetrical bending; Intro to shear center, determination of shear center for a symmetrical channel section	Solution due to sinusoidal bending load on a simply supported plate– step-by-step explanation	Castigliano's 1st theorem, example problems	Additional problems related to bending of beams using Airy's stress function
S-5	SLO-1	Numerical problems (in 2D and 3D based on the above lectures)	determination of shear center for T, unequal I sections	Numerical problems on thin, flat rectangular plates	brief overview of material non-linearity and plasticity;The complementary energy theorem, and Castigliano's 2nd theorem,	overview of torsion of rectangular cross section structural members, Prandtl stress function for torsion, derivation of Poisson's equation (using Prandtl stress function)
S-6	SLO-1	octahedral normal and shear stresses, definition of strain based on small-displacement theory and strain tensor in Cartesian coordinate system	intro to bending of curved beams	Derivation of governing equation for bending of a flat, thin, axi-symmetric circular plate – outline of procedure - definition of strains, stresses, and moments	example problems using Castigliano's 1st& 2ndtheorems (for linear materials)	Membrane analogy, brief discussion of torsion of rectangular cross section
S-7	SLO-1	strain transformation and principal strains in 3D for linear, homogeneous, isotropic material	Derivation of circumferential stress expression	use of strain-displacement, stress-strain, and equilibrium relations in derivation of governing equation (for bending)	Rayleigh's method, example problem of beam bending deflection	torsional stress in hollow closed thin-walled (single cell) tubes – overview and expressions for shear stress and angle of twist
S-8	SLO-1	Numerical problems on 3D strain computation, transformation, and determination of principal strains	Numerical problems on determination of circumferential stresses (rectangular and square sections)	derivation of equations for displacement, support reactions, and maximum stresses for a uniformly loaded, simply supported circular plate	Rayleigh-Ritz method applied to beams in bending	Stresses due to rotation - Radial and tangential stresses in a disc of uniform thickness – derivation of expression for the stresses due to rotation at a constatnt angular speed; maximum stresses
S-9	SLO-1	equilibrium and compatibility relations in differential form, boundary conditions and St. Venant's principle	Additional numerical problems on determination of circumferential stresses (rectangular and square sections); a brief intro (only) to radial stresses in curved beams	Numerical problems on bending of flat, thin, axi-symmetric circular plates	problems based on Rayleigh-Ritz method	Problems related to computation of Radial and tangential stresses in a rotating disc of uniform thickness based on the previous lecture

Learning Resources	1. *Arthur BoresiandRichardh Schmidt, "Advanced Mechanics of Materials," John Wiley & Sons, 6ed, 2009* 2. *Ansel C. Ugural and Saul K. Fenster,"Advanced Mechanics of Materials and Applied Elasticity," Prentice*	6. *G. T. Mase, R, E, Smelser, and G, E, Mase, "Continuum Mechanics for Engineers," 3rd edition, CRC Press, 2004*

	Hall; 5th ed.,2011 3. Richard G Budynas, "Advanced Strength and Applied Stress Analysis," McGraw Hill International Editions, 1999 4. L. S. Srinath, " Advanced Mechanics of Solids," McGraw Hill Education, 3rd edition, 2017 5. S. P. Timoshenko and J N Goodier," Theory of Elasticity," McGraw Hill 2017	7. Y. C. Fung, "Foundations of Solid Mechanics," Prentice Hall International, 1965 8. Stephan H Crandal, Norman C Dahl, Thomas J Lardner," An Introduction to the Mechanics of Solids," McGraw Hill, 2nd edition,1978 9. Robert Cook and Warren Young, "Advanced Mechanics of Materials," Pearson, 2nd edition, 1998

Learning Assessment												
	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	40%	-	30%	-	30%	-	30%	-	30%	-
	Understand										
Level 2	Apply	40%	-	40%	-	40%	-	40%	-	40%	-
	Analyze										
Level 3	Evaluate	20%	-	30%	-	30%	-	30%	-	30%	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
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2. Dr.A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	2. Dr.Ranjith Mohan,IIT Madras, ranjith.m@iitm.ac.in	

Course Code	18MEE307T	Course Name	AUTOMOTIVE ENGINEERING	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 :	*Be familiar with the understanding of automotive architecture and performance*
CLR-2 :	*Be familiar with the transmission system*
CLR-3 :	*Know the working of wheels, tyres, and braking system*
CLR-4 :	*Be familiar with the suspension and steering system*
CLR-5 :	*Be familiar with the electrical system and advances in automotive engineering.*
CLR-6 :	*Understand the structure, transmission system, suspension system, steering system, electrical system and working of wheels, tyres in automotive Engineering*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Broaden the understanding of automotive architecture and performance*	*1&2*	*90*	*85*	*H*	*L*	*L*	*L*	*M*	*L*	*L*	*L*	*L*	*L*	*L*	*L*	*L*	*H*	*L*
CLO-2 :	*Introduce the transmission system*	*1,2&3*	*90*	*85*	*H*	*L*	*L*	*L*	*M*	*L*	*L*	*L*	*L*	*L*	*L*	*L*	*L*	*H*	*L*
CLO-3 :	*Familiarize about the wheels,tyres,and braking system*	*1*	*90*	*85*	*H*	*L*	*L*	*L*	*M*	*L*	*L*	*L*	*L*	*L*	*L*	*L*	*L*	*H*	*L*
CLO-4 :	*Understand the suspension and steering system*	*1,2&3*	*90*	*85*	*H*	*L*	*L*	*L*	*M*	*L*	*L*	*L*	*L*	*L*	*L*	*L*	*L*	*H*	*L*
CLO-5 :	*Familiarize in electrical system in automotive engineering.*	*1,2&3*	*90*	*85*	*H*	*L*	*L*	*L*	*M*	*L*	*L*	*L*	*L*	*L*	*L*	*L*	*L*	*H*	*L*
CLO-6:	*Familiarize all the systems involved in automotive Engineering*	*1,2&3*	*90*	*85*	*H*	*L*		*L*	*M*	*L*	*L*	*L*	*L*	*L*	*L*	*L*	*L*	*L*	*L*

		Automobile Architecture and Performance	Transmission Systems	Wheel, Tyres, and Braking system	Suspension and steering System	Electrical System and Advances in Automotive Engineering
Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Automotive components*	*Clutch types, coil spring and diaphragm type clutch.*	*Types of wheels, construction, wired wheels*	*Types front and rear suspension*	*Battery, general electrical circuits*
S-2	SLO-1	*Subsystem and their position of chassis*	*Single and multi-plate clutch*	*Types, construction, radial, bias tires and belted bias tires*	*Conventional and independent type suspension*	*Dash board instrumentation*
S-3	SLO-1	*Frame and body*	*Centrifugal clutch*	*Slip angle, tread patterns*	*Leaf springs, coil springs, dampers*	*Chip formation and its passenger comfort, safety and security*
S-4	SLO-1	*Front, rear and four wheel drives*	*Gear box types, constant mesh, sliding mesh*	*Tyre retreading cold and hot, tubeless tyres*	*Torsion bars, stabilizers bars, arms ,air suspension system*	*Heating, ventilation and air-conditioning(HVAC), seat belts, air bags*
S-5	SLO-1	*Operation and performance*	*Synchromesh gear box*	*Forces on vehicles, tyre grip*	*Types of steering system, Ackermann principle*	*Automotive electronics, Electronic Control Unit(ECU)*
S-6	SLO-1	*Traction force*	*Layout of gear box, Gear selector and shifting mechanism*	*Load transfer, braking distribution between axles, stopping distance*	*Davis steering gear, steering gear boxes, steering linkages*	*Variable Valve Timing(VVT), Active suspension system (ASS)*
S-7	SLO-1	*Traction resistance*	*Overdrive, automatic transmission*	*Types of brakes, mechanical, hydraulic brakes*	*Introduction to sheet metal working and applications*	*Electronic Brake Distribution(EBD)*
	SLO-2		*Rolling air, gradient resistance*		*Power steering , wheel geometry*	
S-8	SLO-1	*Power required for automobile,*	*Propeller shaft, universal joint, slip joint*	*Air brakes, Disc and Drum brakes*	*Caster, camber toe in,toe out*	*Electronic Stability program (ESP),*

						Traction control System(TCS)
S-9	SLO-1	*Power required for automobile,*	*Differential and real axle arrangement, hydraulic coupling*	*Engine brakes, antilock braking system*	*Wheel Alignment and balancing*	*Global positioning system(GPS), Electric Hybrid Vehicle*

Learning Resources	1. *Kirpal Singh, " Automobile Engineering", standard publishers; Vol-I & II, 2017* 2. *Ramalingam, K. K," Automobile Engineering", SciTech publications, 2014* 3. *Rajput R K, " A Text book of Automobile Engineering", Laxmi Publications., 2015*	4. *Crouse, W.H and Anglia, D.L "Automotive Mechanics", Tata McGraw Hill, 2005* 5. *Narang, G.B , " Automobile Engineering", khanna publishers, 2001* 6. *Kamaraju Ramakrishna, "Automobile Engineering", PHI Learning Pvt Ltd, 2012.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Understand										
Level 2	Apply	*40%*	-	*40%*	-	*40%*	-	*40%*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr.R.Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*DR. K.L.HARIKRISHNA SSN COLLEGE OF ENGINEERING*	*Mr. C. Subramanian, SRMIST*
2. Dr.A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in		*Dr.P.Nandakumar, SRMIST*

Course Code	18MEE308T	Course Name	FOUNDATION SKILLS IN INTEGRARTED PRODUCT 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 fundamentals of Product Development*
CLR-2 :	*Understand requirement Engineering and System Design*
CLR-3 :	*Understand Conceptual design*
CLR-4 :	*Understand detail design*
CLR-5 :	*Understand Obsolescence management and IPR*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)															
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Do global trend and PESTEL analysis*	*1 2&3*	*90*	*85*	*H*		*H*			*H*	*H*		*H*						
CLO-2 :	*Perform requirement Engineering*	*1 2&3*	*90*	*85*	*H*		*H*			*H*	*H*		*H*						
CLO-3 :	*Develop conceptsfor products as solution to engineering problem*	*1 2&3*	*90*	*85*	*H*		*H*			*H*	*H*		*H*						
CLO-4 :	*Perform verification and validation*	*1 2&3*	*90*	*85*	*H*		*H*			*H*	*H*		*H*						
CLO-5 :	*Perform maintenance requirement*	*1 2&3*	*90*	*85*	*H*		*H*			*H*	*H*		*H*						

Duration (hour)		09	09	09	09	09s
S-1	SLO-1	*Global Trends Analysis and Product decision: Types of various trends affecting product decision -Social Trends(Demographic, Behavioral, Psychographic ,*	*Requirement Engineering: Types of Requirements (Functional, Performance, Physical ,Regulatory, Economical, Behavioral);*	*Conceptualization: Industrial Design and User Interface Design*	*System Integration, Testing, Certification and Documentation: Manufacturing/Purchase and Assembly of Systems*	*Sustenance: Maintenance*
S-2	SLO-1	*Economical Trends(Market, Economy, GDP, Income Levels,Spending Pattern, target cost, TCO), Technical Trends(Technology,Applications, Tools, Methods)*	*Types of Requirements (, Technical, Stakeholder, Environmental, Industry specific, Internal-Company Specific)*	*Introduction to Concept generation Techniques*	*Integration of Mechanical, Embedded and S/W systems;*	*Sustenance: Repair; Enhancements.*
S-3	SLO-1	*Environmental Trends(Environmental Regulations and Compliance), Political/Policy Trends,(Regulations, Political Scenario, IP Trends and Company Policies);PESTLE Analysis*	*Requirement Engineering (Gathering (VOC)*	*Concept Screening & Evaluation - Concept Design*	*Introduction to Product verification processes and stages - Industry specific (DFMEA)*	*Product EoL: Obsolescence Management*
S-4	SLO-1	*Introduction to Product Development Methodologies and Management: Overview of Products and Services (Consumer product, Industrial product, Specialty products etc)*	*Analysis (QFD)*	*S/W Architecture, Hardware Schematics and simulation*	*Introduction to Product verification processes and stages - Industry specific (FEA, CFD)*	*Configuration Management; EoL Disposal.*
S-5	SLO-1	*Types of Product Development (NPD/ Re-Engineering (Enhancements, Cost Improvements)/ Reverse Engineering*	*Design Specification*	*Detailed Design: Component Design and Verification*	*Introduction to Product validation processes and stages Industry specific (Sub-system Testing/ Integration Testing*	*The Industry: Engineering Services Industry - overview; PLM,Product development in Industry versus Academia*
S-6	SLO-1	*Design Porting & Homologation);*	*Traceability Matrix and Analysis*	*High Level Design/Low Level*	*Introduction to Product validation processes*	*The IPD Essentials:*

				Design of S/W Programs, S/W testing;	*and stages Industry specific (Functional Testing/ Performance Testing / Compliance Testing*	*Introduction to vertical specific product development processes*
S-7	SLO-1	*Overview of Product Development methodologies (Over the Wall/ Waterfall/ V-Model/ Stage-Gate Process/ Spiral/Systems Engineering/ Agile)*	*Requirement Management*	*Hardware Schematic, Component design, Layout and Hardware Testing.*	*Product Testing standards and Certification - Industry specific;*	*Product development Trade-offs*
S-8	SLO-1	*Product Life Cycle (S-Curve, Reverse Bathtub Curve)*	*Introduction to System Modeling,System Optimization*	*Prototyping: Types of Prototypes (Mockups, Engineering Assessment Prototype, Alpha, Beta, Gama)*	*Product Documentation (Compliance Documentation, Catalogue, Brochures, user manual)*	*Intellectual Property Rights and Confidentiality*
S-9	SLO-1	*Product Development Planning and Management (Budgeting, Risk, Resources and Design Collaboration) Product Development Planning and Management (Scheduling, Change Management, Product Cost Management)*	*System Specification; Sub-System Design; Interface Design.*	*Introduction to Rapid Prototyping and Rapid Manufacturing*	*Product Documentation (maintenance Manual, Spares Parts List, Warranty, Disposal Guide, IETMS, Web Tools)*	*Security and configuration management.*

Learning Resources	*1. Foundation Skills in Integrated Product Development (FSIPD),Ist Edition,2013, Published by NASSCOM.* *2. Ulrich, Karl T. and Eppinger, Steven D (2004) Product Design and Development, 5th Edition, McGraw-Hill, 2012.*	*3. Kevin N. Otto, "product design – techniques in reverse engineering and new product development", PEARSON, New Delhi, 2011*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember / Understand	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply / Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate / Create	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr.R.Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*Dr.R.Prabhusekar, rprabhusekar@mnnit.ac.in, MNNIT Allahabad*	*1. Mr. N. arun, SRM IST*
2. Dr.A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*Dr. Shanmugam. P, Shanmugam.p@sfl.co.in, Sundaram fasteners, Chennai*	*2. Dr. P. Nandakumar, SRMIST*

Course Code	18MEE309T	Course Name	MODELING SYSTEMS	Course Category	E	Professional Elective	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1 :	*Acquire knowledge to model systems seen in reality*
CLR-2 :	*Understand the use of mathematics in modeling*
CLR-3 :	*Understand the basic principles of modeling systems*
CLR-4 :	*Understand and develop simple models*
CLR-5 :	*Understand and recognize that modeling as an interdisciplinary requirement*
CLR-6 :	*Understand and correlate real time problems with mathematical forms*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Understand and correlate engineering systems seen in real time environment with the modeling systems*	*1&2*	*90*	*85*	*H*	*H*	-	-	-	-	*H*	-	-	-	-	-	-	-	-
CLO-2 :	*Understand and realize the use of mathematics in modeling engineering systems*	*1&2*	*90*	*85*	*H*	*H*	-	-	-	-	-	-	-	-	-	-	-	-	-
CLO-3 :	*Understand and able to convert real time problems into mathematical form*	*1&2*	*90*	*85*	*H*	*H*	-	-	-	-	-	-	-	-	-	-	-	-	-
CLO-4 :	*Understand and model various components of engineering systems*	*1,2,&3*	*90*	*85*	*H*	*H*	*H*	*H*	*H*	-	-	-	-	-	-	-	-	-	-
CLO-5 :	*Modeling engineering systems such as mechanical systems and thermal systems*	*1,2&3*	*90*	*85*	*H*	*H*	*H*	*H*	*H*	-	-	-	-	-	-	-	-	-	-
CLO-6 :	*Understand and recognize that modeling is an interdisciplinary requirement*	*1,2*	*90*	*85*	*H*	*H*	-	-	-	-	-	-	-	-	-	-	-	-	-

Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Introduction: Model – Definition, Nature and necessity*	*Use of Modeling Mathematics: Principles of modeling – common aspects of all mechanical systems*	*Generate Simple Models: Introductions to system identification*	*Understanding the Mathematics in Response: Characteristic equation*	*Project: Identify a system*
S-2	SLO-1	*History of modeling*	*Given a simple system – create a model*	*Model mechanical systems - Rectilinear*	*Solution of characteristic equation*	*Objectives of modeling and simulation of a system*
S-3	SLO-1	*Different type of modeling*	*Assessment of reality of the model – degree of accuracy*	*Model mechanical systems - Torsional*	*Introduction to Eigen values – natural frequencies - eigen vectors – mode shapes*	*Identify components*
S-4	SLO-1	*Impact of computers on modeling*	*Quadratic oscillator system and need for this model*	*Model a thermal system*	*Use of Laplace transforms for stability analysis*	*Model components – test each component*
S-5	SLO-1	*Different areas of application – Design, Thermodynamics, Mechanics, Controls etc.*	*Spring mass damper system and need for such a system*	*Response analysis – the reverse engineered explanation*	*Different type of representation of systems*	*Assemble the model*
S-6	SLO-1	*Modeling in software*	*Linearity of springs – modeling*	*Study of response for different inputs – modeling inputs*	*How to analyze for controllability*	*Identify suitable inputs – model them*
S-7	SLO-1	*Introduction to Discrete and continuous systems*	*Modeling damping – different type*	*Time driven models*	*How to analyze for observability, stabilizability*	*Analyze the response to that input*
S-8	SLO-1	*Components of systems*	*Modeling systems – assemble - quadratic*	*Event driven models*	*Conditions for the same*	*Submit a report*
S-9	SLO-1	*Areas of applications*	*Relate mathematics to real system –*	*Numerical experimentation*	*Relevance of these tests to modeling*	*Presentation and viva voce*

			ODEs, Transforms – solutions			

Learning Resources	1. *G. J. Olsder, J. W. van der Woude, J. G. Maks, D. Jeltsema, "Mathematical Systems Theory", VSSD, Leeghwaterstraat, Deelft, Netherlands; 4th Edition, 2011* 2. *Polderman J. W., Willems J. C., "Introduction to mathematical theory of systems and control", Springer, 1997*	3. *Frank L Severence, "Systems modeling and simulation – An introduction", student edition, 2012.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr.R.Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*Dr.R.Prabhu sekar, rprabhusekar@mnnit.ac.in, MNNIT Allahabad*	*Dr. G. Rajasekaran, SRMIST*
2. Dr.A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in		*Dr. P. Nandakumar, SRMIST*

Course Code	18MEE310T	Course Name	HUMAN BODY MECHANICS	Course Category	E	Professional Elective	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	The purpose of learning this course is to:	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLR-1 :	Upon learning the students shall understand the fundamentals of biomechanics, joints, tissue overall anatomical structure and their importance.																		
CLR-2 :	Upon learning the students shall understandthe mechanism of the different parts of the human body.																		
CLR-3 :	Upon learning the students shall understandthe musculoskeletal system with tissue loads and responses and neuromuscular control.																		
CLR-4 :	Upon learning the students shall understand kinematics, is the accurate description of motion and is essential to understanding the biomechanics of human motion. Kinematics can range from anatomical descriptions of joint rotations to precise mathematical measurements of musculoskeletal motions.																		
CLR-5 :	Upon learning the students shall understand, the Newton's Laws of Motion in the human body and how these laws can be applied to human motion in the biomechanical principles of Force–Motion, Force–Time, and Coordination ContinuumPrinciples																		
CLR-6 :	Enableunderstanding of the concepts of human body mechanics that illustrate the application of biomechanics principles. These principles are the application for the biomechanical concepts used to improve movement or reduce injury risk																		
Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:																		
CLO-1 :	Upon learning the students shall understand the fundamentals of biomechanics, joints, tissue overall anatomical structure and their importance.	1,2,3	90	85	H	H				H		H							
CLO-2 :	Upon learning the students shall understand the mechanism of the different parts of the human body.	1,2	95	90	H	H			H	H	H	H							
CLO-3 :	Upon learning the students shall understand themusculoskeletal system with tissue loads and responses and neuromuscular control.	1,2,3	90	85	H	H			H	H	H	H	H			H			
CLO-4 :	Upon learning the students shall understand kinematics, is the accurate description of motion and is essential to understanding the biomechanics of human motion. Kinematics can range from anatomical descriptions of joint rotations to precise mathematicalmeasurements of musculoskeletal motions.	1,2,3	90	85	H	H	H	H	H	H	H		H			H			
CLO-5 :	Upon learning the students shall understand, the Newton's Laws of Motion in the human body and how these laws can be applied to human motion in the biomechanical principles of Force–Motion, Force–Time, and Coordination Continuum Principles	1,2,3	85	80	H	H		H	H	H	H	H				H			

		Introduction to Biomechanics of Human Movement and Anatomy of Human Body.	Equilibrium and Human Movement	Mechanics of the Musculoskeletal System	Kinematics of Human Movement	Angular Kinetics of Human Movement.
Duration (hour)		9	9	9	9	9
S-1	SLO-1	Introduction to biomechanics,Importance of Biomechanics, Improving Performance Preventing and Treating Injury	Equilibrium and Torque	General introduction of tissue and its classifications.	Kinematic convention, Proximal, Flexion, Anterior	Introduction to angular kinematics in arms for the biceps femoris muscle
S-2	SLO-1	Quantitative versus qualitative problems	Resultant Joint Torques	Response of Tissues to Forces, Stress, Strain, Stiffness and Mechanical Strength, Viscoelasticity	absolute spatial reference system for human gait	Sample problems on applying forces in optimal direction for maximum torque output
S-3	SLO-1	Structure, movements and loads on the shoulder	Levers, Anatomical levers	Biomechanics of the Passive Muscle–Tendon Unit (MTU)	Total description of a body segmentation in space	Moment of inertia of a skeleton about a specific axis
S-4	SLO-1	Structure, movements and loads on the elbow and wrist	Equations of static and dynamic equilibrium	Biomechanics of Bone	Direct measurement techniques	Newton's laws to calculate the net forces and torques acting on body segments.

S-5	SLO-1	*Structure, movements and loads on the hip*	*Center of gravity and locating the center of gravity*	*Biomechanics of Ligaments*	*Goniometers Eletro goniometer*	*static equilibrium and a reaction board to calculate whole body center of gravity*
S-6	SLO-1	*Structure, movements and loads on the knee*	*Locating the human body Center of Gravity, Stability and balance.*	*Three Mechanical Characteristics of Muscle, Force–Velocity Relationship, Force–Length Relationship, Force–Time Relationship*	*Image measurement techniques*	*whole body center of gravity of a high jumper using the segmental method and a three-segment model of the body. Most*
S-7	SLO-1	*Structure, movements and loads on the spine*	*Properties of Bone, Maxwell &Voight Models of bone*	*Stretch-Shortening Cycle (SSC)*	*Cinematography*	*PRINCIPLE OF BALANCE*
S-8	SLO-1	*Structure, movements and loads on the foot*	*Biomechanics of human skeletal muscle.*	*Force–Time Principle*	*Optoelectic techniques*	*two-dimensional area within all supporting Biomechanical system.*
S-9	SLO-1	*Common injuries in shoulder, elbow wrist, hip knee, spine and foot.*	*Biomechanics of human Skeletal Articulations*	*Neuromuscular Control, The Functional Unit of Control: Motor Units, Regulation of Muscle Force, Proprioception of Muscle Action and Movement.*	*Problems on calculating velocities and accelerations*	*The position of the line of gravity relative to the limits of the base of support*

Learning Resources	1. *Susan .J. Hall, "Basic biomechanics", Tata Mcgraw Hill, Sixth edition, 2011.* 2. *Y. C. Fung, "Biomechanics", 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., "Biomechanics: A Qualitative Approach for Studying HumanMovement", Pearson, 1996.*	5. *Boston: Allyn and Bacon Alexander. R. Mc. Neill, "Biomechanics", Chapman and Hall, 1975* 6. *Fundamentals of Biomechanics by Duane Knudson (Springer)* 7. *.Biomechanics and Motor Control of Human Movement By David A. Winter*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

Industrial Expert	Academic expert	Internal Expert
1. Dr.R.Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*Dr. Amit Roy Roy Chowdhury, IISER Shibpur, amit@aero.iiests.ac.in*	*Dr. Sandipan Roy,SRMIST*
2. Dr.A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in		*Dr. P. Nandakumar, SRMIST*

Course Code	18MEE401T	Course Name	DESIGN OF TRANSMISSION SYSTEMS	Course Category	E	Professional Elective	L	T	P	C
							3	0	0	3

Pre-requisite Courses	18MEC308T	Co-requisite Courses	Nil	Progressive Courses	//Course code
Course Offering Department	Department of Mechanical Engineering	Data Book / Codes/Standards		Approved Design Data Book	

Course Learning Rationale (CLR):	The purpose of learning this course is to:
CLR-1 :	Selection of flexible drives
CLR-2 :	Design the Parallel gears
CLR-3 :	Design the Non-Parallel gears
CLR-4 :	Design the gear box
CLR-5 :	Selection of bearings

Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	Select the flat belt, V-belt, chain and wire ropes	1,2,3	90	85	H	H	H	M	M	L	H	L	M	L	M	M	L	H	L
CLO-2 :	Design the spur gear and helical gear	1,2,3	90	85	H	H	H	M	M	L	H	L	M	L	M	M	L	H	L
CLO-3 :	Design the bevel gear and worm gear	1,2,3	90	85	H	H	H	M	M	L	H	L	M	L	M	M	L	H	L
CLO-4 :	Design the multi speed gear box for machine tool applications	1,2,3	90	85	H	H	H	M	M	L	H	L	M	L	M	M	L	H	L
CLO-5 :	Select the journal bearing, ball bearings, roller bearings and deep grove bearings	1,2,3	90	85	H	H	H	M	M	L	H	L	M	L	M	M	L	H	L

		Flexible Drives	Parallel Gears	Non-Parallel Gears	Gear Boxes	Bearings
Duration (hour)		9	9	9	9	9
S-1	SLO-1	Belt drives: types, selection of belt drives	Review of gear fundamentals, Forces and stresses in geartooth	Straight bevel gear: Terminology	Geometric progression, standard step ratio,structural andray diagrams Number of teeth calculation	Introduction of Hydrodynamic journal bearings
	SLO-2	Belt materials and applications	Equivalent number of teeth, gear tooth failures, Selection of gear materials	Forces and stresses on gear tooth		Sommerfeld Number, Raimondi and Boyd graphs
S-2	SLO-1	Selection of flat belt drives using fundamental equations	Design procedure on spur gear based on strength consideration	Design procedure on bevel gear based on strength consideration	Design procedure on sliding mesh gear box	Bearing materials, properties required for bearing materials, System of lubrication
	SLO-2	problems on flat belt drives using fundamental equations	Problems on spur gear based onstrength consideration	Problems on bevel gear based onstrength consideration	problems on sliding mesh gear box	
S-3	SLO-1	Selection procedure for flat belt drives using manufacturer's data	Problems on spur gear based onstrength consideration	Problems on bevel gear based onstrength consideration	problems on sliding mesh gear box	Selection procedure for journal bearing
	SLO-2	Problems on flat belt drives using manufacturer's data				
S-4	SLO-1	Selection procedure for V-belt drives using fundamental equations	Design procedure on spur gear based on wear consideration	Design procedure on bevel gear based on wear consideration	Design procedure on constant mesh gear box	Problems injournal bearings
	SLO-2	Problemson V-belt drives using fundamental equations	Problems on spur gear based onwear consideration	Problems on bevel gear based onwear consideration	Problems on constant mesh gearbox	
S-5	SLO-1	Selection procedure for V-belt drives	Problems on spur gear based onwear	Problems on bevel gear based onwear	Design of Multi speed gear box for	Introduction to Roller contact bearings

		using manufacturer's data	*consideration*	*consideration*	*machine toolapplications*	
	SLO-2	*Problems on V-belt drives usingmanufacturer's data*				
S-6	SLO-1	*Wire ropes: types, construction and Selection of wire ropes*	*Design procedure on helical gear based on strength consideration*	*Worm gear: Thermal capacity, efficiency, forces andstresses*	*Design of Multi speed gear box for machine toolapplications*	*Types of bearing, Load rating, bearing materials and bearing failure*
	SLO-2	*Stresses in wire ropes*	*Problems on helical gear based onstrength consideration*	*Design procedure on worm gear based onstrength consideration*		
S-7	SLO-1	*Selection procedure for wire ropes*	*Problems on helical gear based onstrength consideration*	*problems on worm gear based onstrength consideration*	*Variable speed gear box*	*Selection of bearing*
	SLO-2	*Problems on wire ropes*				
S-8	SLO-1	*Power transmission chains: types and applications*	*Design procedure on helical gear based on wear consideration*	*Design procedure on worm gear based on wear consideration*	*Fluid couplings*	*Problems in ball bearing*
	SLO-2		*Problems on helical gear based onwear consideration*	*Problems on worm gear based onwear consideration*		
S-9	SLO-1	*Selection procedure on power transmission chains and sprockets*	*Problems on helical gear based onwear consideration*	*Problems on worm gear based onwear consideration*	*Torque convertor for automotive applications*	*Problems in roller bearing*
	SLO-2	*Problems on power transmission chains and sprockets*				

Learning Resources	1. *Robert. C. Juvinall, Kurt. M. Marshek, "Fundamentals of Machine Component Design", John Wiley&sons, 6th Edition, 2017.* 2. *Joseph Edward Shigley and Charles R. Mischke, "Mechanical Engineering Design", McGraw –HillInternational Editions, New York, 10th Edition, 2014.* 3. *Spotts, M.F., Shoup, T.E., Hornberger, L.E., "Design of Machine Elements", Prentice Hall of IndiaEighth Edition, 2004.* 4. *Paul H Black and O. E. Adams, P., "Machine Design", 3rd edition, Mc Graw Hill Book Company, Inc.,New York, USA, 2007.* 5. *Bernard Hamrock, Steven Schmid, Bo Jacobson, "Fundamentals of Machine Elements", 2nd Edition,Tata McGraw-Hill Book Co., 2006.* 6. *Dr. Sadhu Singh, "Design of Machine Elements (Machine Design)", Khanna Publishers; Fifth edition (1987).* 7. *KhurmiR.S ,Gupta J.M., "A text book of machine design", S.Chand&Company Ltd, 25th revised edition, 2005.* 8. *P.S.G Tech..,"Design Data Book", KalaikathirAchchagam, 2012*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember / Understand	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply / Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate / Create	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr.R.Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*Mr. Vignesh Shanmugam.s, Hyundai Motors India Limited, Irungattukottai – 602117.E mail – 273357@hmil.net*	*Mr. D. Raja, SRM IST*
2. Dr.A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*Dr. Davidson Jebaseelan, davidson.jd@vit.ac.in, VIT, Chennai*	*Dr. P. Nandakumar, SRMIST*

Course Code	18MEE402T	Course Name	OPTIMIZATION IN ENGINEERING DESIGN	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		*Approved design data book*	

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

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*understand optimization principles and its need*	*1& 2*	*90*	*85*	*H*														
CLO-2 :	*understand and apply the concept of conventional optimization techniques*	*1&2*	*90*	*85*	*H*	*H*													
CLO-3 :	*understand and apply the concept of constrained in single variable as well as multivariable*	*1&2*	*90*	*85*	*H*	*H*													
CLO-4 :	*understand and apply the concept unconventional optimization techniques*	*1&2,3*	*90*	*85*	*H*	*H*		*H*											
CLO-5 :	*apply the methods of optimization in real life situation*	*1&2,3*	*90*	*85*	*H*	*H*	*H*	*H*											

		Introduction to optimization	Unconstrained optimization techniques	Constrained optimization techniques	Modern Methods of Optimization	Applications
Duration(hour)		9	9	9	9	9
S-1	SLO-1	*Introduction to optimization: adequate and optimum design*	*Techniques of unconstrained optimization*	*Direct search methods: Random jumping method, Random walk method*	*Genetic Algorithm Introduction*	*Design optimizationof springs*
S-2	SLO-1	*Principles of optimization,design vector, design constraints*	*Golden section method.*	*Tutorials on Random Jumping Method*	*Basic elements of natural genetics—reproduction, crossover, and mutation*	*Design vector for springs*
S-3	SLO-1	*Statement of an optimization problem*	*Fibonacci method*	*Tutorials on Random Walk Method*	*The computational procedure involved in optimizing the fitness function in genetic algorithm*	*Objective function for springs*
S-4	SLO-1	*Formulation of objective function*	*Random search*	*Direct search methods: conjugate gradient method, quasi-Newton methods*	*Tutorials on Genetic Algorithm*	*Design optimizationof shafts and torsionally loaded members.*
S-5	SLO-1	*Design constraints*	*Random search*	*Tutorial on conjugate gradient method*	*Simulated Annealing: Introduction*	*Design vectors for torsionally loaded members*
S-6	SLO-1	*Classical optimization techniques: single variable*	*Pattern search*	*Indirect methods –Penalty function method*	*Simulated Annealing - Steps involved*	*Objective function fortorsionally loaded members*
S-7	SLO-1	*Classical optimization techniques: single variable*	*Gradient search*	*Indirect methods –Penalty function method problems*	*Ant colony optimization:Basic Concept*	*Design optimization of simple truss members*
S-8	SLO-1	*Classical optimization techniques: multivariable*	*Quadratic interpolation method*	*Interior penalty function method*	*Ant colony optimization:Ant Searching Behavior*	*Design vectors forsimple truss members*
S-9	SLO-1	*Classical optimization techniques multivariable*	*Cubic interpolation method*	*Exterior penalty function method*	*Graphical representation of the Ant colonyoptimization process*	*Objective function for simple truss members*

Learning Resources	1. *Rao Singaresu.S, "Engineering Optimization – Theory & Practice", New Age International (P) Limited, New Delhi, 2009.* 2. *Kalyanamoy Deb, "Optimization for Engineering design algorithms and Examples", Prentice Hall of India 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", DhanpatRai& 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, Limited, 1984.*

Learning Assessment											
	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate Create	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr.R.Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*DR. SUBHAS GANGULY, sganguly.met@nitrr.ac.in NIT Raipur*	*Vamsi krishna dommeti SRMIST*
2. Dr.A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*HARESH DURAI KARUPPIAH, Haresh.durai@rntbci.com, RENAULT NISSAN*	*Dr. P. Nandakumar, SRMIST*

Course Code	18MEE403T	Course Name	TOOL ENGINEERING DESIGN	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 :	*Be familiar with tool materials and their properties*
CLR-2 :	*Be familiar with the design of single point cutting tools and twist drills*
CLR-3 :	*Be familiar with the design of various types of dies*
CLR-4 :	*Be familiar with the blank development for different components*
CLR-5 :	*Be familiar with the design of jigs and fixtures for simple components*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Identify suitable tool materials for the specific manufacturing applications*	*1&2*	*85*	*80*	*H*	*L*	*M*	*M*	-	-	-	-	*M*	-	-	-	*H*	*L*	*H*
CLO-2 :	*Design single point cutting tools and twist drill for different machining requirements*	*2&3*	*85*	*80*	*H*	*M*	*M*	*M*	-	-	-	-	*M*	-	-	-	*H*	*L*	*H*
CLO-3 :	*Design various types of dies for manufacturing components*	*2&3*	*85*	*80*	*H*	*H*	*H*	*M*	-	-	-	-	*M*	-	-	-	*H*	*L*	*H*
CLO-4 :	*Develop the blank for cylindrical and non-cylindrical shells*	*2&3*	*85*	*80*	*H*	*H*	*H*	*L*	-	-	-	-	*M*	-	-	-	*H*	*L*	*H*
CLO-5 :	*Design and develop the jigs and fixtures for simple mechanical components*	*2&3*	*85*	*80*	*H*	*H*	*H*	*H*	-	-	-	-	*M*	-	-	-	*H*	*L*	*H*

Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Different types of tool materials: cemented carbides, coatedcarbides, cermets,*	*Press working terminology*	*Principles of jigs and fixtures*	*Design principles of fixtures*	*Case study in jigs*
S-2	SLO-1	*ceramics and polycrystalline and new tool materials*	*Different types of Presses and press accessories*	*Locating principles and different locating elements*	*Design of fixtures for milling operation*	*Case study in jigs*
S-3	SLO-1	*Composition and properties of tool materials*	*Computation of capacities and tonnage requirements ofpresses*	*Clamping principles, clamping devices and types in jigs*	*Design of fixtures for boring operation*	*Case study in jigs*
S-4	SLO-1	*Cutting tool selection and treatments*	*Various types of Strip layout*	*Analysis of clamping force*	*Design of fixtures for broaching & grinding operation*	*Case study in fixture*
S-5	SLO-1	*Design of single point turning tools and multipoint tools*	*Different types of dies, Progressive dies, Combination diesand compound dies*	*Function of drill bush, types drill bushes*	*Design of fixture for assembly*	*Case study in fixture*
S-6	SLO-1	*Problems on the design of single point cutting tool alone*	*Design and development of various types of cutting, forming,bending and drawing dies*	*Different types of jigs , Plate jig, latch jig, channel jig,*	*Design of fixture for inspection*	*Case study in fixture*
S-7	SLO-1	*Selection of tool holders and inserts for turning*	*Design and development of various types of cutting, forming,bending and drawing dies*	*Different types of jigs Post jig, angle plate jig, turn over jig, and pot jigs*	*Design of fixture for welding*	*Case study in press tools*
S-8	SLO-1	*Function of Chip breaker, types of chip breaker*	*Blank development for cylindrical and non-cylindrical shells, blank size calculation*	*Design and development of jigs for given components*	*Design and development of fixtures for given components*	*Case study in press tools*
S-9	SLO-1	*Design of twist drill and reamers*	*Forging dies basics and materials for forging dies*	*Design and development of jigs for given components*	*Design and development of fixtures for given components*	*Case study in press tools*

Learning Resources	1. *Sadasivan.T.A, and Sarathy.D, "Cutting tools for Productive machining", 1st edition, Widia (India) Ltd, Bangalore, 1999.* 2. *Donaldson.C, Lecain.G.H and Goold.V.C, "Tool Design", Tata McGraw Hill publishing company limited, New Delhi, 2002* 3. *Edward G. Hoffman, "Jigs and Fixture design", 2nd edition, Galgotia publication Pvt. Ltd., New Delhi,1987* 4. *Hiram E. Grant, "Jigs and Fixtures - Nonstandard clamping device", Tata McGraw Hill, New Delhi, 1971.*	5. *Prakash H. Joshi, "Press tool design and construction", 1st edition, Wheeler Publishing, New Delhi, 2000.* 6. *Kempster.M.H.A, "An Introduction to Jig and tool design", 3rd edition, ELBS, 1987* 7. *Prakash H. Joshi, "Cutting tools", 1st edition, Wheeler Publishing, New Delhi, 1997.* 8. *Prakash H. Joshi, "Tooling Data", 1st edition, Wheeler Publishing, New Delhi, 2000.*

Learning Assessment												
	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. S.Bhargav, GM,Rane Brake, Trichy	*1. Dr. V.Srinivasan,Annamalai University, srinivraghavan@yahoo.com*	*1. Mr.V.G.Umasekar, SRMIST*
2. Dr. Muthumanikkam, Jt. Director, CVRDE, DRDO,Avadi,Chennai.	*2.Dr.Assaithambi, Govn. Col.of. Eng,sengipatti,Thanjavur, basaithambi@gcetj.edu.in*	*Dr. U. M. Iqbal, SRMIST*

Course Code	18MEE404T	Course Name	COMPUTER GRAPHICS	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 :	Be familiar with the basics of computer graphics and transformations
CLR-2 :	Be familiar with the special curvesand their parametric representation
CLR-3 :	Be familiar with the surface modeling techniques and their mathematical representation
CLR-4 :	Be familiar with the three dimensional graphics techniques
CLR-5 :	Be familiar with the graphics and Communication standards
CLR-6 :	Be familiar with the computer graphics and various modeling techniques

Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLO-1 :	Understand about computer graphics and basic transformations	1	90	85
CLO-2 :	Acquire knowledge on special curves and their parametric representation	1&2	90	85
CLO-3 :	Understand the various surface modeling techniques and their mathematical representation	1&2	90	85
CLO-4 :	Understand the three dimensional modeling techniques and apply these techniques to develop new products	1&2	90	85
CLO-5 :	Acquire knowledge on data exchange and Communication standards	1&3	90	85
CLO-6 :	Understand about computer graphics and various modeling techniques			

Program Learning Outcomes (PLO)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	H	L	M	L	L	L	L	L	L	L	L	L	L	L	L
CLO-2 :	H	L	H	M	L	L	L	L	L	L	L	L	L	L	L
CLO-3 :	H	M	H	M	M	L	L	L	L	L	L	L	L	L	L
CLO-4 :	H	M	H	M	M	L	L	L	L	L	L	L	L	L	L
CLO-5 :	H	M	L	M	L	L	L	L	L	L	L	L	L	L	L
CLO-6 :															

		Introduction to Computer Graphics	Special Curves	Surface modeling	Three Dimensional computer graphics	Graphics and Communication standards
Duration (hour)		9	9	9	9	9
S-1	SLO-1	Origin of computer Graphics	Introduction of Curve representation	Introduction of Surface modeling techniques	Boundary representation (B-rep)	Graphics and data exchange standards
S-2	SLO-1	Interactive graphics display	Introduction to Bezier curve	Coonspatch	Basic elements and building operations	Graphical Kernel System
S-3	SLO-1	Video Display devices	Parametric representation of Bezier curve	Mathematical representation and boundaries of Coons patch	Constructive solid geometry (CSG)	Bit maps
S-4	SLO-1	Types of Display devices	Introduction toCubic spline curve	Bi-Cubic patch	Basic elements and Building operations	open GL (graphics library)
S-5	SLO-1	Algorithm for line, circle	Parametric representation of Cubic spline curve	Mathematical representation of Bi-Cubic patch	Viewing transformations	Data exchange standards (IGES)
S-6	SLO-1	2D transformation (scaling, rotation, translation)	Introduction toB-Spline curve	Bezier surface	Clipping operations	STEP and CALLS
S-7	SLO-1	3D transformation scaling &rotation	Parametric representation of B-Spline curve	Mathematical representation of Bezier surface	Hidden line removal for curved surfaces	DXF Standard and STL
S-8	SLO-1	3D transformation Translation	Introduction toRotational curves	B-Spline surface	Algorithms for shading	Communication standards, LAN
S-9	SLO-1	Concatenation transformations	Parametric representation of Rotational curves	Mathematical representation of B spline surface	Algorithms for rendering	Communication standards, WAN

Learning Resources	1. Donald Hearn and Pauline Baker M. “Computer Graphics”, Prentice Hall, Inc., 2009 2. Ibrahim Zeid“CAD/Cam Theory and Practice”, McGraw Hill, International Edition, 2010.	3. Harington, Stevan, “Computer Graphics: A Programming Approach”, McGraw Hill, 1983 4. Plastock, Roy A., &Kally, “Theory and Problems of Computer Graphics”, McGraw Hill, 1986

Learning Assessment											
	Bloom’s Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr.R.Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*Dr. Davidson Jebaseelan, davidson.jd@vit.ac.in, VIT Chennai*	*Mr.S.ArunPrasath, SRMIST*
2. A. Don Bosco, Valeo, Chennai	*S.DineshBabu, Renault Nissan Technology, Chennai*	*Mr.R.Yogeswaran, SRMIST*

Course Code	18MEE405T	Course Name	FATIGUE, FRACTURE MECHANICS AND CREEP	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 :	Be familiar with fatigue crack propagation and micromechanisms of fatigue
CLR-2 :	Be familiar with the concepts of environmentally assisted cracking in metals
CLR-3 :	Know about fracture mechanics and stress intensity factors
CLR-4 :	Know about deformation at crack tip, crack tip opening displacement, crack initiation and growth
CLR-5 :	Be familiar with characteristics, mechanisms, effects and considerations of creep

Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	Recognize and analyze fatigue crack propagation, crack closure, fatigue threshold, variable amplitude loading and retardation and micromechanisms of fatigue	1&2	90	85	H	H	-	-	-	-	-	-	-	-	-	-	-	-	-
CLO-2 :	Appreciate the knowledge on environmentally assisted cracking,stress corrosion, hydrogen embrittlement and corrosion fatigue in metals	1&2	90	85	H	-	-	-	-	-	H	-	-	-	-	-	-	-	-
CLO-3 :	Understand fracture mechanics and acquire knowledge on energy release rate, stress intensity factors of simple and complex cases	1& 2	90	85	H	H	-	-	-	-	-	-	-	-	-	-	-	-	-
CLO-4 :	Acquire knowledge onanelastic deformation at the crack tip, J-integral, crack tip opening displacement and mixed mode crack initiation and growth	1&2	90	85	H	H	-	-	-	-	-	-	-	-	-	-	-	-	-
CLO-5 :	Understand characteristics of creep and acquire knowledge on mechanisms, tests, interactions, temperature effects, materials and design considerations of creep	1&2	90	85	H	H	-	-	-	-	-	-	-	-	-	-	-	-	-

Duration (hour)		9	9	9	9	9
S-1	SLO-1	Fatigue crack propagation, similitude in Fatigue	Introduction to environmentally assisted cracking in metals, Corrosion principles: electrochemical reactions	Introduction to fracture mechanics: Kinds of failure, brittle and ductile fracture, modes of fracture failure	Anelastic deformation at crack tip: approximate shape and size of plastic zone	Introduction to creep, characteristics of creep
S-2	SLO-1	Empirical fatigue crack growth equations	Corrosion current and polarization, electrode potential and passivity, cathodic protection	Energy release rate: Griffith's dilemma, surface energy, Griffith's analysis, mathematical formulation, compliance approach, strain energy approach	Anelastic deformation at crack tip: effective crack length, effect of plate thickness	Mechanisms of creep: dislocation creep, diffusion creep, grain boundary sliding, Creep deformation mechanism maps
S-3	SLO-1	Crack closure, closer look at crack-wedging mechanisms, loading variables on closure	Environmentally assisted cracking (EAC) overview: Cracking mechanisms	Energy release rate: anelastic deformation at crack tip, thin plate vs thick plate	Definition of J-Integral, path independence, stress-strain relation	Creep under multiaxial loading, combined stresses, stress relaxation
S-4	SLO-1	The fatigue threshold: a two-criterion model, threshold behavior in inert environments	Crack growth rate vs applied stress intensity, threshold for EAC, small crack effects	Energy release rate: crack resistance, stable and unstable crack growth, critical energy release rate	Further discussion on J-integral from a designer's point of view, critical J-integral, safety or failure	Creep-fatigue interaction, creep fractures
S-5	SLO-1	Variable amplitude loading and retardation: reverse plasticity at crack tip, the effect of overloads and underloads	Static, cyclic and fluctuating loads, cracking morphology, life prediction	Introduction to Stress intensity factors, Investigations closer to crack tip, LEFM	J-Integral: engineers approach, simplified relation, applications	Creep test, stress rupture test, representation of creep rupture data

S-6	SLO-1	*Models for retardation and variable amplitude fatigue*	*Stress corrosion cracking, film rupture model*	*Stress intensity factor: Stress and displacement fields in isotropic elastic materials, field equations*	*Introduction to CTOD, relationship between CTOD, K_I and G_I, Equivalence between CTOD and J*	*Creep and Stress Rupture: Deformation and fracture at Elevated Temperature*
S-7	SLO-1	*Growth of short cracks: microstructural and mechanical*	*Crack growth rate in stage II, corrosion product wedging*	*Stress intensity factor: Westergaard's approach, Mode I (opening mode), Mode II (sliding mode), Mode III (tearing mode)*	*Introduction to mixed mode crack initiation and growth*	*Theories of low and high temperature creep*
S-8	SLO-1	*Micromechanisms of fatigue: Fatigue in region II, micromechanisms near the threshold*	*Hydrogen embrittlement, cracking mechanisms, Variables that effect cracking behavior: load, hydrogen, temperature*	*SIF of more complex cases: Other applications of Westergaard approach, applications of principle of superposition*	*Mixed mode crack propagation: maximum tangential stress criteria, Strain energy density criterion*	*Prediction of longtime properties, effect of metallurgical variables, Creep resistant materials, hightemperature alloys*
S-9	SLO-1	*Damage tolerance methodology*	*Corrosion fatigue, time dependent and cycle dependent behavior, Mechanisms of corrosion fatigue, effect of corrosion product wedging on fatigue*	*Edge cracks, embedded cracks, critical stress intensity factor*	*Mixed mode examples, crack growth*	*Design considerations to avoid creep*

Learning Resources	1. *T. L. Anderson, "Fracture Mechanics Fundamentals and Applications", CRC Press Taylor & Francis; 4th edition, 2017* 2. *Prashant Kumar, " Elements of Fracture Mechanics" Tata McGraw-Hill; 2009*	3. *C. T. Sun, Z. -H. Zin, " Fracture Mechanics ", Elsevier; 2012* 4. *G. E. Dieter, "Mechanical Metallurgy ", McGraw-Hill; 2017*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*30%*	-	*30%*	-	*40%*	-	*40%*	-	*30%*	-
	Understand										
Level 2	Apply	*50%*	-	*50%*	-	*40%*	-	*40%*	-	*50%*	-
	Analyze										
Level 3	Evaluate	*20%*	-	*20%*	-	*20%*	-	*20%*	-	*20%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr.R.Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*Dr. Sudheesh Kumar, sudheeshkumar3@gmail.com, GCE, Kannur*	*Dr T V V L N Rao, SRMIST*
2. Dr.A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*Dr.R.Prabhusekar, rprabhusekar@mnnit.ac.in, MNNIT Allahabad*	*Dr P Nandakumar, SRMIST*

Course Code	18MEE406T	Course Name	LINEAR ELASTICITY	Course Category	E	Professional Elective	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Advanced calculus and complex Analysis, mechanics of solids*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Department of Mechanical Engineering*	Data Book / Codes/Standards	*Nil*		

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1 :	*To studyConcept of Stress- Strains and Deformation*
CLR-2 :	*To ApplyBoundary Conditions for different kind of problems*
CLR-3 :	*To solve the problem using different solution method*
CLR-4 :	*To solve the plane elasticity problems using different solution method*
CLR-5 :	*To solvetorsion and elastic cylinders problems*
CLR-6 :	*To studyConcept of Stress- Strains and Deformation*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*understand the basics of Tensors, Index Notation, Coordinate Transformations, Deformation and Strain, Strain Transformation, Principal Strains, StrainCompatibility,*	1,2			*H*	*H*													
CLO-2 :	*apply boundary conditions and can get the general result*	1,2			*H*	*H*	*H*												
CLO-3 :	*solve the problem using different solution method*	1,2,3			*H*	*H*	*H*												
CLO-4 :	*solve the plane elasticity problems using different solution method*	1,2,3			*H*	*H*	*H*												
CLO-5 :	*Solve torsion and elastic cylinders problems*	1,2,3			*H*	*H*		*H*								*H*			
CLO-6 :	*Able to understand the basics of Tensors, Index Notation, Coordinate Transformations, Deformation and Strain, Strain Transformation, Principal Strains, StrainCompatibility,*	1,2			*H*	*H*													

		Foundations	General Results	System Response	Plane Elasticity Problems	Torsion And Flexure Of Elastic Cylinders
Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Mathematical Preliminaries-Scalar, Vector, Matrix, and Tensor Definitions*	*Review of Field Equations*	*Anti-plane Strain*	*Plane Stress and Plane Strain*	*General solution of the torsion problem*
S-2	SLO-1	*Index notation*	*Field equations and boundary conditions, Navier equations*	*Field Equations and Boundary Conditions*	*Introduction to Airy Stress Function*	*Prandtl Stress Function*
S-3	SLO-1	*Concept of Stress- Strains and Deformation*	*Stress Formulation-Beltrami-Michell compatibility equations*	*Complex Variable Solutions to Anti-plane Strain Problems*	*Stress function, stress function for plane stress and plane strain cases*	*Torsion Solutions Derived from Boundary Equation*
S-4	SLO-1	*Coordinate Transformations -Strain Transformation*	*Displacement Formulation Principle of Superposition*	*Solution using Taylor Series*	*Introduction to Cartesian Coordinate Using Polynomials*	*Torsion Solutions Using Fourier Methods*
S-5	SLO-1	*Principal Strains, Strain Compatibility*	*2D approximations (plane stress and plane strain) and solution strategies*	*Solution using Laurent Series*	*Cartesian Coordinate Solutions Using Polynomials*	*Torsion of Hollow Cylinders*
S-6	SLO-1	*TractionVector*	*Uniqueness Theorems-Reciprocal Theorem*	*Solution using Cauchy Integral Formula*	*Introduction to Cartesian Coordinate Using Fourier Methods*	*Torsion of Circular Shafts of Variable Diameter*
S-7	SLO-1	*Stress Transformation*	*Principle of Virtual Work*	*Solution using Cauchy Integral Formula*	*Cartesian Coordinate Solutions Using Fourier Methods*	*Torsion of elliptic cross sections*
S-8	SLO-1	*Equilibrium Equations&Generalized*	*Principle of Minimum Potential and*	*Solution using Conformal Mapping*	*Introduction to Solutions in Polar Coordinates*	*Flexure Formulation*

		Hooke's law.	*Complementary Energy*			
S-9	SLO-1	*Review of Continuum Mechanics Concepts*	*Saint-Venant's Principle*	*Solution using Conformal Mapping*	*Axisymmetric problems, thick-walled cylinders, rotating disks of uniform thickness, stress concentration, effect of circular holes on stress distribution in plates.*	*Flexure Problems without Twist*

Learning Resources	1. *Martin H. Sadd, Elasticity: Theory, "Applications and Numeric's", Elsevier India, 2005* 2. *Timoshenko.S.P, Goodier.J.N, "Theory of Elasticity", Tata McGraw-Hill Education, 2010.* 3. *England.A.H, "Complex Variable Methods in Elasticity", Dover Publications, 2003.* 4. *Malvern.L.E, "Introduction to the Mechanics of a Continuous Medium", Prentice Hall, 1977.*	5. *Love.A.E.H, "The Mathematical Theory of Elasticity", Dover, 2011.* 6. *Landau.L.D and Lifshitz.E.M, "Theory of Elasticity, Butterworth-Heinemann", 1986.* 7. *Atkin.R.J and Fox.N, "An Introduction to the Theory of Elasticity", Dover,2005.* 8. *Barber.J.R, "Elasticity", Springer, 2009.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*30%*	-	*30%*	-	*40%*	-	*40%*	-	*30%*	-
	Understand										
Level 2	Apply	*50%*	-	*50%*	-	*40%*	-	*40%*	-	*50%*	-
	Analyze										
Level 3	Evaluate	*20%*	-	*20%*	-	*20%*	-	*20%*	-	*20%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr.R.Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*Dr. R. Damodaram, SSN College of Engineering, Chennai, damodaramr@ssn.edu.in*	*Mr. K. Jegadheesan, SRMIST*
2. Dr.A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*Dr.R.Prabhusekar, rprabhusekar@mnnit.ac.in, MNNIT Allahabad*	*Dr. M. Iqbal, SRMIST*

Course Code	18MEE407T	Course Name	DESIGN OF PRESSURE VESSEL AND PIPING	Course Category	E	Professional Elective	L	T	P	C
							3	0	0	3

Pre-requisite Courses	18MEC206T	Co-requisite Courses	NIL	Progressive Courses	NIL
Course Offering Department	Mechanical Engineering	Data Book / Codes/Standards	ASME Pressure Vessel and Boiler Code; Section VIII Div. 1&2; 2003.American Standard Code for Pressure Piping; B 31.1.		

Course Learning Rationale (CLR):	The purpose of learning this course is to:
CLR-1:	Familiarize with basics of Pressure vessel design
CLR-2:	Familiarize with different types of stresses and their effects in Pressure vessel.
CLR-3:	Equip with Pressure vessel design.
CLR-4:	Expose to failuremechanisms in Pressure vessel.
CLR-5:	Expose to the concept of piping layout and the stresses acting on it.
CLR-6	Analyse and design of pressure vessel and piping.

Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	Learning 1 Level of Thinking (Bloom)	2 Expected Proficiency (%)	3 Expected Attainment (%)	PLO 1 Engineering Knowledge	2 Problem Analysis	3 Design & Development	4 Analysis, Design, Research	5 Modern Tool Usage	6 Society & Culture	7 Environment & Sustainability	8 Ethics	9 Individual & Team Work	10 Communication	11 Project Mgt. & Finance	12 Life Long Learning	13 PSO - 1	14 PSO - 2	15 PSO - 3
CLO-1:	understand the basics of pressure vessel design	1&2	90	85	H	H	H	M										L	
CLO-2:	determine various stresses, and their effects in pressure vessel.	12&3	90	85	H	H	H											L	
CLO-3:	design pressure vessel.	12&3	90	85	H	H	H											L	
CLO-4:	know the various types of failures in pressure vessel.	12&3	90	85	H	H	H											L	
CLO-5:	know the concepts of piping layout and the stresses acting on it	12&3	90	85	H	H	H											L	
CLO-6	Know the design concepts of pressure vessel and piping	1 2&3	90	85	H	H	H											L	

		Overview of Pressure Vessel and stresses	Stresses in Pressure Vessels	Design of Pressure Vessels	Failure Analysis of vessels	Fundamentals of piping design
Duration (hour)		09	09	09	09	09
S-1	SLO-1	Introduction, construction and design procedure.	Stresses in cylinder, Dilation of pressure vessels, Intersecting spheres.	Stress concentration at a variable thickness transition section in a cylindrical vessel, circular hole, Elliptical Openings	Buckling phenomenon, vessels under external pressure.	Introduction to piping, definition,codes, standards and specifications.,
S-2	SLO-1	. Design approach, design by rule, design by analysis.	Membrane stresses in vessel under internal pressure, cylindrical vessel, spherical, conical vessel.	Stress concentration factor for superposition, Dynamic and thermal transient condition.	Elastic buckling of circular ring, deflectioncurve, buckling.	Piping components, pipe, pipe fittings, flanges, valves, bolt and gaskets.
S-3	SLO-1	Introduction, Stress intensity, Stresses in a circular ring.	Thermal stresses in long hollow cylinder, logarithmic, thermal gradient.	Design of tall cylindrical self-supporting process columns for short vertical vessels.	Buckling of long cylinder or tubes, inelastic collapse, initial non-circularity.	Flow diagram, piping layout
S-4	SLO-1	Stress significance, stress pattern.	Linear thermal gradient, Steady state Thermal stresses.	Design of supports for short vertical vessel.	Collapse of thick walled cylinder, fully plastic wall,	underground, above ground pipelines
S-5	SLO-1	Residual stress, shape of a member	Thermal stresses due to thermal gradients.	Theory of reinforced openings.	Collapse of the wall of a cylinder.	Piping stress analysis, Forces and moments
S-6	SLO-1	Methods for determining stresses, strain gauge, Photo elastic, Moiré.	Ultra-high-pressure vessel -design principle, wedge, segment principle.	Nozzle reinforced placement shape, single nozzles, Multiple nozzles, Nonradical nozzles.	Effect of supports on elastic buckling, buckling, collapse coefficient.	Piping specifications, static and dynamic loads
S-7	SLO-1	Thermal stresses, thermal strains and	Cascade principle, yoke Beam and ties,	Pressure vessel design, welded joints,	Buckling under combined external	nomenclature of pipe supports, guided

		their significance.	*Anvil principle, Bridge man massive conical anvils.*	*strength of weldments.*	*pressure and axial loading*	*cantilever method*
S-8	SLO-1	*Terminology of vessel, vessel Ligament.*	*Discontinuity stresses in pressure vessels, Cylindrical vessels with various heads, Infinite long beam, semidefinite beam.*	*Bolted joints and gaskets, thread and nut design, bolt head, shank design.*	*interaction method, interaction equations in design.*	*Design of piping system, pressure components design*
S-9	SLO-1	*Ligament efficiency, Longitudinal, circumferential ligaments in a cylindrical and spherical shape.*	*Stresses in a bimetallic joint, deformation and stresses in flanges.*	*Introduction to ASME pressure vessel codes.*	*Safety factors in design, Imperfection sensitivity*	*minimum wall thickness of pipe, pipe span calculations, Ansi piping codes.*

Learning Resources	1. *John F. Harvey, "Theory and Design of Pressure vessels", CBS publishers and Distributors, 1987.* 2. *Henry H Bedner, " Pressure Vessels, Design Hand Book ", CBS publishers and Distributors ,1987.* 3. *Somnath Chattopadhyay," Pressure vessels: Design and practice ", CRC Press ,2004.* 4. *Smith P., "Fundamentals of piping design", Elsevier Gulf Publishing Company 2007.*	5. *William. J. Bees"Approximate Methods in the design and analysis of pressure vessels and piping ", Pre ASME-pressure vessels and piping conference ,1997.* 6. *ASME Pressure Vessel and Boiler code, section viii Div. 1&2,2003 American standard code for pressure piping, B31.1* 7. *Brownell. L E & Young E.D," Process equipment design ", Wiley Eastern Ltd, India.*

Learning Assessment											
	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Understand										
Level 2	Apply	*40%*	-	*40%*	-	*40%*	-	*40%*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr.R.Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*Dr V.MARIAPPAN, vmari@nitt.edu, NIT Trichy*	*Dr. P.Nandakumar, SRMIST*
2. Dr.A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in		*Mr.R.Harris Samuel, SRMIST*

Course Code	18MEE408T	Course Name	KINEMATICS AND DYNAMICS OF ROBOTS	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 :	Acquire the fundamental concepts of Robot Transformation
CLR-2 :	Impart the Knowledge about the concepts of Direct kinematics of Robot
CLR-3 :	Impart the Knowledge about the concepts of Inverse kinematics of Robot
CLR-4 :	Acquire fundamental knowledge about theplanning trajectories on workspace of robot
CLR-5 :	Enable students withthe basic knowledge of Robot Dynamics
CLR-6 :	Understand the kinematics and dynamics models of robots

Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLO-1 :	Understanding rigid body transformations, homogeneous transformation matrices of Robot.	1 &2	85	75
CLO-2 :	Derive the direct kinematics equation for robot manipulators.	2	80	70
CLO-3 :	Derive the inverse kinematics equation for robot manipulators.	1 &2	80	70
CLO-4 :	Generate workspace and trajectory planning in Cartesian and joint spaces.	1 &2	75	70
CLO-5 :	Understand the equations of motion (dynamics model) of manipulators using Lagrange-Euler and Newton-Euler methods.	1 &2	75	70
CLO-6 :	Analyze the kinematic and dynamic model of robot	2	75	70

Program Learning Outcomes (PLO)														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
H	H	M	M	M	L	L	L	M	M	M	M	M	M	M
H	H	M	M	M	L	L	L	M	M	M	M	M	M	M
H	H	H	M	M	L	L	L	M	M	M	M	M	M	M
H	H	H	M	M	L	L	L	M	M	M	M	M	M	M
H	H	H	M	M	L	L	L	M	M	M	M	M	M	M
H	H	M	M	M	L	L	L	M	M	M	M	M	M	M

Duration (hour)		9	9	9	9	9
S-1	SLO-1	Introduction about machines and mechanisms – Robot anatomy	Link coordinates for D-H representation	Inverse Kinematics of transformation	Introduction & analysis of work space	Introduction to manipulator dynamics
	SLO-2					
S-2	SLO-1	Arm and wrist configuration of Robot	Arm matrix and Arm equation – DH representation of Kinematics model	General properties of solution	Workspace analysis for 4 axis SCARA robot	Lagrange's equation - kinetic and potential energy
	SLO-2					
S-3	SLO-1	Position and orientation of objects, descriptions: Positions, Orientations and Frames	Direct Kinematics of 2 DOF Planar Manipulator arm	Inverse Kinematics for 2 DOF planar robot	Work space fixtures	Link inertia tensor
	SLO-2					Link jacobian manipulator inertia tensor
S-4	SLO-1	Coordinate transformation / Mapping in fixed angle rotation	Direct Kinematics of 3 axis articulated robot – Link	Inverse kinematics – 3 DOF articulated robot – Guide lines, solution techniques	Trajectory planning - Terminology	Gravity and generalized forces
	SLO-2				Trajectory planning – pick and place motion	
S-5	SLO-1	Mappings: Changing descriptions from Frame to Frame		Inverse kinematics – 3 DOF articulated robot – Derivation of equations	Continuous path motion – Joint space technique and Cartesian space technique	Lagrange – Euler Dynamic model formulation
	SLO-2					
S-6	SLO-1	Operators: Translations, Rotations and Transformations, Transformation Arithmetic	Direct Kinematics of 3 DOF wrist	Inverse kinematics of RPY wrist	Trajectory planning – Interpolated motion	Kinetic and Potential Energy Formulation for Two axis planar robot
	SLO-2					

S-7	SLO-1 SLO-2	*Transformation of Vectors for Rotation, translation and composite*		*Inverse kinematics of – 4 axis SCARA robot – General solution*	*Trajectory planning – straight line motion*	*L-E Dynamics model for Two axis planar robot*
S-8	SLO-1 SLO-2	*Inverting Transformation*	*Direct Kinematics Analysis of 4 axis SCARA Robot*	*Tool Configuration*	*Trajectory planning for 3 DOF Manipulator*	*Newton – Euler formulation*
S-9	SLO-1 SLO-2	*Rotation Matrix – fixed and Euler angle representation*		*Tool configuration of a 4 axis SCARA robot*	*Trajectory planning for 4 DOF SCARA Manipulator*	*N-E Dynamics model for Two axis planar robot*

Learning Resources	1. *1.Robert J. Schilling, Fundamentals of Robotics Analysis and Control, Prentice Hall of India Pvt. Ltd., 2003* 2. *Richard D. Klafter, Thomas. A, Chmielewski, Michael Negin, Robotics Engineering an Integrated Approach, Prentice Hall of India Pvt. Ltd., 1993* 3. *P.A. Janaki Raman, Robotics and Image Processing An Introduction, Tata Mc Graw Hill Publishing company Ltd., 1995*	4. *John J. Craig, Introduction to Robotics Mechanics and Control, Fourth Edition, Pearson Education International, 2018.* 5. *Mittal RK, Nagrath IJ, Robotics and Controls, Tata McGraw Hill Publications, 2003*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*40%*	-	*30%*	-	*30%*	-	*30%*	*15%*	*30%*	-
Level 2	Apply Analyze	*40%*	-	*40%*	-	*40%*	-	*40%*	*20%*	*40%*	-
Level 3	Evaluate Create	*20%*	-	*30%*	-	*30%*	-	*30%*	*15%*	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
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1. Dr.R.Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*Dr. Yogesh Singh, Yogesh@mech.nits.ac.in, NIT Silchar*	*Mr. KR. Arun prasad, SRMIST*
2. Dr.A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*Dr.R.Prabhu sekar, rprabhusekar@mnnit.ac.in, MNNIT Allahabad*	*Dr. P. Nandakumar, SRMIST*

Course Code	18MEE409T	Course Name	COMPUTER APPLICATIONS IN DESIGN	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 overall design process and the types of three-dimensional modeling schemes.
CLR-2 :	write programs in MATLAB for Mechanical Engineering Design problems
CLR-3 :	understand in applying CAD model for design
CLR-4 :	know how the model data is stored, retrieved and to organize for CIM applications
CLR-5 :	know uses of parametric modeling. Uses of Rapid prototyping and Artificial Intelligence
CLR-6 :	understand the overall design process and the types of three-dimensional modeling schemes.

Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLO-1 :	understand the overall design process and can able to apply on any projects.	1&2	90	85
CLO-2 :	write interactive programs in MATLAB for design problems.	1	90	85
CLO-3 :	understand in applying CAD model in design	1	90	85
CLO-4 :	organize data for CIM applications and various aspects of data storage and manipulation	1&2	90	85
CLO-5 :	understand the uses of parametric modelling and artificial intelligence.	1&2	90	85

Program Learning Outcomes (PLO)														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
H	-	-	-	-	-	-	-	-	-	-	-	-	-	-
H	H	-	-	-	-	-	-	-	-	-	-	-	-	-
H	-	M	-	-	-	-	-	-	-	-	-	-	-	-
H	-	M	-	-	-	-	-	-	-	-	-	-	-	-
H	-	M	-	-	-	-	-	-	-	-	-	-	-	-

		Introduction to CAD	Writing design programs in MATLAB for Machine Elements	Applying the CAD model in design	Entity Manipulation and Data Storage:	Expanding the capability of CAD
Duration (hour)		9	9	9	9	9
S-1	SLO-1	The design process	Introduction to Machine Drawing	Applications to draughting	Manipulation of the model	Parametric modeling
S-2	SLO-1	Different types of design process	Introduction to Machine Drawing	The use of 3D modeling for 2D representation	Model storage	Variation modeling
S-3	SLO-1	Role of CAD in Design	Introduction to MATLAB software	Approaches to 3D modelling	Data structures	Feature based modeling
S-4	SLO-1	Types and applications of design models	Introduction for Writing interactive programs to solve design problems in MATLAB	Direct assessment for the geometric model	Database consideration	Feature recognition
S-5	SLO-1	Computer representation of drawings	Design problems using MATLAB for Shafts	Generation of new models from the geometric model	Object oriented representations	Design by features
S-6	SLO-1	Three-dimensional modeling schemes	Design problems using MATLAB for Gears	The scope of customization and design automation	CIM	
S-7	SLO-1	Wire frame model	Design problems using MATLAB for Pulleys	Typical facilities for system customization	Organizing data for CIM application	Rapid prototyping
S-8	SLO-1	Surface representation model	Design problems using MATLAB for flywheel	The graphics Kernel System	ERP (Enterprise Resource planning)	
S_9	SLO-1	Solid modeling	Design problems using MATLAB for connecting rods	Standard for exchanging images	Design information system	Artificial intelligence in design

Learning	1. Charles. S. Knox, "Organising data for CIM Applications", Marcel Dekker Inc. New York 1987.	5. Chandupatla and Belagundu, "Introduction to Finite Element Methods in Engineering", Prentice

Resources	2. *Ibrahim Zeid, "CAD/ CAM - Theory and Practice" - McGraw Hill, International Edition, 1998.* 3. *Chris McMahon and Jimmi Browne, "CAD CAM Principles, practice and Manufacturing Management", Pearson Education Asia, 2002.* 4. *Kr. Gopalakrishna, "Machine Drawing" , Subhas Stores, 2007*	*Hall of India Private Limited, New Delhi, 1997.* 6. *http://www.machinedesign.com* 7. *MATLAB: Easy Way of Learning,S. Swapna Kumar and S. V. B. Lenina,2016*

Learning Assessment											
	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*20%*	-	*15%*	-	*15%*	-	*15%*	-	*15%*	-
	Understand										
Level 2	Apply	*20%*	-	*20%*	-	*20%*	-	*20%*	-	*20%*	-
	Analyze										
Level 3	Evaluate	*10%*	-	*15%*	-	*15%*	-	*15%*	-	*15%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr.R.Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*Dr. Davidson Jebaseelan, davidson.jd@vit.ac.in VIT Chennai.*	*Mr. S. Balamurugan,SRM IST*
2. Dr.A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*Mr. Vignesh Shanmugam.S, 273357@hmil.net Hyundai Motors Limited, Chennai*	*Dr. P. Nandakumar, SRMIST*

Course Code	18MEE321T	Course Name	ELEMENTS OF MECHATRONICS	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:*	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	*Acquire the fundamental knowledge of mechatronics systems*			
CLR-2 :	*Understand the sensors and transducers.*			
CLR-3 :	*Understand the actuation systems, signal processing and controllers.*			
CLR-4 :	*Acquire knowledge about the PLC.*			
CLR-5 :	*Know mechatronics system design and its applications.*			
CLR-6 :	*Knowledge about the concept and components of mechatronics systems.*			

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)													
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Differentiate the basic key elements of mechatronics systems*	*1*	*90*	*85*	*M*	-	*M*	-	-	-	-	-	-	-	-	-	*L*	*L*	*L*
CLO-2 :	*Have cognizance on performance of sensors and transducers.*	*1*	*90*	*85*	*H*	*M*	*M*	*L*	*L*	-	-	-	-	-	-	-	*H*	*H*	*L*
CLO-3 :	*Differentiate and utilize actuation systems, signal processing and controllers.*	*1*	*90*	*85*	*H*	*M*	*M*	*M*	-	-	-	-	-	-	-	-	*H*	*M*	*L*
CLO-4 :	*program the PLC.*	*2*	*90*	*85*	*H*	*H*	*M*	*M*	-	-	-	-	-	-	-	-	*H*	*H*	*L*
CLO-5 :	*Design of mechatronics system and its applications.*	*3*	*90*	*85*	*H*	*M*	*H*	*H*	-	-	-	-	-	-	-	-	*H*	*M*	*L*
CLO-6 :	*Differentiate, analysis and design mechatronics systems.*	*3*	*90*	*85*	*H*	*M*	*M*	*M*	*L*	-	-	-	-	-	-	-	*H*	*M*	*L*

		Introduction to Mechatronics	Sensors and Transducers	Electrical Drives and Controllers	Programmable Logic Controllers	Mechatronics System Design and Application
Duration (hour)		9	10	10	8	8
S-1	SLO-1	*Introduction to Mechatronics systems*	*Introduction to sensors and transducers, classification and Static and dynamic characteristics.*	*Introduction, Electromagnetic Principles, Solenoids and Relays*	*Basic structure, Programming units and Memory of Programmable logic controller*	*Mechatronics in Engineering Design, Traditional and mechatronics design*
S-2	SLO-1	*Mechatronics system components and Measurement Systems, Control Systems.*		*Electrical drives of stepper motors, servo motors.*		*Car park barriers using PLC*
S-3	SLO-1	*Open and Closed Loops Systems temperature control*	*Principle and working of Resistive, capacitive, inductive transducer.*		*Input and Output Modules, Mnemonics for programming*	*Pick and Place robots and Bar code reader*
S-4	SLO-1		*Resonant transducer and Optical measurement systems for absolute and incremental encoders*	*Operational amplifier*	*Latching and Internal relays*	
S-5	SLO-1	*Water level controller and Shaft speed control*	*Photo electric sensor and vision system*	*A/D converters*	*Timers, Counters and Shift Registers*	*Automotive control systems*
S-6	SLO-1		*Fibre optic transducers*	*D/A converters*		*Robotics Applications*
S-7	SLO-1	*Sequential Controllers : Washing machine control*	*Solid state sensors and transducers for magnetic measurements*	*Signal processing, Multiplexer and Introduction to Data acquisition system*	*Master relay and Jump Controls*	*Case studies for Coin counters, Robot walking and Boiler control using PID.*

S-8	SLO-1	*Sequential Controllers : Digital camera*	*Temperature measurements*	*Proportional, Integral, Derivative and PID controller*	*Programming the PLC using Ladder diagram for Simple applications.*	
S-9	SLO-1	*MEMS and the automobile airbag*	*Chemical measurements, piezoelectric sensor and accelerometers*	*Introduction to Micro controller : M68HC11 and ATMEGA328*		
S-10	SLO-1		*Ultrasonic sensors and transducers for flow and distance*			

Learning Resources	*TEXT BOOKS* *1. Bolton.W, "Mechatronics", Pearson, 6th Edition, 2015.* *2. Bradley.D.A, Dawson.DBurdN.C.and Loader A.J, "Mechatronics", CRC Press, 1993, First Indian Print 2010.* *3. Jacob Fraden, "Handbook of Modern Sensors Physics, Designs, and Applications", 5th Edition, Springer International Publishing, 2016.*	*REFERENCES* *1. James Harter, "Electromechanics, Principles and Concepts and Devices", Prentice Hall, New Delhi, 1995.* *2. David W. Pessen, "Industrial Automation Circuit Design and Components", Wiley India, 2011.* *3. Bolton.W, "Programmable Logic Controllers", Elsevier, 2015.* *4. Brian Morris, "Automatic Manufacturing Systems Actuators, Controls and Sensors", McGraw Hill, New York, 1994* *5. Godfrey C. Onwubolu, "Mechatronics Principles and applications", Butterworth-Heinemann, New Delhi, 2006.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
Mr. B. Sriram, WABCO INDIA LTD, sriram.b@wabco-auto.com	*DR J.Prasanna, CEG, Anna University, pras_me@yahoo.com*	*1. Mr.N. Karthikeyan, SRMIST*
Dr.R.Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*Dr.R.Sivaramakrishnan, MIT, Anna University, srk@mitindia.edu, srk@annauniv.edu*	*2. Mr.V.Manojkumar, SRMIST*

Course Code	18MEE322T	Course Name	FLUID POWER CONTROL	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*NIL*	Co-requisite Courses		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 construction and working of hydraulic power generating and utilizing elements*
CLR-2 :	*Know the working of various control valves and familiar with accessories in hydraulic systems*
CLR-3 :	*Be familiar with the construction and working of pneumatic systems and fluidic control*
CLR-4 :	*Be familiar with designing of fluid power circuits for given applications*
CLR-5 :	*Know the maintenance procedures and trouble shooting*
CLR-6 :	*understand the fluid power systems and to develop circuits for industrial applications*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)													
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Recognize the use of power generating elements, and acquire knowledge the principles and characteristics of hydraulic components*	*1&2*	*90*	*85*	*H*	-	-	-	-	-	-	-	-	-	-	-	*L*	*L*	*L*
CLO-2 :	*Acquire knowledge on working of various control valves and familiar with accessories in hydraulic systems*	*1*	*90*	*85*	*H*	-	-	-	-	-	-	-	-	-	-	-	*M*	*L*	*L*
CLO-3 :	*Acquire knowledge on the principles and working of pneumatic components.*	*1*	*90*	*85*	*H*	-	-	-	-	-	-	-	-	-	-	-	*M*	*L*	*L*
CLO-4 :	*Design the circuit for given applications*	*1,2&3*	*90*	*85*	*H*	*H*	*H*	-	*M*	-	-	-	-	-	-	-	*H*	*H*	*H*
CLO-5 :	*Acquire knowledge on maintenance and analyze the trouble shooting of fluid power systems*	*1&2*	*90*	*85*	*H*	-	-	-	-	-	*M*	-	-	-	-	*M*	*H*	*H*	*H*
CLO-6 :	*Understand fluid power systems and apply knowledge to develop fluid power circuits for industrial applications*	*1,2&3*	*90*	*85*	*H*	*H*	*H*	-	-	-	*M*	-	-	-	-	-	*M*	*M*	*M*

Duration (hour)		Hydraulic Power Generating And Utilizing Systems	Hydraulic Valves And Accessories	Pneumatic Systems	Design Of Fluid Power Systems	Applications, Maintenance And Trouble Shooting
		10	9	9	9	8
S-1	SLO-1	*Introduction to fluid power system, Hydraulic fluids functions, types, properties, selection and application.*	*Construction and working of manually, pilot and solenoid operated 2/2, 3/2, 4/2,4/3, directional control valves*	*Introduction, comparison with hydraulic systems and electrical systems*	*Fluid power actuators: Speed and force calculations in fluid power systems*	*Industrial hydraulic circuits for riveting machine.*
S-2	SLO-1	*POWER GENERATING ELEMENTS: Construction, operation, characteristics of External Gear pump, internal Gear pump*	*Construction and working of pressure relief, compound pressure relief, pressure sequence valves*	*Construction, operation, characteristics and symbols of reciprocating and rotary compressors*	*Pump performance calculations, Sizing of reservoirs. Calculation of pressure and pressure drop across components in fluid power circuits*	*Hydraulic circuits for grinding and shaping machine.*
S-3	SLO-1	*Construction, operation, characteristics of Lobe, Gerotor and Screw pumps*	*Construction and working of pressure reducing, counter balance valves*	*Construction, operation, characteristics and symbols of 3/2, 5/2, 5/3 manual operated, pilot operated and solenoid operated DCVs*	*Finding the capacity of accumulators required for hydraulic systems.*	*Working of hydraulic press and pump unloading circuits*
S-4	SLO-1	*Construction, operation, characteristics of Un balanced and balanced vane pump*	*Working principle of check valve, throttle valve, one way FCV.*	*Need for air treatment, Filter, Regulator, Lubricator, Muffler and Dryers*	*Selection of different components such as reservoir, various valves, actuators, filters, pumps for a practical application.*	*Hydraulic / pneumatic circuits for material handling Systems*
S-5	SLO-1	*Construction, operation, characteristics of pressure compensated vane pump*	*Working principle of pressure compensated FCV, and their applications.*	*Introduction to fluidic devices, working of Bi-stable, monostable devices*	*Design of hydraulic/pneumatic circuits for simplereciprocation, regenerative, speed control of actuators*	*Preventive and breakdown, maintenance procedures in fluid power systems*

S-6	SLO-1	*Construction, operation, characteristics of bent axis piston pump, swash plate piston pump and Radial Piston Pump*	*Importance of proportional valves, Servo valves and its applications*	*Fluidic application circuits – continuous reciprocation and sequencing*	*Design of hydraulic/pneumatic circuits for sequencing, synchronization*	*Trouble shooting of fluid power systems : problems, causes and remedies- hydraulics*
S-7	SLO-1	*Construction and working of single acting, double acting hydraulic linear actuators*	*Need for intensifier in hydraulic systems, applications*	*Pneumatic Sensors types and applications*	*Cascading circuit for trapped signals : two cylinders*	*Trouble shooting of fluid power systems : problems, causes and remedies- pneumatics*
S-8	SLO-1	*Special cylinders: Tandem, Rodless, Telescopic*	*Different switches, filters, seals, fittings and other accessories used in hydraulic systems*	*Introduction to Electro Pneumatics – switches, relays, solenoids*	*Cascading circuit for trapped signals : three cylinders*	*Safety aspects involved fluid power systems*
S-9	SLO-1	*Cushioning arrangement for cylinders to reduce the impact on the cylinders, Various cylinder mountings*	*Functions, types and applications of accumulators in hydraulics*	*Constructing electrical ladder diagrams for various fluid power applications.*	*Fail-safe circuit, counter balance circuit, actuator locking*	
S-10	SLO-1	*Construction and working of Gear, Vane, Piston motors to obtain rotary motion*				

Learning Resources	1. *Anthony Esposito, "Fluid Power with applications", Pearson Education Inc, 2015.* 2. *Majumdar.S.R, "Oil Hydraulic Systems: Principles and Maintenance", Tata McGraw Hill Publishing company Ltd, New Delhi, 2006.* 3. *Majumdar.S.R, "Pneumatic systems – principles and maintenance", Tata McGraw Hill Publishing company Ltd, New Delhi, 2006* 4. *Ilango Sivaraman, "Introduction to Hydraulics and Pneumatics", PHI Learning Pvt. Ltd, New Delhi, 2017.*	5. *Joji Parambath "Industrial Hydraulic Systems: Theory and Practice", Universal Publishers, USA, 2016.* 6. *Eurlng Ian C. Thrner, "Engineering Applications of Pneumatics and Hydraulics", Routledge, Taylor & Francis group, London and Newyork, 2011.* 7. *Andrew Parr, "Hydraulics and Pneumatics: A technician's and engineer's guide", Elsevier Ltd, 2011.* 8. *Anton H Hehn, "Fluid Power Trouble Shooting", Marcel Dekker Inc., NewYork, 1995*

Learning Assessment											
	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. R. Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in, rkpearls@yahoo.com	*1. Dr. P. Hariharan, Anna University, hari@annauniv.edu, hariharan2311@gmail.com*	*Dr. M. R. Stalin John, SRMIST*
Mr. S. Sendilkumar- Festo India Pvt Ltd	*2. Dr.N.Arunachalam, IIT Madras, chalam@iitm.ac.in*	*Mr. R. Murugesan, SRMIST*

Course Code	18MEE323T	Course Name	PROCESS PLANNING AND COST ESTIMATION	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*18MEC103T*	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:*	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	*Acquire knowledge about Process planning*			
CLR-2 :	*Understand Different Cost and its components*			
CLR-3 :	*Learn about cost estimation of products manufactured in foundry and forging shops*			
CLR-4 :	*Acquire knowledge about various cost involved in welding and sheet metal shops*			
CLR-5 :	*Calculate Machining time for different process*			
CLR-6 :	*Impart clear knowledge about process planning, costing, and estimation of machining time*			

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)													
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Design and plan for various process and various manufacturing methodologies*	*1,2*	*90*	*85*	*H*	*L*	*H*	*M*	*H*	-	-	-	-	-	-	*M*	*H*	*L*	*H*
CLO-2 :	*Estimate various cost involved in a product*	*1,2*	*90*	*85*	*H*	*M*	-	*M*	-	-	-	-	-	-	*M*	*H*	*H*	*L*	*M*
CLO-3 :	*Estimate cost in different manufacturing shops*	*1,2*	*90*	*85*	*H*	*H*	-	*H*	-	-	-	-	-	-	*M*	*M*	*M*	*L*	*H*
CLO-4 :	*Estimate cost in different fabrication shops*	*1,2*	*90*	*85*	*H*	*H*	-	*H*	-	-	-	-	-	-	*M*	*M*	*M*	*L*	*H*
CLO-5 :	*Estimate machining time of various metal removal operations*	*1,2*	*90*	*85*	*H*	*H*	-	*H*	-	-	-	-	-	-	*M*	*M*	*M*	*L*	*H*
CLO-6 :	*Familiarize in process planning, costing and estimation of machining time*	*1,2*	*90*	*85*	*H*	*H*	*M*	*M*	*M*	-	-	-	-	-	*M*	*M*	*M*	*L*	*H*

		Process Planning	Costing and Estimation	Estimation of costs in different shops	Estimation of costs in fabrication shops	Estimation of machining times and costs
Duration (hour)		8	9	9	9	10
S-1	SLO-1	*Production system and Types of production*	*Objectives of costing and estimation*	*Estimation in foundry shop*	*Welding, Types of weld joints, Gas welding*	*Machine shop operations, Estimation of Machining time*
S-2	SLO-1	*Standardization and Simplification*	*costing and estimation: Functions and procedure*	*Pattern cost, Casting cost*	*Estimation of Gas welding cost, Gas cutting*	*Estimation of machining time for turning, knurling and facing operations : Tutorials*
S-3	SLO-1	*Production design and selection*	*Introduction to costs, Computing material cost*	*Cost estimation in Foundry shop: Tutorials-1*	*Arc welding: Equipments, Cost Estimation*	*Estimation of machining time for reaming, threading and tapping operations : Tutorials*
S-4	SLO-1	*Process planning, Selection and analysis*	*Direct labor cost, Analysis of overhead costs*	*Cost estimation in Foundry shop: Tutorials-2*	*Cost estimation in Welding shop: Tutorials-1*	*Estimation of machining time for drilling: Tutorials*
S-5	SLO-1	*Manual/Experience based planning, Variant type CAPP*	*Expenses: Factory expenses*	*Forging: Types, Operations*	*Cost estimation in Welding shop: Tutorials-2*	*Estimation of machining time for boring : Tutorials*
S-6	SLO-1	*Generative type CAPP*	*Administrative expenses, Selling and distributing expenses*	*Estimation of Losses and time in forging*	*Estimation in sheet metal shop*	*Estimation of machining time for shaping Tutorials*
S-7	SLO-1	*Economics of process planning, case studies*	*Cost ladder ,Cost of product*	*Estimation of Forging cost*	*Shearing and forming*	*Estimation of machining time for planning Tutorials*
S-8	SLO-1	*Processes analysis, Break even analysis*	*Depreciation, Analysis of depreciation*	*Cost estimation in Forging shop: Tutorials -1*	*Cost estimation in Sheet metal shop: Tutorials - 1*	*Estimation of machining time for milling operations : Tutorials*
S-9	SLO-1		*Problems in depreciation method*	*Cost estimation in Forging shop: Tutorials -2*	*Cost estimation in Sheet metal shop: Tutorials - 2*	*Estimation of machining time for grinding operations : Tutorials*
S-10	SLO-1					*Case studies: Estimation of cost for a product*

Learning Resources	1. *Banga.T.R and Sharma.S.C, "MechanicalEstimating and Costing", Khanna publishers, New Delhi, 17th Edition, 2015.* 2. *Adithan.M.S and Pabla, "Estimating and Costing", Konark Publishers Pvt., Ltd, 2013.* 3. *Nanua Singh, "System Approach to Computer Integrated Design and Manufacturing", John Wiley & Sons, New York, 2011.* 4. *Joseph G. Monks, "Operations Management, Theory and Problems", McGraw Hill Book Company, New Delhi, 2008.*	5. *Narang.G.B.S and Kumar.V, "Production and Planning", Khanna Publishers, New Delhi, 2014.* 6. *Chitale.A.K and Gupta.R.C, "Product Design and manufacturing", Prentice Hall of India, New Delhi, 2014.* 7. *Peter Scalon, Process planning, Design/Manufacture Interface, Elsevier Sci. & Tech. 2002.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. R. Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in, rkpearls@yahoo.com	*1. Dr. P. Hariharan, Anna University, hari@annauniv.edu, hariharan2311@gmail.com*	*Mr. I. Aatthisugan, SRMIST*
2. Dr. A. Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*2. Dr.N.Arunachalam, IIT Madras, chalam@iitm.ac.in*	*Mr.M.Dhanasekaran, SRMIST*

Course Code	18MEE324T	Course Name	FOUNDRY ENGINEERING	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:*	Learning			Program Learning Outcomes (PLO)													
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLR-1 :	*Understand the basics of foundry, castings, limitations, patterns, materials, allowances*																		
CLR-2 :	*Learn design, types of mold, materials, equipment's, sand mold, core, runner, raiser air vents, gatings, methods of solidification.*																		
CLR-3 :	*Be familiar with the casting process, permanent mold, gravity, pressure die casting, centrifugal casting, precision, shell molding.*																		
CLR-4 :	*Melting, pouring, qualities issues, types of furnaces, remelting, molten metal treatment, pouring temperature, casting inspection, rectification, cause and remedies for casting defects, destructive testing, NDT, dye penetrant, magnetic particle, X-ray, elimination of dissolved gasses, use of statistical quality control in foundry.*																		
CLR-5 :	*Understand the Need and area for automation material handling, of raw, molten metal, storage and dispatch, overhead crane, trolley, pollution control, computers in castings and foundry.*																		
CLR-6 :	*Understand about castings, patterns, molds, quality control, modernization in foundry*																		
Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*																		
CLO-1 :	*Understand the process in foundry, patterns, allowances*	*1&2*	*90*	*85*	*H*	*L*	*M*	*M*	*H*	*L*			*L*	*M*		*M*	*H*	*H*	*M*
CLO-2 :	*Learn the mold types, core making, methods of solidification*	*1&2*	*90*	*85*	*H*	*H*	*M*	*M*	*H*					*M*		*M*	*H*	*H*	*M*
CLO-3 :	*Study the various casting process*	*1*	*90*	*85*	*H*	*L*	*L*	*M*	*H*					*M*		*M*	*H*	*H*	*M*
CLO-4 :	*Gain knowledge about furnaces, and quality control in castings.*	*1&2*	*90*	*85*	*H*	*L*	*L*	*M*	*H*							*M*	*H*	*H*	*M*
CLO-5 :	*Understand the automation in foundry, for handling raw, molten metal finished products,*	*1&2*	*90*	*85*	*H*	*L*	*M*	*M*	*H*	*M*	*M*					*M*	*H*	*H*	*M*
CLO-6 :	*Learn the foundry techniques in broader sense and able to implement.*	*1&2*	*90*	*85*	*H*	*L*	*M*	*M*	*H*	*M*						*M*	*H*	*H*	*M*

		Foundry, patterns, materials, allowances.	Mold types, core making, runner and raisers,	– Different casting types, second operations, rework	Melting of metal and testing of casting and quality control	Modernization economic way of producing castings
Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Introduction to foundry technology, ,*	*Types of mold*	*Types of casting process*	*Types of furnace*	*Need for modernization in foundry*
S-2	SLO-1	*Over view of Casting, patterns*	*Mold equipment's*	*Permanent molds, gravity casting*	*Selection of furnace*	*Materials handling*
S-3	SLO-1	*Patterns materials,*	*Mold and core preparation*	*Co2 process*	*Melting and remelting*	*In house metal melting and handling*
S-4	SLO-1	*allowances*	*Gatings*	*Image sharpening, Butterworth filters*	*Inspection of castings*	*Storage of raw materials,.*
S-5	SLO-1	*Castings limitations*	*Runner and raiser*	*Generation of spatial masks from frequency domain specification,*	*Defects analysis and remedies, molten metal purification.*	*work in process, Finished products*
S-6	SLO-1	*Tupes of patterns*	*Air vents and its importance*	*Basic steps in frequency domain filtering*	*Destructive testing, nondestructive testings. Magnetic particle testings, ultrasonic cell*	*Types of materials handling*
S-7	SLO-1	*Advantages of castings*	*So[idification,typesof solidification*	*Nonlinear filters, function, Max filter, Min filter*	*Quality control of castings, techniques.*	*Electric cranes and trolleys*
S-8	SLO-1	*Limitations of castings*	*Defects related to solidifications*	*Homomorphic filtering, False color, Pseudo color and its approaches and*	*Application of statistical quality control methods*	*pollution control*
S-9	SLO-1	*Assignment on casting, patterns and allowances*	*Assignment on molds, runner, riser, solidification*	*Assignments on image filtering in MATLAB/Open CV/Python*	*Assignment in furnace, casting defects Quality control*	*Assignment on automation, Materials handling, Materials handling equipments,*

						pollution control

Learning Resources	TEXT BOOKS 1. Complete casting handbook: Metal casting process, metallurgy., techniques and design-john Campbell. 2. Banga.T.R. and Agelhiarwal.R.I. Foundry engineering, Khanna publishers. New Delhi.1992. 3. Jain.P.L. Principles of foundry technology, Dhanpat rai & sons. New Delhi.1996	REFERRENCE BOOKS 4. Taylor.H.F.Flemings.M.C.and Wulff.J. Foundry engineering, WILEY EASTERN LTD. New Delhi.1989 5. Gupta.R.B. Foundry engineering, SATHYA PRAKASAM, New Delhi.1989. 6. ASM Metals, Hand book on castings, vol .15,14 th edition. 2002.

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate Create	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. R. Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in, rkpearls@yahoo.com	*1. Dr. P. Hariharan, Anna University, hari@annauniv.edu, hariharan2311@gmail.com*	*1.,Mr.P.Karthikeyan, SRMIST*
2. Dr. A. Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*2. Dr.N.Arunachalam, IIT Madras, chalam@iitm.ac.in*	*2. Mr.V.Manojkumar, SRMIST*

Course Code	18MEE325T	Course Name	THEORY OF METAL FORMING	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 :	*Impart knowledge about various metal forming process*
CLR-2 :	*Be familiar with the stress criterion for plastic deformation*
CLR-3 :	*Attain the ability to identify the process parameters responsible for metal forming*
CLR-4 :	*Provide good exposure towards recent trends in metal forming process*
CLR-5 :	*Understand the defects and overcome with remedies*
CLR-6 :	*Be familiar with the basic science of metal forming, plastic deformation of bulk and sheet metals, in addition to acquire knowledge about the modern processes such as high velocity & super plastic forming.*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Apply & analyze the theories involved in plastic behavior of metals*	*1&2*	*90*	*85*	*H*	*M*	*L*	*L*									*H*	*H*	*H*
CLO-2 :	*Estimate the metal working process under various conditions*	*1,2&3*	*90*	*85*	*H*	*M*	*L*	*L*									*H*	*M*	*H*
CLO-3 :	*Appreciate the types of plastic forming and equipment's used.*	*1&2*	*90*	*85*	*H*				*M*								*H*	*L*	*H*
CLO-4 :	*Utilize the various processes of sheet metal forming.*	*1&2*	*90*	*85*	*H*				*M*								*H*	*L*	*H*
CLO-5 :	*Appreciate the importance of modern metal forming processes.*	*1&2*	*90*	*85*	*H*				*M*								*H*	*L*	*H*
CLO-6 :	*Apply the theories of plasticity and inspecting methods in various metal forming processes and produce engineering components*	*1,2&3*	*90*	*85*	*H*	*M*	*L*	*L*	*M*								*H*	*H*	*H*

Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Theory of plasticity: State of stress*	*Mechanics of metal working -Flow stress determination*	*Classification of rolling process, Types of rolling mills, Hot and cold rolling*	*Introduction to Sheet metal forming processes*	*Comparison with conventional forming methods*
S-2	SLO-1	*Components of Stress- Stress tensor*	*Effect of temperature in metal working*	*Forces and geometric relationship in rolling*	*Rod and wire drawing equipment*	*High Energy Rate Forming, fine blanking*
S-3	SLO-1	*Engineering stress strain relationship*	*Strain rate effects*	*Rolling of bars and shapes, Rolling defects, causes and remedies*	*Shearing, blanking, bending, stretch forming,*	*P/M forging-Isothermal forging*
S-4	SLO-1	*Flow curve and flow rules*	*Hot, cold and warm working*	*Classification of Forging process, Forging Equipment, Open and closed die forging*	*Explosive and press brake forming*	*Electrohydraulic forming*
S-5	SLO-1	*True stress and true strain*	*Metallurgical structure, Anisotropy*	*Forging defects, residual stresses*	*Deep drawing & tube drawing*	*Magnetic pulse forming*
S-6	SLO-1	*Yield criteria*	*Effects of hardening ,friction and lubrication*	*Classification of extrusion process, Variables affecting extrusion*	*Principles and process parameters*	*Rubber pad forming*
S-7	SLO-1	*Slip line field theory*	*Hydrostatic pressure*	*Hydrostatic extrusion, Production of seamless pipe and tubing*	*Sheet metal formability*	*Superplastic forming*
S-8	SLO-1	*Plastic work, Plastic anisotropy*	*Workability, Spring back*	*Deformation, lubrication and defects in extrusion*	*Formability limit diagram*	*Types of Severe plastic forming: ECAP*
S-9	SLO-1	*Plastic deformation of crystals*	*Residual stresses, Deformation processing system*	*Basics of Severe plastic deformation and its approaches*	*Defects in formed parts*	*Accumulative Roll Bonding*

Learning Resources	1. *George E Dieter, "Mechanical Metallurgy", Tata McGraw-Hill Education Pvt. Ltd, 2014.* 2. *Iuzalec, Andrzej, "Theory of Metal Forming Plasticity", Springer Berlin Heidelberg, 2010* 3. *A.Rosochowski, "Severe Plastic Deformation Technology", Whittles Publishing, 2017.* 4. *Z. R. Wang, Weilong Hu, S. J. Yuan, Xiaosong Wang, "Engineering Plasticity: Theory and Applications in Metal Forming", Wiley, 2018, ISBN: 978-1-119-23730-3* 5. *Serope Kalpakjian and Stevan R Schmid, "Manufacturing Process for Engineering Materials", Pearson Education, 2007*	6. *Surendar Kumar, "Technology of Metal Forming Processes", PHI Learning Pvt Ltd, 2008* 7. *William F Hasford, Robert M Caddell "Metal Forming: Mechanics and Metallurgy", Cambridge University Press, 2011* 8. *ASM "Metals Handbook, Volume 14, Forming and Forging", ASM Metals Park, Ohio, USA, 1998*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
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2. Dr. A. Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*Dr.V..S. Sethilkumar,CEG,Anna University*	*Dr.U. Mohammed Iqbal , SRMIST*

Course Code	18MEE326T	Course Name	WELDING TECHNOLOGY	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 :	*Be familiar with the welding power sources and welding fundamentals*
CLR-2 :	*Be familiar with the fusion welding processes*
CLR-3 :	*Be familiar with the solid-state welding processes*
CLR-4 :	*attain the knowledge about welding metallurgy*
CLR-5 :	*attain the knowledge about brazing and soldering technology*
CLR-6 :	*Understand the concept of weldability, weld quality, welding defects and welding inspection*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLO-1 :	*Understand the fundamentals of welding processes and to recognize the importance of arc physics , weld protection*	*1 & 2*	*90*	*85*
CLO-2 :	*Understand the fusion welding processes and to recognize the various types of fusion techniques and be able to apply those techniques for any work*	*1, 2 &3*	*90*	*85*
CLO-3 :	*Understand the solid-state welding processes and to recognize the various types of solid-state techniques and be able to apply those techniques for any work*	*1, 2 &3*	*90*	*85*
CLO-4 :	*Obtained the knowledge about welding metallurgy and be able to apply the principle of metallurgy to recognize weld joint microstructure*	*1, 2 &3*	*90*	*85*
CLO-5 :	*Understand the concept of brazing and soldering techniques and able to apply the concept to critical welding aspects*	*1 & 2*	*90*	*85*
CLO-6 :	*Understand the concept of weldability, weld quality, and welding defects, acquire the knowledge of welding inspection and testing and be able to apply the concept to identify any weld defects*	*1, 2 &3*	*90*	*85*

Program Learning Outcomes (PLO)														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
H	*M*	*L*	*M*	-	-	*M*	*M*	-	-	-	-	*H*	*L*	*M*
H	*M*	*M*	*H*	*M*	-	*H*	*M*	-	-	-	-	*H*	*M*	*H*
H	*M*	*M*	*H*	*M*	-	*H*	*M*	-	-	-	-	*H*	*H*	*H*
H	*H*	-	*H*	-	-	*H*	*M*	-	-	-	-	*H*	*M*	*M*
H	*L*	*L*	*L*	-	-	*M*	*M*	-	-	-	-	*H*	*L*	*M*
H	*H*	*M*	*H*	*L*	-	*M*	*M*	-	-	-	-	*H*	*M*	*H*

		Welding Fundamentals & Basic Fusion Welding Processes	Advanced Fusion Welding Processes	Solid-State Welding Processes	Welding Metallurgy	Weld Quality & Inspection
Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Manufacturing and Joining, Welding, Need for welding, Applications, Advantages and Disadvantages*	*Fundamentals of gas metal arc welding, process variables, effect of filler metals on weld*	*Fundamental aspects of solid state processes, common process variables, bonding mechanism*	*Basic solidification concepts, solidification modes and constitutional supercooling, dendrite and cell spacing*	*Design of weldments, Concept of weldability*
S-2	SLO-1	*Fundamental Mechanisms of welding, Classifications of welding process*	*Fundamentals of gas tungsten arc welding, process variables, flux*	*Fundamentals of forge welding, characteristics, application*	*Epitaxial and nonepitaxial growth, effect of welding parameters, weld metal nucleation mechanisms*	*Weldability of ferrous and nonferrous alloys, Weldability test method*
S-3	SLO-1	*Heat Input and Power density of different welding processes, Cooling rate effect*	*Pulsed TIG Welding process, process variables*	*Fundamentals of roll bonding, characteristics, application*	*Dissimilar welds: issues and solutions*	*Fundamental concepts of residual stress and distortion,*
S-4	SLO-1	*Weld protection, Shielding gas, Flux, Types of flux coatings*	*Cold metal transfer welding process , Process Variables*	*Fundamentals of ultrasonic welding, characteristics, application*	*Weld Thermal Cycle*	*Welding defects, classification and characteristics*

S-5	SLO-1	*Principle of Fusion welding process, Gas welding process, Types of flames in gas welding process*	*Fundamentals of flux cored arc welding, process variables, electrode classification*	*Fundamentals of friction welding, characteristics, application*	*Heat affected zone thermal cycle*	*Solidification crack, Hydrogen induced crack*
S-6	SLO-1	*Shielded Metal arc welding process, welding variables, electrode classification, Physics of welding arc, polarity*	*Fundamentals of submerged arc welding, process variables, flux*	*Fundamentals of friction stir welding, process variables, application*	*Post weld heat treatment of weldments: Need and selection of PWHT parameters*	*Destructive testing of welded joints, tensile and hardness*
S-7	SLO-1	*Volt - Ampere Characteristics: Constant current, constant voltage and alternating current*	*Fundamentals of plasma arc welding, process variables, Hybrid Plasma TIG process.*	*Friction stir welding tools, effect of tool geometry*	*Formation of heat affected zone, recrystallization and grain growth*	*Destructive testing of welded joints, toughness, fatigue and creep*
S-8	SLO-1	*Arc characteristics: Arc plasma, effect of temperature, Arc distribution, Arc blow*	*Fundamentals of resistance welding, process variables, types*	*Fundamentals of explosive welding, characteristics, application*	*Fundamental concepts of brazing, characteristics, applications*	*Concept of non-destructive testing, classification*
S-9	SLO-1	*Fundamentals of weld bead geometry, Types of welded joints, Welding positions and welding processes*	*Fundamentals of laser beam welding, process variables, Hybrid laser welding process*	*Fundamentals of diffusion bonding process, process variables, applications*	*Fundamental concepts of soldering, characteristics, applications*	*Concept of Radiography, dye penetration and Ultrasonic test*

Learning Resources	1. *John C. Lippold, Welding Metallurgy and Weldability, John Wiley & Sons, Inc., publication, 2015.* 2. *A.C. Davies, The science and practice of welding, Vol. 1 and 2, Tenth Edition, Cambridge University Press, 2010.* 3. *Welding Handbook – 9th Edition, Volume 1 to volume 5, American Welding Society, 2007.* 4. *Sindo Kou, Welding Metallurgy, 2nd edition, John Wiley & Sons, Inc., publication, 2003.*	5. *Robert W. Messler, Jr., Principles of Welding-Processes, Physics, Chemistry, and Metallurgy, John Wiley & Sons, Inc., publication, 1999.* 6. *R S Parmar, Welding Engineering and Technology, Khanna Publisher, 2008* 7. *O. P. Khanna, Welding Technology, Dhanpat Rai Publications; 2013 edition (2011)* 8. *Richard L. Little, Welding and Welding Technology, McGraw Hill Education (1 July 2017)*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
Dr. B. Arivazhagan *Scientific Officer- E,Materials Technology Division, Metallurgy and Materials Group, IGCAR, Kalpakkam 603 102*	*Dr. P. Sathiya, Professor, Department of Production Engineering, NIT Trichy*	*Dr. Madhavan S, SRMIST*
Dr. Manidipto Mukherjee, Sr. Scientist *Advanced Manufacturing Centre, Design and Manufacturing Research Group, CSIR-Central Mechanical Engineering Research Institute, , Mahatma Gandhi Rd., City Centre, Durgapur 713209, West Bengal, India*	*Dr.S.Aravindan, Professor, Department of Mechanical Engineering, IIT Delhi*	*Dr. Shashi Kumar, SRMIST*

Course Code	18MEE327T	Course Name	MECHANICAL HANDLING SYSTEMS AND EQUIPMENT	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		*PSG Tech "Design Data Book" Kalaikathir Achchagam Coimbatore*	

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1 :	*Be familiar with Fundamentals of material handling and intraplant transporting facilities*
CLR-2 :	*Be familiar with Common material handling systems*
CLR-3 :	*Be familiar with automated feeding mechanism and design*
CLR-4 :	*Be familiar with Unit Built Machines (UBM), Automated systems in transfer lines*
CLR-5 :	*Be familiar with Transfer mechanisms, conveyors, part feeding devices*
CLR-6 :	*Be familiar with material handling equipments,and their automated systems*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)															
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Understand about Fundamentals of material handling and intraplant transporting facilities*	1	90	85	H	M	L	L	L							M	H	H	M
CLO-2 :	*Acquire knowledge on Common material handling systems*	1&2	90	85	H	M	M	M	H							M	H	L	M
CLO-3 :	*Acquire knowledge on automated feeding mechanism and design*	1&2	90	85	H	L	M	M	H							M	H	L	M
CLO-4 :	*Understand the Automated systems in transfer lines*	1&2	90	85	H	L	M	M	H							M	H	H	M
CLO-5 :	*Understand Transfer mechanisms, conveyors, part feeding devices*	1	90	85	H	L	M	M	H							M	H	L	H
CLO-6 :	*Understand material handling equipments, and their automated systems*	1&2&3	90	85	H	L	M	M	H							M	H	H	H

		Introduction	Common Material Handling Equipment	Automation of Material Handling	Classification of Automated System	Automated Material Handling Equipment
Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Introduction to work handling concepts - types of intraplant transporting facility*	*Concepts of Unit Loads, Material handling and Storage*	*Automated feeding arrangements for discrete parts*	*Concepts of Unit Built Machines (UBM)*	*Automated handling and storage systems in manufacturing environment*
S-2	SLO-1	*Principles of material handling-manual and mechanical handling*	*Equipments operation and selection*	*Design based in work piece requirements, orienting methods*	*Gain lean and green endorsement, collaboration to achieve lean and green goals*	*Rail Guided Vehicles (rgvs), Automated Guided Vehicles (agvs)*
S-3	SLO-1	*Principle groups of material handling*	*Containers, Pallets, Conveyor systems, Industrial trucks, Wagon tipplers*	*One by one feeding, agonizing, stapling etc*	*Classification and elements, Power Units, self-contained and separate feed type, Change over UBM*	*Applications of rgvs and agvs, Automated Storage and Retrieval Systems (AS / RS)*
S-4	SLO-1	*Choice of material handling equipment, hoisting equipment*	*Transporters, stackers, reclaimers*	*Feeding continuous material liquids, granules etc*	*Transfer lines – classification and their components*	*AS / RS in the Automated factory*
S-5	SLO-1	*Surface and overhead equipment-General characteristics of overhead equipments and their application*	*Silos & hoppers and their accessories, Ropeways, Ship loaders, Cable cranes*	*Automated assembly system, elements,*	*Automated systems for handling and transfer of prismatic, axis symmetric parts and asymmetric parts in transfer lines*	*Considerations for planning an AS /RS system, Applications of AS / RS*
S-6	SLO-1	*Introduction to control of hoisting equipments*	*Container handling systems, Electric lifts*	*Automated assembly system ,configuration design, details and control*	*Case studies on transfer lines – interlocked*	*Principles of work holding devices – Modular fixturing*
S-7	SLO-1	*Storage – open and closed storage systems*	*Hoists, EOT cranes, Elevators*	*Special feeding mechanisms*	*Case studies on palletized and flexible inter linkage transfer lines*	*Flexible fixturing systems*
S-8	SLO-1	*Bulk loading, Unloading, Shipping*	*Material handling equipments in Steel*	*Automated inspection and their design*	*Control systems for flexible inter linkage*	*Fixturing for FMS*

			mills, Power plants, Mines, Automobile and Transport Industries		*transfer lines*	
S-9	SLO-1	*Receiving systems and operations-First in first out(FIFO),last in first out(LIFO)*	*Large scale Constructions etc. Case Study for All Above Mentioned Handling systems.*	*Case study for automated material handling.*	*SWARF handling and disposal systems*	*Robots and their applications in handling and storage*

Learning Resources	1. *Groover. M. P., "Automation, Production Systems and CIM", Prentice hall India, 2007.* 2. *Morris A. Cohen, Uday M. Apte., "Manufacturing Automation", Irwin, Chicago,* 3. *James A. Tompkins., "Facilities planning", John wiley& Sons Inc, 1984.*	4. *James. M. Apple, "Principles of layout and material handling", Ronald press, 1977* 5. *N.Rudenko" Materials Handling equipment" Envee publisher,New Delhi*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate Create	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. R. Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in, rkpearls@yahoo.com	*1. Dr. P. Hariharan, Anna University, hari@annauniv.edu, hariharan2311@gmail.com*	*1. Mr. C. Balasuthagar, SRMIST*
2. Dr. A. Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*2. Dr.N.Arunachalam, IIT Madras, chalam@iitm.ac.in*	*Dr. M. Iqbal, SRMIST*

Course Code	18MEE328T	Course Name	NON-TRADITIONAL MACHINING TECHNIQUES	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:*	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	*Be familiar with the concept of Non-traditional machining techniques and their need and advantages over traditional machining techniques*			
CLR-2 :	*Be familiar with the classification of Non-traditional machining techniques*			
CLR-3 :	*Be familiar with the Mechanical energy based Non-traditional machining techniques*			
CLR-4 :	*Be familiar with the Electro-chemical energy based Non-traditional machining techniques*			
CLR-5 :	*Be familiar with the Thermal energy based Non-traditional machining techniques*			
CLR-6 :	*Be familiar with the latest developments in various Non-traditional machining techniques*			

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Differentiate between Traditional and Non-traditional machining techniques.*	*1, 2*	*90*	*85*	*H*	-	-	-	-	-	*M*	-	-	-	-	-	-	-	*M*
CLO-2 :	*Acquire knowledge on basic components and working principles of different Non-traditional machining techniques.*	*1*	*90*	*85*	*H*	-	-	-	-	-	-	-	-	-	-	-	*H*	-	-
CLO-3 :	*Understand the major process parameters like operating voltage, current, time on, time off etc.*	*1*	*90*	*85*	*H*	-	-	-	*M*	-	-	-	-	-	-	-	*H*	-	-
CLO-4 :	*Evaluate the effect of various process parameters on machining characteristics like surface roughness, surface integrity, etc.*	*1, 2, 3*	*90*	*85*	*H*	-	-	-	*L*	-	-	-	-	-	-	-	*H*	-	-
CLO-5 :	*Learn the processes of machining hard to cut and high strength materials and alloys.*	*1, 2*	*90*	*85*	*H*	-	-	-	*L*	-	*M*	-	-	-	-	-	*H*	-	-
CLO-6 :	*Understand the recent developments and applications in Non-traditional machining techniques.*	*1, 3*	*90*	*85*	*H*	-	-	-	-	-	-	-	-	-	-	-	*H*	-	*M*

		Basics of Non-Traditional Machining and Mechanical Energy Techniques-I	Mechanical Energy Techniques-II	Chemical and Electro Chemical Techniques	Thermo Electrical Energy Techniques	Thermal Energy Techniques
Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Introduction of non-traditional machining*	*Operating principles and equipment of water jet machining*	*Fundamentals, operating principle, advantages, limitations, applications of chemical machining process.*	*Operating principles and equipment of electrical discharge machining*	*Operating principle and equipment of electron beam machining*
	SLO-2	*Difference between traditional and non-traditional machining*	*Process parameters, applications, advantages and limitations of water jet machining*	*Classification and selection of Etchant and maskant*	*Subsystems of electrical discharge machining*	*Generation and control of electron beam*
S-2	SLO-1	*Need for non-traditional machining*	*Operating principles and equipment of abrasive water jet machining*	*Operating principles, equipment and subsystems of electrochemical machining*	*Power circuits and electrode feed mechanism in electrical discharge machining*	*Parameters influencing metal removal in electron beam machining*
	SLO-2	*Machining characteristics and classification of non-traditional machining*	*Mechanism of metal removal in abrasive water jet machining*	*Material removal rate and tool design in electrochemical machining*	*Process parameters, selection of tool electrode in electrical discharge machining*	*applications, advantages and limitations of electron beam machining*
S-3	SLO-1	*Consideration in process and material selection.*	*Parameters influencing metal removal rate*	*Tool Material, Tool Feed System, Design For Electrolyte Flow*	*Dielectric fluids and flushing methods in electrical discharge machining*	*Operating principle and equipment of plasma arc machining*

	SLO-2	*Applications of non-traditional machining*	*Applications, advantages and limitations of abrasive water jet machining*	*Process parameters in electrochemical machining*	*Characteristics of spark eroded surface*	*Gas mixture, Types of Torches of plasma arc machining*
S-4	SLO-1	*Operating principle, elements and equipment of Ultrasonic machining*	*Operating principle and equipment of abrasive flow machining*	*Problems for estimation of material removal rate in electrochemical machining*	*Recast layer formation*	*Parameters influencing metal removal in plasma arc welding*
	SLO-2	*Tool feed Mechanism*	*Mechanism of metal removal in abrasive flow machining*	*Advantages, limitations, applications and recent development of electrochemical machining*	*Surface finish and machining accuracy in electrical discharge machining*	*Applications, advantages and limitations of plasma arc machining*
S-5	SLO-1	*Cook's model for material removal*	*Process parameters in abrasive flow machining*	*Operating principle and equipment of electro chemical grinding*	*Tool Electrode design, Tool wear characteristics of spark eroded surfaces*	*Operating principle and equipment of laser beam machining*
	SLO-2	*Problems in estimation of Material removal rate (MRR) for Ultrasonic machining*	*Classification of abrasive flow machining, Applications, advantages and limitations of abrasive flow machining*	*Metal removal rate and process parameters in electro chemical grinding*	*Problems in estimation of material removal rate in electrical discharge machining*	*Process Characteristics and Thermal Features of laser beam machining*
S-6	SLO-1	*Process parameters of Ultrasonic machining*	*Operating Principle of magnetic abrasive machining*	*Problems for estimation of metal removal rate in electro chemical grinding*	*Operating principle of wire cut electrical discharge machining*	*Types of lasers used in laser beam machining*
	SLO-2	*Applications, Advantages and limitations of Ultrasonic machining*	*Elements and equipment of magnetic abrasive machining*	*Process Characteristics of electro chemical grinding*	*Equipment of wire cut electrical discharge machining*	*Parameters influencing metal removal, applications, advantages and limitations of laser beam machining*
S-7	SLO-1	*Operating Principle of Abrasive jet machining*	*Mechanism of metal removal in magnetic abrasive machining*	*Benefits, limitations and applications of electro chemical grinding*	*Process parameters of wire cut electrical discharge machining*	*Operating principle and equipment of Ion beam machining*
	SLO-2	*Elements and equipment of Abrasive jet machining*	*Process parameters of magnetic abrasive machining*	*Recent developments in electro chemical grinding process*	*Advantages, limitations and applications of wire cut electrical discharge machining*	*Process Characteristics of Ion beam machining*
S-8	SLO-1	*Mechanism of metal removal in Abrasive jet machining*	*Applications, advantages and limitations of magnetic abrasive machining*	*Electrochemical Drilling*	*Operating principles and equipment in electrical discharge grinding*	*Material removal rate, Accuracy and surface effects in Ion beam machining*
	SLO-2	*Process parameters of Abrasive jet machining*	*Process capabilities of magnetic abrasive machining*	*Electro Stream (Capillary) and Electrochemical jet drilling.*	*Process parameters, surface finish and machining accuracy in electrical discharge grinding*	*Parameters influencing metal removal rate*
S-9	SLO-1	*Process capabilities of Abrasive jet machining*	*Operating Principle of Ice jet machining*	*Fundamentals of electro chemical honing*	*Machine tool selection*	*Applications, advantages and limitations of Ion beam machining*
	SLO-2	*Applications, Advantages and limitations of Abrasive jet machining*	*Process description of Ice jet machining*	*Fundamentals of deburring process*	*Application and recent developments in electrical discharge grinding*	*Recent developments and trends in Thermal energy based non-traditional machining techniques*

Learning Resources	1. *P. C. Pandey and H.S. Shan, "Modern Machining Processes", McGraw Hill, 2017.* 2. *Vijay K. Jain, "Advanced Machining Processes". Allied Publishers, 2007.* 3. *P K Mishra, "Nonconventional Machining", Narosa Publishing House, 2007.* 4. *G. F. Benedict, "Non-Traditional Manufacturing Processes", CRC Press, New York, 1987.* 5. *Sahu R.K. and Somashekhar S.H, "Corona Discharge Micromachining for the Synthesis of Nanoparticles: Characterization and Applications", CRC Press, Taylor & Francis, New York, 2019.*	6. *Amithaba Bhattacharya, 'New Technology', Tata McGraw Hill, 2006.* 7. *Hassan El-Hofy, 'Advanced Machining Processes', McGraw Hill, 2005.* 8. *Wellar P C, 'Non-Traditional Machining Processes', SME Michigan, 1984.* 9. *Carl Sommer, 'Non Traditional Machining Handbook', Advanced Pub, 2000.*

Learning Assessment											
	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr.K.Balasubramanian, AGM, Lucas TVS Ltd., Puducherry	*1. Dr.V.Satheesh Kumar, Assistant Professor, Production Engg., NIT Trichy*	*1. Mr.V.Veeranaath, SRMIST*
2. Mr.Durga PrasadPadhy, Manager, Vendata Resources Ltd., Jharsuguda, Orissa		*2. Dr.Ranjeet Kumar Sahu, SRMIST*

Course Code	18MEE329T	Course Name	MODERN MANUFACTURING TECHNIQUES	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 :	*Be familiar with the modern casting methods*
CLR-2 :	*Know the modern methods of manufacturing from powders*
CLR-3 :	*Be familiar with the micro-electronic manufacturing*
CLR-4 :	*Acquire knowledge about polymers and composites manufacturing*
CLR-5 :	*Learn the methods of rapid prototyping and additive manufacturing*
CLR-6 :	*Be acquainted with manufacturing approaches of modern intricate products*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLO-1 :	*Acquire knowledge of modern and non-conventional casting methods for manufacturing complex intricate shapes of metals*	*1 & 2*	*90*	*85*
CLO-2 :	*Understand the manufacturing methods using powders of metals and ceramics*	*1 & 2*	*90*	*85*
CLO-3 :	*Get acquaintance with manufacturing methods of semiconductors and microelectronic devices*	*1, 2,3*	*90*	*85*
CLO-4 :	*Obtain knowledge of polymers and composites manufacturing methods*	*1 & 2*	*90*	*85*
CLO-5 :	*Understand the purpose and methods of rapid prototyping and additive manufacturing*	*1 & 2*	*90*	*85*
CLO-6 :	*Identify suitable methods for various product manufacturing*	*1, 2 ,3*	*90*	*85*

Program Learning Outcomes (PLO)														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
H				*L*		*M*						*H*		*H*
H				*M*		*M*						*H*		*H*
H				*H*		*L*						*H*		*M*
H						*L*						*H*		*H*
H				*H*								*H*		*M*
H				*H*		*L*						*H*		*M*

		Modern Casting Methods	Modern Forming Methods	Manufacturing Of Semiconductors And Electronic Deivices	Manufacturing Of Composite Materials	Rapid Proptotyping And Additive Manufacturing
Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Introduction to conventional and modern casting methods*	*High speed metal forming- Explosive, Electromagnetic and electrohydraulic*	*Semiconductors and silicon-Introduction, Structure of silicon, Properties*	*Selection of composite matrices and reinforcements*	*Rapid prototyping - Introduction, Steps in RP Technology, STL Format, Support Structures*
S-2	SLO-1	*Expendable pattern casting - Pattern making process, Advantages, Applications*	*Semisolid metal forming Types (Thixocasting, Rheocasting, Thixomolding) Advantages, Applications*	*Crystal growing and wafer preparation*	*Overview of polymer matrix composites, Types of reinforcements, Preforms, Prepegs*	*Rapid prototyping- Advantages, Limitations, Applications*
S-3	SLO-1	*Plaster mold casting – Conventional and Antioch Process, Advantages, Applications*	*Peen forming of sheet metals - Process, Advantages, Applications*	*Film deposition -Evaporation, Sputtering, CVD*	*Open mould processes - Hand lay-up, Spray-up, Vacuum Bagging, Automated tape -laying machines*	*Introduction to Additive Manufacturing for product development – Advantages, Materials*
S-4	SLO-1	*Ceramic mold casting - Process, Advantages, Applications*	*Super plastic forming - Material requirements, Advantages, Disadvantages*	*Oxidation - Dry oxidation, Wet oxidation*	*Closed mould processes - Compression moulding, Transfer moulding, Injection moulding*	*Stereo lithography*
S-5	SLO-1	*Vacuum casting - Process, Advantages, Applications*	*Design consideration for Powder Metallurgy forming*	*Lithography - Photolithography process*	*Filament winding, Pultrusion, Pulforming, Cutting of FRP*	*Laminated object manufacturing*

S-6	SLO-1	*Squeeze casting - Process, Advantages, Applications*	*Production of metal powders Atomization, Reduction, Electrolytic Deposition, Carbonyls, Comminution, Mechanical Alloying*	*Etching - Wet chemical etching, Dry plasma etching, Cryogenic dry etching*	*Fabrication of metal matrix composites- Liquid state and Solid state*	*Selective laser sintering*
S-7	SLO-1	*Rapid solidification for amorphous alloys, Melt Spinning Process*	*Sintering, Finishing of sintered parts, Secondary and finishing operations*	*Diffusion, Drive-in Diffusion and Ion implantation*	*Deposition technique for MMC, Insitu composites*	*Fused deposition modeling*
S-8	SLO-1	*Casting techniques for single crystal components*	*Ceramic forming -casting, powder*	*Metallization - Requirement, Methods and testing*	*Conventional manufacturing of ceramic composites, Prepeg formation-slurry impregnation*	*Solid ground curing, 3D ink jet printing*
S-9	SLO-1	*Conventional casting of Turbine blades, Directional solidified blades, Single crystal blades*	*Forming and shaping glass-Flat Sheet, Rods and Tubes, Discrete Products, Glass Fiber*	*Bonding and packaging, MEMS, NEMS*	*Porous preform infiltration- Melt, Sol-gel, Polymer, Reactive liquid, Chemical vapour, Directed oxidation*	*Additive manufacturing-Applications*

Learning Resources	1. *Serope Kalpakjian, "Manufacturing Engineering and Technology", Fourth Edition, Addison-Wesley Publishing Co., Boston, 2014.* 2. *Mikell P. Groover, "Principles of Modern Manufacturing SI Version", Wiley India, 2018.* 3. *Parasuraman Swaminathan, "Semiconductor Materials, Devices and Fabrication", Wiley India, 2017.* 4. *Madou.M.J, "Fundamentals of micro fabrication: The Science of Miniaturization, Second Edition", CRC Press, USA, 2002.*	5. *C. S. Lim, K. F. Leong, C. K. Chua, "Rapid Prototyping: Principles and Applications" (3rd Edition), World Scientific Publishing Company, 2009.* 6. *P. D. Hilton, P.F. Jacobs, "Rapid Tooling: Technologies and Industrial Applications", ist Ed., Marcel Dekker, Inc., 2010.* 7. *Steinar Westhrin Killi, "Additive Manufacturing: Design, Methods, and Processes", Pan Stanford Pub., 2017.* 8. *T. DebRoy et al., Review Article – "Additive manufacturing of metallic components – Process, structure and properties", Progress in Materials Science, Volume 92 (2018), 112-224.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate Create	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
Dr. Saurabh Kundu *Head Product Research* *Tata Steel Jamshedpur* *Email: saurabhkundu@tatasteel.com*	*Dr. Debdulal Das, Associate Professor* *Dept of Metallurgy and Materials Engineering* *Indian Institute of Engineering Science and Technology, Shibpur* *Howrah, Email: debdulal_das@metal.iiests.ac.in*	*1. Dr.Shubhabrata Datta*
Dr. A. Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*2. Dr.N.Arunachalam, IIT Madras, chalam@iitm.ac.in*	*Dr. M. Iqbal, SRMIST*

Course Code	18MEE330T	Course Name	FLEXIBLE MANUFACTURING SYSTEMS	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*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 basic types of production systems*
CLR-2 :	*understand the group technology, methods and FMS*
CLR-3 :	*Be familiar with the fundamentals and need of FMS planning*
CLR-4 :	*Detailed study of flexible manufacturing cells and systems*
CLR-5 :	*Be familiar with the FMS software*
CLR-6 :	*Familiar with production systems, grouping of parts and FMS, FMC and different software's, hard ware components involving.*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLO-1 :	*Understand and acquire knowledge on Basics types of production systems, inventory and scheduling*	*1*	*90*	*85*
CLO-2 :	*Understand the group technology, types of coding systems and FMS*	*1,2*	*90*	*85*
CLO-3 :	*Understand the basic fundamentals and analysis methods for FMS planning*	*1,2*	*90*	*85*
CLO-4 :	*Understand the Flexible manufacturing cells and Communication networks for different systems*	*1,2*	*90*	*85*
CLO-5 :	*Acquire knowledge on FMS software's*	*1,2*	*90*	*85*
CLO-6 :	*Understand about production systems, group technology coding and FMS, FMC systems*	*1,2*	*90*	*85*

Program Learning Outcomes (PLO)														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
H	*H*	-	-	-	-	-	-	-	-	-	-	*L*	-	*H*
H	*H*	*H*	-	-	-	-	-	-	-	-	-	*M*	*L*	*H*
H	*M*	-	-	-	-	-	-	-	-	-	-	*M*	-	*M*
H	*M*	-	-	-	-	-	-	-	-	-	-	*M*	-	*M*
H	*M*	-	-	-	-	-	-	-	-	-	-	*M*	-	*M*
H	*H*	*H*	-	-	-	-	-	-	-	-	-	*M*	*L*	*M*

		Production systems	Group technology and FMS	Flexible Planning	Flexible Manufacturing Cells	FMS Software
Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Types of production systems job, batch and mass production system with examples*	*Introduction to GT, Formation of part families*	*Physical planning for FMS, Objective, guide line*	*Introduction of cell description and its classifications*	*Introduction to Different FMS software's and advantages*
S-2	SLO-1	*Different manufacturing functions, Manufacturing support*	*Part classification methods and different coding systems with examples*	*Need for flexibility and FMS in industries*	*Definition of unattended machining, Requirement and features.*	*General structure and Requirements for FMS software*
S-3	SLO-1	*Organization and information processing in manufacturing.*	*Production flow analysis methods, Machine cell design, Clustering algorithm.*	*User supplier responsibilities in planning, user – supplier role in site preparation.*	*Component handling and storage systems*	*Functional descriptions and operational overview*
S-4	SLO-1	*Different types of plant layouts and advantages of each layout.*	*Bond Energy algorithm method with example*	*Machine tool selection and layout of FMS.*	*Difference between Cellular system and FMS system*	*FMS installation*
S-5	SLO-1	*Plant location selection methods with examples*	*Scheduling and control in cellular manufacturing*	*Computer control system and different Data files, Reports and planning the FMS system.*	*FMC hardware configuration and controllers*	*Acceptance testing, Performance goals*
S-6	SLO-1	*Work in progress inventory models*	*System planning guide lines and sizing and human resources.*	*Human resources for FMS, Objective, staffing, supervisor role.*	*PLC and computer controllers, Different FMC Communication networks*	*FMS application in machining, sheet metal fabrication*
S-7	SLO-1	*Scheduling and its types and advantages*	*Industrial case study for total parts moving to machine cell and machine cell formation, Manufacturing cell*	*Quantitative Analysis methods for FMS, Simple problems for FMS System analysis.*	*A case study for modular control design method for a flexible manufacturing cell.*	*Prismatic component production*

S-8	SLO-1	*Simple problems in selection of plant location.*	*Introduction to FMS, components of FMS.*	*Benefits and limitations for FMS system*	*Lean manufacturing with example*	*FMS development towards factories of the future*
S-9	SLO-1	*Design the different layouts like automobile plant and supermarket and hospitals and airport…etc*	*FMS need and types FMS systems.*	*Simple example of FMS planning for Automobile plant.*	*Agile manufacturing and example case study*	*Example case study for FMS*

Learning Resources	1. *William W. Luggen, "Flexible manufacturing Cells and systems", Prentice hall of New Jersey 1991.* 2. *Mikell P. Groover, "Automation Production systems and Computer Integrated manufacturing", prentice hall of India, New Delhi, 2007.*	*3. Jha N.K, " Hand book of Flexible Manufacturing systems", Academic Press, 1991.* *4. David J. Parrish, "Flexible Manufacturing", Butterworth-Heinemann, Newton, MA, USA, 1990.*

Learning Assessment											
	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr.Mariappan Kanagaraj (Manager - Part Quality Engineering (STA) at Renault Nissan Technology & Business Centre India Pvt Ltd, Chennai Area, India	*1. Dr. B. K .Ragunath, Associate Professor, Dept. of Manufacturing Engineering, Annamalai University*	*1. Mr. Abburi Lakshman Kumar, AP Mech, SRMIST, Kattankulathur*
2. Dr. A. Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*2. Dr.G. Elatharasan, Asst.Professor, Dept. of Mechanical Engg., Anna University, Pattukottai.*	*Dr. M. Iqbal, SRMIST*

Course Code	18MEE421T	Course Name	SUSTAINABLE GREEN MANUFACTURING	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:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CLR-1 :	*Be familiar with objectives, concepts and role of Green Manufacturing*	Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLR-2 :	*Be familiar with the tools of Green Manufacturing*																		
CLR-3 :	*Be familiar with the attribute's decision-making methods*																		
CLR-4 :	*Be familiar with creating Lean and Green organization*																		
CLR-5 :	*Be familiar with the Design resources saving into product and processes*																		
CLR-6 :	*Be familiar with the concepts, tools, attributes, design resources of green manufacturing*																		
Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*																		
CLO-1 :	*Understand Green Manufacturing and Sustainable engineering concepts*		*90*	*85*	*M*	*M*	*M*	*L*	*H*	*H*	*M*	*L*					*H*	*H*	*M*
CLO-2 :	*Develop Multi attributes decision making methods*		*90*	*85*	*M*	*M*	*M*	*L*	*H*	*H*	*M*	*L*					*H*	*H*	*M*
CLO-3 :	*Develop Green manufacturing management*		*90*	*85*	*M*	*M*	*M*	*L*	*H*	*H*	*M*	*L*					*H*	*H*	*M*
CLO-4 :	*Develop Applications in green manufacturing*		*90*	*85*	*M*	*M*	*M*	*L*	*H*	*H*	*M*	*L*					*H*	*H*	*M*
CLO-5 :	*Develop design resources saving into product and process*				*M*	*M*	*M*	*L*	*H*	*H*	*M*	*L*					*H*	*H*	*M*
CLO-6 :	*Understand about the green manufacturing concepts, management, applications and design development.*				*M*	*M*	*M*	*L*	*H*	*H*	*M*	*L*					*H*	*H*	*M*

Duration (hour)		8	9	9	9	10
S-1	SLO-1	*Definition of manufacturing, Impact of manufacturing in environmental ecology*	*Principles of green manufacturing and its efficiency*	*Introduction to Multi attributes decision making methods*	*Question wasteful practices*	*Design resources saving into product and processes*
S-2	SLO-1	*Role of manufacturing sector in national growth*	*Green manufacturing and sustainability*	*definition, structure for Multi attributes decision making methods*	*Gain lean and green endorsement, collaboration to achieve lean and green goals*	*Closed loop & Open Loop production system*
S-3	SLO-1	*Technological change and evolving risk*	*System model architecture and module*	*variants and analysis of different methods like Simple Additive Method (SAM)*	*Track progress for environment and profits*	*Green manufacturing through clean energy supply*
S-4	SLO-1	*concepts of "green" manufacturing need of green manufacturing*	*Design and planning, control or tools for green manufacturing (Qualitative Analysis)*	*Weighted Product Method (WPM)*	*Creation of sustainable growth*	*Various case studies of implementation of semiconductors manufacturing at industries*
S-5	SLO-1	*Green manufacturing strategies*	*Consumption Analysis, Life Cycle Analysis, Efficiency, Sustainability tools).*	*Analytic Hierarchy Process (AHP)*	*Enabling techniques for assuring green manufacturing*	*Green packaging and supply chain*
S-6	SLO-1	*Green manufacturing – motivation, barriers, regulation, policy*	*Standards for green manufacturing (ISO 14000 and OHSAS 18000)*	*Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Grey Relation Analysis (GRA)*	*Drivers of green manufacturing, impact, advantages and disadvantages of drivers*	*Various case studies of implementation of Optimizing Logistics solution at industries*
S-7	SLO-1	*Casting defects and remedies.*	*Waste stream mapping and application*	*Elimination and Choice Expressing Reality (ELECTRE)*	*Green architecture and buildings, Sustainable manufacturing resources management*	*Environmental implication of Nano manufacturing*
S-8	SLO-1	*Advantages and limitations of green*	*Identify and apply the concepts of product*	*VIKOR method*	*Carbon footprint analysis and*	*Various case studies of implementation of*

		manufacturing	*and process design with environmental forethought*		*management of manufacturing processes*	*lean manufacturing at industries*
S-9	SLO-1	*Significance of green manufacturing*	*Design for environment and for sustainability – Discuss the Product Life Cycle of manufactured goods.*	*Problems based on different MADMs. 1 C 3 3,4*	*Green Process Economics, Resource Recovery and Reuse*	*Various case studies of implementation of Optimizing process or product at industries*

Learning Resources	1. *Ronald G. Askin& Jeffrey B. Goldberg, "Design and Analysis of Lean Production Systems", John Wiley & Sons, 2003.* 2. *Rao.P.N, "Manufacturing Technology, Vol I and II", Tata McGraw Hill Publishing Co., 3rd edition, Sixth Reprint 2010* 3. *Charles Wankel "21st century management: a reference handbook" SAGE Publications, Inc., 2008.* 4. *Christian N. Madu "Handbook of environmentally conscious manufacturing" London : Kluwer Academic Publishers, 2001.*	5. *T.E. Graedel& B.R. Allenby "Industrial Ecology" Pearson Education, Inc. 2003.* 6. *Joseph Sarkis "Greener manufacturing and operations: from design to delivery and back" Greenleaf Pub., 2001.* 7. *Ranky, P.G.: "An Introduction to Alternative Energy Sources: An interactive multimedia 3D eBook publication by CIMware USA, Inc. and CIMware Ltd., UK, ISBN 1-872631- 97-5, 2008.* 8. *Ranky, P.G.: "Digital Product Design: Design For Quality, Manufacturing, Assembly & Disassembly Principles, and an Inkjet Printer Disassembly Use Case", DVD video publication by CIMware USA, Inc. and CIMware Ltd., UK, 2008, UPC 632568002983*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate Create	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. R. Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in, rkpearls@yahoo.com	*1.Dr. U. Natarajan, ACGCET-Karaikudi, u.natarajan@accetedu.in*	*E.Muthu, AP(OG), SRMIST*
2. Dr. A. Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*2.Dr. D. Dinakaran, HITS Padur, dinakaran.d@hindustanuniv.ac.in*	*Dr.P. Nandakumar, SRMIST*

Course Code	18MEE422T	Course Name	ADDITIVE MANUFACTURING TECHNOLOGY	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:*	Learning		
		1	2	3
CLR-1 :	*Be familiar with the evolution of Additive manufacturing (Why it is disruptive in nature based on evolution) and the materials and design involved*	Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-2 :	*Be familiar with the various process steps involved in Additive manufacturing (Generic process flow for AM systems)*			
CLR-3 :	*Learn the various types of machines and systems involved in Additive manufacturing*			
CLR-4 :	*Know the working of powder based Additive manufacturing processes and their applications and limitations*			
CLR-5 :	*Know the working of solid and liquid based Additive manufacturing processes and their applications and limitations (Understanding the feedstock material in various AM process)*			
CLR-6 :	*Be familiar with components of Additive manufacturing and its applications in industries (Understanding the requirement of process certification for various industrial applications) – Fabrication and repair applications*			

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Program Learning Outcomes (PLO)														
					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
					Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Understand the basic concepts of Additive manufacturing (Why they are classed as disruptive technology(ies)*	*1&2*	*90*	*85*	*H*														
CLO-2 :	*The knowledge acquired on the process chain of Additive manufacturing and the various steps involved (Opportunities of implementation in India, global relevance of AM in supply chain – The concepts of Remanufacturing)*	*1&2*	*90*	*85*	*H*		*M*		*H*							*M*	*H*	*H*	
CLO-3 :	*Recognize the various machines and systems involved in Additive manufacturing and understand their role (in industrial application – fabrication or repair of component)*	*1*	*90*	*85*	*H*	*M*	*M*	*H*	*H*							*M*	*H*	*H*	
CLO-4 :	*Understand the major solid and liquid based Additive manufacturing processes such as stereolithography and fused deposition modeling and recognize their application and potential*	*1&2*	*90*	*85*	*H*	*M*	*M*	*H*	*H*							*M*	*H*	*H*	
CLO-5 :	*Understand the major powder based Additive manufacturing processes such as 3D printing (Directed Energy deposition, powder bed fusion)and electron beam melting, Binder jetting and recognize their application and potential in fabrication and repair for various industrial application*	*1&2*	*90*	*85*	*H*	*M*	*M*	*H*	*H*							*M*	*H*	*H*	
CLO-6 :	*Recognize the importance of Additive manufacturing and its various processes and systems – Industry specific (such as Aerospace, power generation, heavy machinery, Automotive)*	*1&2*	*90*	*85*	*H*														

		Introduction To Additive Manufacturing	Process Chain Of Additive Manufacturing	Machines And Systems Of Additive Manufacturing	Solid And Liquid Based Additive Manufacturing	Powder Based Additive Manufacturing
Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Evolution of Additive manufacturing, Need, Comparison with CNC machining (Concepts of Hybrid manufacturing & applications)*	*Conceptualisation, Synergistic interaction of processes (AM + CNC/Adaptive)*	*Introduction to various machines and systems of Additive manufacturing (based on feedstock material, based on energy used, application)*	*Classification (scale of printing)*	*Classification (scale of printing)*
S-2	SLO-1	*Basic principles of additive manufacturing (Complex interaction of process, design and materials)*	*CAD model preparation, CAM operations (Tool path generation)*	*Construction of CNC machines, Process chamber (Subtractive process conversion to AM process)*	*Guidelines for process selection*	*Powder fusion mechanisms: solid-state sintering, Chemically induced sintering*
S-3	SLO-1	*Classification of Additive manufacturing*	*Part orientation and support generation*	*Energy Delivery: Lasers and electron beam,*	*Fused deposition modeling - Processes and*	*Selective laser sintering: process,*

		processes		*plasma arc, kinetic energy (cold spray in AM)*	*principle*	*principles*
S-4	SLO-1	*Materials for Additive manufacturing (selection of feedstock materials)*	*Conversion to Stereolithographic file format*	*Material delivery: Powder feeding and wire feeding systems (difference in powder and wire feedstock – adantages and limitations for both), handling of feedstock material*	*Advantages, applications*	*Advantages, applications*
S-5	SLO-1	*Designing for Additive manufacturing (Design optimization)*	*Transfer to Additive manufacturing machine and file manipulation*	*Rapid tooling equipment: direct and indirect methods*	*Laminated object manufacturing*	*3D printing: process, principles*
S-6	SLO-1	*Role of Additive manufacturing in product development (Complex geometry requirements, strength to weight requirements)*	*Machine setup and build, Health & Safety practice (best practice), Feedstock material handling*	*Post processing equipment: support material removal , preparation for use as a pattern*	*Stereolithography apparatus: processes and principle*	*Advantages, applications*
S-7	SLO-1	*Advantages, Disadvantages, Applications and Opportunities of Additive manufacturing (Opportunities in Indian industries, global prospective)*	*Removal and clean up, Health & Safety practice (best practice),*	*Temperature, humidity, oxygen level controllers (process monitoring, affect on mechanical and microstructural properties with these variables)*	*Advantages, applications*	*Laser engineered net shaping (LENS process, unique advantages on hybrid scale), process control advantages, limitations,*
S-8	SLO-1	*Emerging trends and business models (Concepts of Remanufacturing)*	*Post processing (insitu or external transformative post processing such as heat treatments), machining*	*Scanning: Raster scan, patterned vector scanning*	*Challenges in solid and liquid AM processes*	*Electron beam melting*
S-9	SLO-1	*Related technologies: Reverse engineering, Computer aided engineering, AM process simulation concepts, preditive modelling*	*Property enhancement by thermal and non-thermal methods (In relation to type of material)*	*Post processing: surface texture, accuracy and aesthetic improvement*	*Case study (with relevance to technology certification)*	*Case study (with relevance to technology certification)*

Learning Resources	1. *Ian Gibson, David W Rosen, Brent Stucker., "Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing", Springer, 2015.* 2. *Chua C.K., Leong K.F., and Lim C.S., "Rapid prototyping: Principles and applications", Third Edition, World Scientific Publishers, 2010.* 3. *Gebhardt A., "Rapid prototyping", Hanser Gardener Publications, 2003.* 4. *Liou L.W. and Liou F.W., "Rapid Prototyping and Engineering applications: A tool box for prototype development", CRC Press, 2007.* 5. *Kamrani A.K. and Nasr E.A., "Rapid Prototyping: Theory and practice", Springer, 2006.*	6. *Hilton P.D. and Jacobs P.F., "Rapid Tooling: Technologies and Industrial Applications", CRC press, 2000.* 7. *Pham D.T, Dimov S.S, "Rapid Manufacturing: The Technologies and Applications of Rapid Prototyping and Rapid Tooling", Springer 2001.* 8. *Gu D, "Laser Additive Manufacturing of High-Performance Materials", Springer, 2014.* 9. *Rafiq Noorani, "Rapid prototyping: Principles and Applications in Manufacturing" John Wiley & Sons, 2006.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember / Understand	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply / Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate / Create	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
Mr.Purushothaman, Tesscorn Nano Science Inc.	*1. Dr. P. Hariharan, Anna University, hari@annauniv.edu, hariharan2311@gmail.com*	*Dr. P. Mohan Babu, SRMIST*
Dr. A. Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*2. Dr.N.Arunachalam, IIT Madras, chalam@iitm.ac.in*	*Dr. M. Iqbal, SRMIST*

Course Code	18MEE423T	Course Name	PRECISION ENGINEERING	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 concept of accuracy and precision in various parametric testing*
CLR-2 :	*Realize the striving need for precision and applications*
CLR-3 :	*Know the causes for dimensional and geometrical characteristics errors prior and during machining*
CLR-4 :	*Impart knowledge about basics of precision and ultra precision machining methods*
CLR-5 :	*Be familiar with different precision measuring systems at micro/nano level*
CLR-6 :	*Be familiar with the various lithography techniques*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLO-1 :	*Acquire knowledge about the basics of accuracy and alignment tests*	*1&3*	*80*	*85*
CLO-2 :	*Identify the dimensional and geometrical errors prior and during machining*	*1&2*	*70*	*85*
CLO-3 :	*Deepen the knowledge of static stiffness and thermal effects*	*1, 2&3*	*75*	*85*
CLO-4 :	*Understand the principles of precision machining and importance of digitization in micro-machining*	*1,2&3*	*85*	*85*
CLO-5 :	*Understand the principles of nano measuring systems*	*1&2*	*80*	*85*
CLO-6 :	*Understand the principles of various lithographic techniques and currently emerging microscopic techniques*	*1&2*	*80*	*85*

Program Learning Outcomes (PLO)														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
H				*M*		*M*					*H*	*M*		*H*
H	*L*			*M*								*M*		*M*
H	*L*		*M*	*M*								*H*	*M*	
H	*H*	*L*	*M*	*M*		*M*		*L*			*H*	*H*		*H*
M			*M*	*H*		*L*		*M*			*M*			*M*
M	*H*	*L*	*M*	*M*		*M*		*L*			*H*	*H*		*H*

Duration (hour)		9	9	9	9	9
S-1	SLO-1	*General concept of accuracy, repeatability and precision; Spindle rotation accuracy*	*Static stiffness*	*Introduction to precision Engineering and need for having high precision*	*Introduction to nanotechnology and need for measurement in nanotechnology*	*Nano Lithography*
S-2	SLO-1	*Test methods for displacement accuracy*	*Nature of deformation in a machine tool*	*Precision machining and finishing operations*	*Measuring Systems for Nano-manufacturing*	*Photolithography*
S-3	SLO-1	*Dimensional wear of cutting tools*	*Overall stiffness of a lathe*	*Ultra-precision Processes*	*In - process measurement of position of processing point*	*Electron beam lithography*
S-4	SLO-1	*Accuracy of NC systems, Clamping errors, Setting errors*	*Compliance of work piece*	*Tool Materials for Precision Machining: Carbides, Ceramic, Diamond, Cubic Boron Nitride*	*Post process and online measurement of dimensional features*	*Ion Beam lithography*
S-5	SLO-1	*Location of rectangular prism, cylinder*	*Errors due to the variation of the cutting force and total compliance*	*Ultra-Precision Machine Elements*	*Mechanical measuring systems*	*Optical lithography*
S-6	SLO-1	*Basic type of tests, Measuring instruments used for testing machine tools*	*Case study: Errors caused by cutting force deformation in turning and milling*	*Machining of micro-sized components*	*Optical measuring systems*	*LIGA process*
S-7	SLO-1	*Alignment, Straightness, Flatness tests*	*Study of thermal effects on machine tool accuracy*	*Positioning mechanisms and drives – precision gears, servo control systems, electromagnetic and piezo actuators*	*Electron beam measuring systems*	*Nanocoatings*
S-8	SLO-1	*Parallelism, Squareness tests*	*Methods of decreasing thermal effects*	*Micro- electro-Mechanical Systems: Characteristics and Principles, Materials, and Fabrication processes*	*X-ray imaging systems*	*Micro-metrology*

S-9	SLO-1	*Circularity, Cylindricity tests*	*Influence of vibration and noise on accuracy*	*Emergence of digital precision machining*	*Pattern recognition and inspection systems*	*Microscopy techniques for materials characterization: Electron microbe analysis and atom probe tomography*

Learning Resources	*1. Murthy.R.L, "Precision Engineering in Manufacturing", New Age International, New Delhi, 2005.* *2. V.C.Venktesh, Precision Engineering, Tata Mc.Graw Hill, New Delhi 2007* *3. Kalpakjian S., Manufacturing Engineering and Technology. 3rd Ed. Addision-Wesley Publishing Co.,New York, 2001.* *4. Norio Taniguchi, "Nanotechnology", Oxford university press, Cambridge, 1996.*	*5. Lee Tong Hong, "Precision Motion control, Design and Implementation", Springer Verlag, U.K., 2001.* *6. Liangchi Zhang, "Precision Machining of Advanced Materials", Trans Tech Publications Ltd., Switzerland, 2001.* *7. HiromuNakazawa, "Principles of precision engineering", Oxford University Press, 1994.* *8. Sahu R.K. and Somashekhar S.H, "Corona Discharge Micromachining for the Synthesis of Nanoparticles: Characterization and Applications", CRC Press, Taylor & Francis, New York, 2019.*

* Combination of surprise, quiz and assignment tests.

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate Create	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
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Dr. A. Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*2. Dr.N.Arunachalam, IIT Madras, chalam@iitm.ac.in*	*Dr. M. Iqbal, SRMIST*

Course Code	18MEE424T	Course Name	TECHNOLOGY OF SURFACE COATING	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 fundamentals of surface engineering*
CLR-2 :	*Understand the practical application and importance of coatings*
CLR-3 :	*Understand the different methods of coatings in micro and nano level*
CLR-4 :	*Understand the measurement techniques of different properties of coating*
CLR-5 :	*Understand the maintenance procedures and trouble shooting*
CLR-6 :	*Understand the special surface coating techniques*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Be familiar with the concepts of surface engineering of various types of coatings.*	*1&2*	*90*	*75*	*H*												*H*	*L*	*M*
CLO-2 :	*Be familiar with the concepts of surface science of various types of coatings*	*1 & 2*	*90*	*75*	*H*												*H*	*L*	*M*
CLO-3 :	*Be familiar with the concepts of surface characterization methods for various types of coatings*	*1 & 2*	*90*	*75*	*H*		*M*	*H*									*L*	*H*	*M*
CLO-4 :	*Be familiar on the principles and working of special coating methods*	*1 & 2*	*90*	*75*	*H*	*H*	*M*		*M*		*L*						*M*	*L*	*H*
CLO-5 :	*Be familiar on the application of suitable methods of coatings on the surface*	*3*	*90*	*75*	*H*	*H*	*H*	*M*	*H*	*M*	*M*						*H*	*H*	*H*
CLO-6 :	*solve various unwanted problems raised on material surface because of degradation by using suitable methods and measurement*	*2 & 3*	*90*	*75*	*H*	*H*	*H*	*M*	*H*	*M*	*M*						*M*	*H*	*H*

		Fundamental Of Surface Engineering	Special Surface Coating And Surface Modification Techniques I	Special Surface Coating And Surface Modification Techniques II	Surface Characterization Techniques Of Coatings	Applications Of Surface Coatings
Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Introduction: Engineering components,*	*Introduction to Electro Chemical Deposition - Electro Plating*	*Surface Coating by Wetting, Mechanism of Wetting*	*Measurement of coatings thickness*	*Cold Spraying and Hard Facing*
S-2	SLO-1	*Surface dependent properties and failures,*	*Anodizing and Electro-Less Plating*	*Coating on Ceramics by Wetting,*	*porosity & adhesion of surface coatings*	*Case studies based on coatings of important engineering components II*
S-3	SLO-1	*Importance and scope of surface engineering*	*Thermal Spray Coating-Combustion Spray and Plasma Spray Process*	*Coating of Monolayer Abrasive grain by Wetting*	*Measurement of residual stress & stability*	*Case studies based on surface modification of important engineering components I*
S-4	SLO-1	*Surface and surface energy: Structure and types of interfaces, surface energy and related equations.*	*Sputter deposition of thin films & coatings – DC & RF*	*DLC and diamond coatings,*	*Spectrum of secondary electrons, Scanning Electron Microscopy*	*Case studies based on surface modification of important engineering components II*
S-5	SLO-1	*Surface engineering: classification, definition, scope and general principles*	*Sputter deposition of thin films & coatings – Magnetron & Ion Beam*	*Antifriction and anti-scratch coatings*	*Electron energy analyzers*	*Functional and nano-structured coatings*
S-6	SLO-1	*Surface engineering by material removal: Cleaning, pickling, etching, grinding, polishing*	*Hybrid / Modified PVD coating processes*	*Sol Gel Coating,*	*Auger Electron spectroscopy, Transmission Electron Microscopy*	*Functional and nano-structured coatings applications in photovoltaic*
S-7	SLO-1	*Buffing / puffing (techniques employed, its principle). Role and estimate of surface*	*CVD Coating of TiC, Nitride, Chromium, Aluminum Oxide and Diamond*	*Laser Assisted Surface Engineering*	*Surface microscopy & topography by scanning probe microscopy*	*Functional and nano-structured coatings applications in bio- and chemical sensors*

		roughness.				
S-8	SLO-1	*Surface engineering by material addition (principle and its application with examples).*	*Plasma and ion beam assisted surface modification*	*Micro Arc Oxidation,*	*Electron Energy Loss Spectroscopy*	*Surface engineering of polymers*
S-9	SLO-1	*Surface modification of steel, non-ferrous and ferrous components: (principle and scope of application).*	*Surface modification by Ion implantation and Ion beam mixing*	*Electro Spark Coating*	*Photoelectron Spectroscopy*	*Surface engineering of composites*

Learning Resources	1. *K.G. Budinski, Surface Engineering for Wear Resistances, Prentice Hall, Englewood Cliffs, 1988.* 2. *M. Ohring, The Materials Science of Thin Films, Academic Press Inc, 2005* 3. *D. Satas, Arthur A. Tracton, "Coatings technology handbook", Marcel Dekker, 2000* 4. *K. Oura, V. G. Lifshits, A. A. Saranin, A. V. Zotov and M. Katayama, "Surface Science – An Introduction" Springer, 2009.*	5. *B G Miller, "Surface coatings for protection against wear", Wood head Publishing, 1st Edition, 2006* 6. *Riviere.J.C and Myhra.S, "Handbook of Surface and Interface analysis", CRC Press, 2009.* 7. *Hari Singh Nalwa, "Nanostructured Materials and Nanotechnology", Academic Press, 2002.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
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2. Dr. Prasanta Kumar Padhi, Deputy General Manager, SAIL Raurkela, Odisha – 769011 prasantakumar.padhi@sailrsp.co.in	*2. Dr. T V K Gupta, VNIT Nagpur, tvkgupta@mec.vnit.ac.in*	*Dr. T V V L N Rao, SRMIST narasimharao.t@ktr.srmuniv.ac.in*

Course Code	18MEE425T	Course Name	SUPPLY CHAIN MANAGEMENT	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 role of logistics*
CLR-2 :	*Understand the phases of supply chain*
CLR-3 :	*Understand the evolution of supply chain models*
CLR-4 :	*Understand the supply chain activities*
CLR-5 :	*Understand the SCM organization and information system*
CLR-6 :	*Understand the role, phases, evolution, activities and SCM information system*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Familiar in Logistics and its role of operations.*	*1 2&3*	*90*	*85*	*H*		*L*			*M*	*M*		*L*						
CLO-2 :	*Familiar in Supply chain and its different phases.*	*1 2&3*	*90*	*85*	*H*		*L*			*M*	*L*		*L*						
CLO-3 :	*Familiar in evolution of supply chain models and solution for engineering problem*	*1 2&3*	*90*	*85*	*H*		*L*			*M*	*L*		*L*						
CLO-4 :	*Familiar with the activities of supply chain*	*1 2&3*	*90*	*85*	*H*		*L*			*M*	*L*		*L*						
CLO-5 :	*Familiar in Understanding different SCM organization and different ERP systems*	*1 2&3*	*90*	*85*	*H*		*L*			*M*			*M*						
CLO-6 :	*Familiar in logistics operations, SCM phases, SCM models, SCM activities, SCM organization and different ERP systems*	*1 2&3*	*90*	*85*	*H*		*L*			*M*			*M*						

		Introduction to Logistics	Phases of Supply Chain	Evolution of Supply Chain Models	Supply Chain Activities	Scm Organisation and Information System
Duration (hour)		09	09	09	09	09
S-1	SLO-1	*Introduction of Logistics and its concepts*	*The new paradigm shift*	*Strategy of supply chain*	*Introduction of Structuring the supply chain*	*The management task*
S-2	SLO-1	*Logistics definitions*	*The modular company*	*structure of supply chain*	*Supply chain challenge – five tasks for management*	*Types of Logistics organization*
S-3	SLO-1	*Different Logistics approaches*	*Introduction to strategic core, network structures, management networks and vertical integration*	*Factors of supply chain*	*Supply Chain as activity systems*	*The logistics in information systems*
S-4	SLO-1	*Factors influencing logistics*	*The network relations in supply chain*	*Manufacturing strategy stages*	*New products of supply chain*	*Topology of Supply chain application*
S-5	SLO-1	*Basic tasks of supply chain*	*Supplier relationship, partnerships and alliances, cooperation and integration, Governance, boundary management, global networks*	*Supply chain progress*	*Foundation for supply chain change*	*Product Data Management*
S-6	SLO-1	*Defection of supply chain*	*Supply processes in supply chain*	*Introduction of Model for competing through supply chain management*	*Functional roles in supply chain change*	*Warehouse management system MRP- I,*
S-7	SLO-1	*Approaches of supply chain*	*Process flow, product design, product issues, product structure, logistics issue*	*PLC grid in supply chain management*	*Frame work Design for supply chain*	*Warehouse management system MRP- 2*
S-8	SLO-1	*Influencing supply chain*	*Procurement processes in supply chain*	*Redesigning of supply chain*	*Institutionalizing supply chain changes*	*ERP case study*
S-9	SLO-1	*A new corporate model.*	*Distribution management in supply chain*	*linking supply chain with customer*	*Collaborative product commerce*	*ERP software's*

Learning Resources	*1. Shari, P. B. and Lassen, T. S., Managing the global supply chain, Viva books, New Delhi, 2000.* *2. Ayers, J. B., Hand book of supply chain management, The St. Lencie press, 2000. 1.*	*3. Nicolas, J. N., Competitive manufacturing management – continuous improvement, Lean production, customer focused quality, McGrawHill, New York, 1998.* *4. Steudel, H. J. and Desruelle, P., Manufacturing in the nineteen – How to become a mean, lean and world class competitor, Van No strand Reinhold, New York, 1992.*

Learning Assessment											
	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
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2. Dr. A. Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*2.Mr.A.Prabukarthi A, PSG College of Technology Coimbatore-641004*	*Dr. M. Iqbal, SRMIST*

Course Code	18MEE426T	Course Name	COMPOSITE MATERIALS AND MECHANICS	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1 :	*Understand the overview, constituents, classifications, and advanced applications of composites*
CLR-2 :	*Understand the mechanics and performance of composite materials*
CLR-3 :	*Understand the manufacturing techniques and inspection of various composite materials*
CLR-4 :	*Learn to test and understand the failure, and analysis methods of laminated composites and their constituents and analyze the characteristics of laminated composites*
CLR-5 :	*Learn design aspects and acquiring knowledge on material selection for advanced engineering composite materials.*
CLR-6 :	*Understand the applications, performance, inspection of composites*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)													
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Familiar with the Overview, constituents, classifications, and advanced applications of composites and composites mechanics*	*1& 2*	*90*	*85*	*H*				*M*										
CLO-2 :	*Familiar the mechanics and performance of composite materials*	*1& 2*	*90*	*85*	*H*	*H*													
CLO-3 :	*Familiar with the manufacturing techniques and inspection of various composite materials*	*1& 2*	*90*	*85*	*H*		*M*	*L*											
CLO-4 :	*Familiar with the testing and understand the failure, and analysis methods of laminated composites and their constituents and analyze the characteristics of laminated composites*	*1& 2*	*90*	*85*		*M*	*H*		*M*										
CLO-5 :	*Familiar with the Design and select the material for advanced engineering composite materials.*	*1& 2*	*90*	*85*	*H*		*H*	*M*	*M*										
CLO-6 :	*Familiar with overview, performance, applications and inspection of composites*	*1&2*	*90*	*85*	*H*		*H*	*M*	*L*										

		Overview of Composites	Mechanics and Performance	Manufacturing	Testing and Analysis	Design and Material selection
Duration (hour)		9	9	9	9	9
S-1	SLO-1 & 2	*Introduction to composites - Definitions Classification of composite materials*	*Introduction to solid mechanics - lamina and laminates*	*Overview of composite manufacturing processes*	*Fiber test, Neat resin matrix test Tensile, compressive test In-plane shear, Interlaminar shear tests Flexural, Interlaminar fracture, Fiber/Matrix interface tests*	*Failure predictions in a Unidirectional Lamina*
S-2	SLO-1 & 2	*Polymer matrix Ceramic matrix,*	*Mechanics terminology Interlaminar stresses*	*Overview of glass fibre production*	*Analysis of an orthographic lamina*	*Failure predictions for Unnotched Laminates*
S-3	SLO-1 & 2	*Metal matrix; Special composites - Functionally graded materials*	*Unidirectional and angle lamina and laminates*	*Carbon fiber production*	*Analysis of an orthographic laminates*	*Laminated Design Consideration*
S-4	SLO-1 & 2	*Characteristics of composite materials Mechanical behavior of composite materials*	*Engineering constants of an angle lamina and laminates*	*Spray-up, Hand lay-up*	*Hooke's law, stiffness and compliance matrices*	*Bonded joints; Bolted joints; Bonded-Bolted joints*
S-5	SLO-1 & 2	*Structural Materials Constituent materials for composite materials*	*Static Mechanical Properties Hooke's law for different types of materials*	*Filament winding Fiber placement*	*Strengths of orthographic lamina*	*Design requirements and design failure criteria*
S-6	SLO-1 & 2	*Matrix materials – types and properties Reinforced materials– types and properties*	*Effective modulus in stress-strain*	*Closed-mould processes, Bag Moulding*	*Stress analysis of laminated composite beams*	*Design load definitions Design analysis philosophy for composite structures*

S-7	SLO-1 & 2	*Fibers for advanced composites Current and potential advantages of fiber-reinforced composite materials*	*Symmetry in stress-strain*	*Compression moulding, Pultrusion, and Other manufacturing processes*	*Stress analysis of laminated composite Plates*	*Laminate optimization Design examples*
S-8	SLO-1 & 2	*Applications of composite materials - Military aircraft, Civil aircraft*	*Fatigue and Impact properties and Environmental effects*	*Quality Inspection method*	*Stress analysis of laminated composite Shells*	*Materials selection criteria Different material section factors*
S-9	SLO-1 & 2	*- Automotive applications, Commercial applications,*	*Fracture Behavior and Damage Tolerance*	*Composite defects, detection and possible solution*	*Free vibration*	*- Fiber selection factor - Matrix selection factor - Importance of constituents*

Learning Resources	1. *P.K. Mallick, FIBRE REINFORCED COMPOSITES: MATERIALS, MANUFACTURING AND DESIGN, Marcel Dekker, 1993.* 2. *J.C. Halpin, PRIMER ON COMPOSITE MATERIALS, ANALYSIS, Techomic Publishing Co., 1984.* 3. *B.D. Agarwal, and L.J. Broutman, ANALYSIS AND PERFORMANCE OF FIBRE COMPOSITES, John Wiley and Sons, New York, 1990.* 4. *P.K. Malick and S. Newman, (eds), COMPOSITE MATERIALS TECHNOLOGY: PROCESSES AND PROPERTIES, Hansen Publisher, Munich, 1990.* 5. *R.P.L. Nijssen, COMPOSITE MATERIALS AN INTRODUCTION, A VKCN publication, 1st Edition, 2015.* 6. *Robert M. Jones, MECHANICS OF COMPOSITE MATERIALS, 2nd Edition, Taylor & Francis, 1999.* 7. *Ronald F. Gibson, PRINCIPLE OF COMPOSITES MATERIAL MECHANICS, McGraw Hill, 1994.*	8. *Autar K. Kaw, MECHANICS OF COMPOSITE MATERIALS, 2nd Edition, Taylor & Francis, 2006.* 9. *Valery V. Vasiliev and Evgeny V. Morozov, ADVANCED MECHANICS OF COMPOSITE MATERIALS AND STRUCTURAL ELEMENTS, 3rd Edition, Elsevier, 2013.* 10. *Madhujit Mukhopadhyay, Mechanics of Composite Materials and Structures, University Press, 2018.* 11. *Reddy J. N., Mechanics of Laminated Composites Plates and Shells, CRC Press, 2016.* 12. *Bhagwan D. Agarwal, Analysis and Performance of Fiber, Wiley India, 2015.* 13. *Balasubramaniam, Composite Materials, John Wiley & Sons, Indian Ed., 2013.* 14. *K.K. Chawla, Composite Materials, Springer, 2012.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
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Dr. A. Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*2. Dr.N.Arunachalam, IIT Madras, chalam@iitm.ac.in*	*2 Dr. Sumit PRAMANIK* *Research Associate Professor, ME, SRM Institute of Science and Technology, Kattankulathur, H/P: +91-8777740422* *Email: sumitpramanik.s@ktr.srmuniv.ac.in*

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Course Code	18MEE427T	Course Name	GLOBAL OPTIMIZATION ALGORITHMS	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 :	*Be familiar with evolutionary algorithm*
CLR-2 :	*Be familiar with particle genetic algorithm*
CLR-3 :	*Be familiar with modern optimization techniques*
CLR-4 :	*Be familiar with search algorithms*
CLR-5 :	*Be able to apply the knowledge of optimization in mechanical engineering applications*
CLR-6 :	*Be familiar with evolutionary algorithm, genetic algorithm, modern optimization techniques, search algorithms and optimization applications*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Recall the concepts of optimality criteria for various types of optimization problems.*	*1*	*90*	*85*	*H*				*M*				*H*	*H*	*M*		*H*	*H*	*M*
CLO-2 :	*Understand the problems*	*2*	*90*	*85*	*H*	*H*		*H*	*M*	*M*			*M*	*H*	*H*		*H*	*H*	*M*
CLO-3 :	*Apply the methods of optimization to solve real life problems*	*3*	*90*	*85*	*H*	*H*	*H*	*H*	*H*	*M*		*M*	*M*	*M*	*M*		*H*	*H*	*M*
CLO-4 :	*Analyze the methodology followed and test the results*	*4*	*90*	*85*	*H*	*H*	*H*		*H*		*M*				*M*		*H*	*H*	*M*
CLO-5 :	*Investigate the results to obtain the optimized solution*	*5*	*90*	*85*	*H*	*H*			*H*	*M*							*H*	*H*	*M*
CLO-6 :	*Investigate with evolutionary algorithm, genetic algorithm, modern optimization techniques, search algorithms and optimization applications*	*1-5*	*90*	*85*	*H*	*H*	*H*	*H*	*H*	*M*		*M*	*M*	*M*	*M*		*H*	*H*	*M*

		Global optimization technique	Modern optimization techniques Part I	Modern optimization techniques Part Ii	Search Methods	Applications of optimization techniques
Duration (hour)		9	9	9	9	9
S-1	*SLO-1*	*Introduction to Optimization Algorithms*	*Introduction to Particle Swam Optimization (PSO)*	*Introduction to Simulated Annealing algorithm (SAA)*	*Linear search and binary search*	*Desirable and undesirable effects, functional requirements such as geometry and materials.*
S-2	*SLO-1*	*The Structure of Optimization - Formulae and Search Space/Operator Design*	*Theoretical derivatives in particle swarm optimization, Variants of PSO*	*Asymtotic convergence and typical behavior of SAA,Multi objective SA*	*Jump search,interpolation search*	*Stochastic optimization*
S-3	*SLO-1*	*Evolutionary algorithms, ranking selection, VEGA, Convergence prevention*	*Performance Enhancing techniques in PSO, Applications of PSO*	*External optimization, Tabu Search,Memetic and Hybrid algorithms*	*Exponential search, Fibonacci search*	*Integrating simulation in optimization models*
S-4	*SLO-1*	*Optimization problems in engineering, Inverse problems; Scheduling and Routing*	*Introduction to Ant colony optimization(ACO), Framework of ACO*	*Downhill simplex , Applications of SAA*	*Golden selection, Random, pattern and gradient search methods*	*Multi-Disciplinary Optimization in enhancing the features of an automobile.*
S-5	*SLO-1*	*Data Mining, Intelligent System designing, Introduction to Genetic Algorithm, Operators of GA"s, Differences and similarities between genetic algorithms and traditional techniques*	*Hill Climbing, Multi-Objective Hill Climbing*	*Introduction to Differential Evolution (DE)*	*State Space Search, Uninformed Search*	*Optimization for modular design.*

S-6	*SLO-1*	*Introduction to utilization of computer programs in GA, Schema Algorithm, Advanced operators and techniques in genetic search*	*Problems in Hill Climbing, Hill Climbing with Random Restarts*	*Structure of Differential algorithm (DA)*	*Breadth-First Search, Depth-First Search*	*Optimization of design parameters to design a mechanical component.*
S-7	*SLO-1*	*Genetic algorithm and machine learning, Introduction to multi objective optimization, Types of multi objective problems and principles*	*GRASP, Raindrop Method, Random Optimization*	*Computing environments in DE*	*Depth-limited Search, Iterative Deepening Depth*	*Optimization of process parameters in machining operations.*
S-8	SLO-1	*Pareto optimality, Non-Elitist multi objective algorithms, Elitist multi objective algorithms*	*Monte Carlo methods*	*Applications of DA*	*Informed Search - Greedy Search- A* search - Adaptive Walks, Tree search,*	*Optimization in minimizing cost and enhancing strength mechanical elements*
S-9	SLO-1	*Constrained multi objective algorithm, Usage of multi objective optimization in various optimization techniques*	*Multi disciplinary optimization methods and their applications in engineering.*	*Optimization with parameter uncertainities – Robust Optimisation, formulation, algorithms, applications*	*Interpolation methods: quadratic and cubic, direct root method.*	*Optimization problems on scheduling.*

Learning Resources	1. *Kalyanmoy Deb, "Optimization for Engineering design-Algorithms and Examples", Prentice Hall, India, 2012.* 2. *Kalyanmoy Deb, "Multi objective optimization using Evolutionary algorithms", John Wiley, 2001.* 3. *Joshua Knowles, David Corne, Kalyanmoy Deb "Multiobjective Problem Solving from Nature: From Concepts to Applications",Springer- 2008.*	4. *Thomas Weise, "Global Optimization Algorithms – Theory and Application", Thomas Weise, 2009.* 5. *S.S Rao, "Optimization – Theory and Applications", Wiley Eastern, New Delhi, 2009* 6. *Parsopoulos K and Vrahatis M.N, " Particle Swarm Optimization and Intelligence:Advances and Applications", IGI Global, 2010.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
Dr. Chiradeep Ghosh, Principal Scientist, TATA Steel. Chiradeep.ghosh@tatasteel.com	*1. Dr. P. Hariharan, Anna University, hari@annauniv.edu, hariharan2311@gmail.com*	*Shubrajit Bhaumik, SRMIST*
Dr. A. Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*2. Dr.N.Arunachalam, IIT Madras, chalam@iitm.ac.in*	*Dr. Shubhabrata Datta,SRMIST*

Course Code	18MEE428T	Course Name	SIMULATION OF MECHANICAL SYSTEMS	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*NIL*	Co-requisite Courses	*NIL*	Progressive Courses	*NIL*
Course Offering Department	*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 function of physical system*
CLR-2 :	*Be familiar with the models use in need for simulation*
CLR-3 :	*understand about different methods of simulation*
CLR-4 :	*Be familiar with translational simulation*
CLR-5 :	*Be familiar with rotational mechanical systems*
CLR-6 :	*Be familiar with simulation of hydraulic and manufacturing system*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)													
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Recognize and analyze the use of different methods of simulation*	*1&2*	*90*	*85*	*H*	*M*	*M*	*M*	*L*					*L*		*L*	*H*		*L*
CLO-2 :	*Acquire knowledge on basic components and working of various mechanical systems*	*1*	*90*	*85*	*H*	*M*	*H*	*M*	*L*		*L*						*H*		*L*
CLO-3 :	*Recognize the application of Random variables and their properties, estimation of means, variance and correlation*	*1*	*90*	*85*	*H*	*H*	*M*	*M*	*M*								*M*		
CLO-4 :	*Understand the Static and dynamic modeling*	*1&2*	*90*	*85*	*H*	*M*	*M*	*M*									*H*		
CLO-5 :	*Recognize the Numerical computation techniques based upon the application*	*1&2*	*90*	*85*	*H*	*M*	*M*	*H*	*H*								*H*		
CLO-6 :	*Simulation of rotational systems and translational system as well as the hydraulic system*	*1*	*90*	*85*	*H*	*M*	*L*	*L*	*M*					*L*			*H*		*M*

		Introduction	Types and principles ofmodeling	Methods of simulation	simulation of translational and Rotational systems	Simulation of hydraulic systems and manufacturing system
Duration (hour)		09	09	09	09	09
S-1	SLO-1	*Need for modeling and simulation in mechanical systems*	*Static modeling with examples*	*Monte Carlo simulation*	*Building of simulation models in mechanical systems*	*Simulation of hydraulic systems*
S-2	SLO-1	*Basics of modeling of physical systems*	*dynamic modeling with examples*	*Experimental nature of simulation*	*Simulation of translational systems*	*hydraulic systems with real time examples*
S-3	SLO-1	*methods of modeling*	*Stochastic models with examples*	*Numerical computation techniques*	*Case studies – Translatory motion for Serial Manipulator*	*Simulation of material handling systems in manufacturing*
S-4	SLO-1	*Review of basic probability and statistics*	*Principles of modeling*	*Analog system models*	*Simulation of rotational systems*	*Case studies –Automated guided vehicle (AGV) in Goods Transportation*
						Simulation in flexible manufacturing
S-5	SLO-1	*Random variables and their properties, estimation of means, variance and correlation*	*Study and evaluation of model*	*hybrid system models*	*real time examples*	*Case studies- vice casting product*
S-6	SLO-1					
S-7	SLO-1	*Concept of system and environment, continues and discrete systems*	*Continues system models*	*Continues system models*	*Transform Function Analysis. Developing a Linear Model*	*Simulation of waiting line system*
S-8	SLO-1	*Linear systems*	*Introduction to simulation, basic simulation, advantages of simulation*	*Role of computers in simulation*	*Case studies – Rotary Joint Link for SCARA ROBOT*	*waiting line system in manufacturing with examples*
S-9	SLO-1	*nonlinear systems*	*Role of simulation in model evaluation*	*introduction to simulation software*	*Techniques for variance reduction*	

			with examples	*packages*		

Learning Resources	1. *Dym C.L, "Principles of Mathematical Modeling", Elsevier, 2nd Edition 2004.* 2. *Geoffrey Gordon, "System Simulation" Phi Learning, 2nd Edition 2002* 3. *M. Close and Dean K. Frederick, "Modeling and Analysis of Dynamic Systems", Houghton Mifflin, 3rd Edition, 2002* 4. *Guy L, Richard M. Feldman, "Manufacturing Systems Modeling and Analysis", Springer, 2011.*	5. *Performance Modeling of Automated Manufacturing Systems (Prentice Hall Information and System Sciences Series) 1st Edition Edition, 1992* 6. *J. Schwarzenbach and K.F. Gill, "System Modeling and Control".Halsted Press, New York, 1992* 7. *Robert E. Shannon, "System Simulation: The Art and Science", Prentice Hall, 1975* 8. *Automation, Production Systems, and Computer-Integrated Manufacturing 4 Edition (English, Paperback, Mikell P. Groover), 2016*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate Create	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,
SLO – Session Learning Outcome

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. S.Bhargav, GM,Rane Brake, Trichy	*1. Dr. V.Srinivasan,Annamalai University, srinivraghavan@yahoo.com*	*1. Dr. M. Prakash, SRMIST*
2. Dr. Muthumanikkam, Jt. Director, CVRDE, DRDO, Avadi, Chennai.	*2. Dr.Ashok Kumar, Govn. Col.of. Eng, Bargur, Krishnagiri, Tamil Nadu Akrt02au@gmail.com*	*2. Dr.A.Arul Jeya Kumar, SRMIST*

Course Code	18MEE429T	Course Name	INDUSTRY 4.0	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 Architectural Overview of Internet of Things*
CLR-2 :	*Be familiar with the concepts of big data analytics*
CLR-3 :	*Learn the basics of cloud computing*
CLR-4 :	*Be familiar with method and new frameworks of information security management.*
CLR-5 :	*understand the fundamentals concepts of digital manufacturing*
CLR-6 :	*Understand the concepts of Internet of things, big data analysis, cloud computing, cyber security and digital manufacturing*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)													
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Recognize and analyze the use of different methods of simulation*	*1&2*	*90*	*85*	*H*	*M*	*M*	*M*	*L*					*L*		*L*	*H*		*L*
CLO-2 :	*Acquire knowledge on basic components and working of various mechanical systems*	*1*	*90*	*85*	*H*	*M*	*H*	*M*	*L*		*L*						*H*		*L*
CLO-3 :	*Recognize the application of Random variables and their properties, estimation of means, variance and correlation*	*1*	*90*	*85*	*H*	*H*	*M*	*M*	*M*								*M*		
CLO-4 :	*Understand the Static and dynamic modeling*	*1&2*	*90*	*85*	*H*	*M*	*M*	*M*									*H*		
CLO-5 :	*Recognize the Numerical computation techniques based upon the application*	*1&2*	*90*	*85*	*H*	*M*	*M*	*H*	*H*								*H*		
CLO-6 :	*Simulation of rotational systems and translational system as well as the hydraulic system*	*1*	*90*	*85*	*H*	*M*	*L*	*L*	*M*					*L*			*H*		*M*

Duration (hour)	9	9	9	9	9
S-1	*IoT-An Architectural Overview*	*Big Data Platforms for the Internet of Things*	*Introduction to the Cloud Computing*	*Myths Of Information Security Mana*	*Introduction To Digital Manufacturing*
S-2	*Building an architecture*	*Network protocol*	*History of cloud computing*	*The big picture*	*Features and development of digital manufacturing*
S-3	*Main design principles and needed capabilities*	*Data dissemination –current state of art*	*Cloud service options*	*Learning from experience*	*Theory system of digital manufacturing science*
S-4	*An IoT architecture outline, standards considerations*	*Improving Data and Service Interoperability with Structure*	*Cloud Deployment models*	*Weaknesses in Information Security*	*Operation Mode*
S-5	*M2M and IoT Technology Fundamentals*	*Compliance, Conformance*	*Business concerns in the cloud,Cloud Orchestration*	*The extent of crime in cyberspace*	*Architecture of Digital Manufacturing System*
S-6	*Devices and gateways, Local and wide area networking*	*Context Awareness*	*Exploring virtualization, Load balancing*	*The cyberspace crimoid syndrome*	*Additive Manufacturing - overview, Techniques.*
S-7	*Data management, Business processes in IoT*	*interoperability problem in the IoT context*	*Hypervisors, Machine imaging,*	*Policies and technologies*	
S-8	*Everything as a Service (XaaS)*	*Big Data Management Systems for the Exploitation of Pervasive Environment*	*Cloud marketplace overview*	*A new framework for information security.*	*Rapid manufacturing-Future development-Virtual prototyping*
S-9	*M2M and IoT Analytics, Knowledge Management.*	*Big Data challenges and requirements coming from different Smart City applications.*	*Comparison of Cloud providers.*		

Learning Resources	1. *Vijay Madisetti and ArshdeepBahga, "Internet of Things (A Hands-on-Approach)", 1st Edition, VPT, 2014.* 2. *Bernd Scholz-Reiter, Florian Michahelles, "Architecting the Internet of Things", ISBN 978-3-642-19156-5 e-ISBN 978-3-642-19157-2, Springer* 3. *Stackowiak, R., Licht, A., Mantha, V., Nagode, L.," Big Data and The Internet of Things Enterprise Information Architecture for A New Age", Apress, 2015*	4. *Cloud Computing: Principles and Paradigms by RajkumarBuyya, James Brobergand Andrzej M. Goscinski, Wiley, 2011.* 5. *Zude Zhou, Shane (Shengquan) Xie and Dejun Chen, Fundamentals of Digital Manufacturing Science, Springer-Verlag London Limited,2012* 6. *Chua.C.K, "Rapid Prototyping", John Wiley, New York, 1997.*

Learning Assessment											
	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,
SLO – Session Learning Outcome

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. R. Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in, rkpearls@yahoo.com	*1. Dr. P. Hariharan, Anna University, hari@annauniv.edu, hariharan2311@gmail.com*	*Dr.U.Mohammed Iqbal*
2. Dr. A. Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in *3. Mr.P.Karthikeyan, Head Operations Improvement, Nokia Solutions, Oragadam Kartikeyan.p@nokia.com*	*2. Dr.N.Arunachalam, IIT Madras, chalam@iitm.ac.in*	*J.Santhakumar*

Course Code	18MEE430T	Course Name	TQM AND RELIABILITY ENGINEERING	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:*	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	*Understand the importance of TQM and its concepts, tools and techniques and apply in the real-world environment*			
CLR-2 :	*Analyze the role of human involvement to improve the quality of product and service*			
CLR-3 :	*Understand, apply and evaluate the tools and techniques used for product and service quality*			
CLR-4 :	*Understand the basic concepts of reliability, apply and evaluate reliability for different systems*			
CLR-5 :	*Understand and apply the concept of maintainability of a system to evaluate time for different cases*			
CLR-6 :	*Understand the importance of quality and reliability in every process in the current scenario*			

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Recognize the importance of quality in every activity of an organization and in personal life*	*1,2*	*80*	*75*	*M*	*M*	*M*	-	*M*	-	-	*M*	*H*	*M*	-	-	-	-	*M*
CLO-2 :	*Apply the different tools and techniques to solve day to day issues and will seek an opportunity to practice*	*1,2,3*	*80*	*75*	*M*	*H*	-	-	*H*	-	-	-	*H*	*M*	-	*M*	-	-	*M*
CLO-3 :	*Think from the customer perspective and will plan for customer retention through total quality management*	*1,2,3*	*80*	*75*	*M*	*H*	*M*	-	*H*	*M*	-	*M*	*H*	*H*	-	-	-	-	*M*
CLO-4 :	*Develop and test a system for its reliability*	*1,2*	*80*	*75*	*M*	*M*	*M*	-	*M*	-	-	-	-	-	-	-	-	-	*M*
CLO-5 :	*Estimate MTTF, MTTR, MMT and MDT and plan for a maintenance strategy*	*1,2,3*	*80*	*75*	*M*	*H*	*M*	-	*H*	-	-	-	-	-	-	-	-	-	*M*
CLO-6 :	*Recognize the importance of quality in every activity of an organization and in personal life*	*1,2*	*80*	*75*	*M*	*M*	*M*	-	*M*	-	-	*M*	*H*	*M*	-	-	-	-	*M*

		Evolution, theories and implementation	Principles and 7 QC tools	Management Tools	Reliability	Maintainability
Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Evolution of Total Quality Management*	*Customer Satisfaction – Types of customers, customer supplier chain*	*Affinity diagram – Relations diagram*	*Probabilistic nature of failures*	*Introduction Availability and Maintainability*
S-2	SLO-1	*Definition of quality, Dimensions of Quality*	*Customer perception of quality customer feed back*	*Tree diagram – Matrix diagram – Matrix data analysis diagram*	*Mean failure rate – Meantime between failures*	*Types of maintenance strategy*
S-3	SLO-1	*Deming's theory*	*Customer complaints – Customer retention – Service quality*	*Process decision program chart, Arrow diagram*	*Hazard rate – Hazard models*	*Mean time– to repair (MTTR)*
S-4	SLO-1	*Juran and Crosby theories*	*Employee involvement and motivation – Maslow's hierarchy of needs*	*5S Principles*	*Weibull model*	*Factors contributing to Mean Down Time (MDT)*
S-5	SLO-1	*Taguchi and Ishikawa theories*	*Herzberg theory – Empowerment and team work*	*Quality Function Deployment (QFD)*	*System reliability improvement*	*Fault diagnosis, and routine testing for unrevealed faults*
S-6	SLO-1	*Quality costs, Product quality Vs Service quality*	*Seven QC tools – Check sheets*	*Failure mode and effects analysis (FMEA)*	*Redundancy*	*Factors contributing to Mean Maintenance Time – (MMT) on condition maintenance*
S-7	SLO-1	*Goal setting*	*Histograms, control charts*	*Root cause analysis, poka-yoke*	*Series – Parallel and Mixed configurations*	*Total Productive Maintenance (TPM)*
S-8	SLO-1	*Strategic Quality planning*	*Pareto diagram, Cause and effect diagram*	*Introduction to Six Sigma*	*Problems in Series – Parallel and Mixed configurations*	*Periodic condition monitoring, Continuous condition monitoring*
S-9	SLO-1	*TQM implementation*	*Stratification, Scatter diagrams*	*DMAIC*	*Problems in Series – Parallel and Mixed configurations*	*Economics of maintenance*

Learning Resources	1. *M. P. Poonia, S.C. Sharma, "Total Quality Management", Khanna Publishing, 2019.* 2. *R Kiran, "Total Quality Management: Key Concepts and Case Studies", Elsevier Inc., 2017.* 3. *Dale H Besterfield, "Total Quality Management", Fourth Edition, Pearson Education Asia, 2015.* 4. *John Oakland, Peter Morris "TQM – A pictorial guide for managers", Routledge, 2011.*	5. *Roderick A Munro, Govindarajan Ramu and Daniel J Zrymiak, "The Certified Six Sigma Green Belt Handbook", Second Edition, American Society for Quality, USA, 2015.* 6. *L S Srinath, "Reliability Engineering", Fourth Edition, Affiliated East West Press, 2008.* 7. *E Balagurusamy, "Reliability Engineering", Tata McGraw Hill Education, 2010.*

Learning Assessment											
	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate Create	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
Mr. R. Nanda Kumar, Vice Chairman, *National Institution for Quality and Reliability (NIQR)*	*1. Dr. P. Hariharan, Anna University, hari@annauniv.edu, hariharan2311@gmail.com*	*Mr. E. Vijayaragavan, SRM IST*
Mr. N. Palani, Head – Quality Assurance *Rane TRW Steering Systems Limited*	*2. Dr.N.Arunachalam, IIT Madras, chalam@iitm.ac.in*	

Course Code	18MEE431T	Course Name	DESIGN OF JIGS, FIXTURE AND PRESS TOOLS	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		*DESIGN DATA BOOK*	

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1 :	*Explore the various locating and clamping method*
CLR-2 :	*Understand the functions and design principles of Jigs*
CLR-3 :	*Understand the functions and design principles of Fixtures*
CLR-4 :	*Understand the functions and design principles of press work*
CLR-5 :	*Understand the functions and design principles of bending, forming and drawing*
CLR-6 :	*Be Familiar with design of jigs, Fixtures and Press Tools*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)													
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Able to design the locator and the clamp for the mechanical component*	*1&2*	*80*	*85*	*H*	*M*	*H*	-	-	-	-	-	-	-	-	-	*M*	-	-
CLO-2 :	*Acquire knowledge on different type of jigs and its application*	*1*	*80*	*85*	*H*	*M*	*H*	-	-	-	-	-	-	-	-	-	*H*	-	-
CLO-3 :	*Acquire knowledge on different type of fixture and its application*	*1*	*80*	*85*	*H*	*M*	*H*	-	-	-	-	-	-	-	-	-	*H*	-	-
CLO-4 :	*Understand the major design principle of press work and element of cutting die*	*1&2*	*80*	*85*	*H*	*L*	*M*		-	-	-	-	-	-	-	-	-	-	-
CLO-5 :	*Understand the functions and design principles of bending, forming and drawing*	*1&2*	*80*	*85*	*H*	-	*M*		-	-	-	-	-	-	-	-	-	-	-
CLO-6 :	*Understand the functions and design principles of locator and clamping of jigs and fixtures, use of press tools in bending, forming and drawing operations*	*1&2*	*80*	*85*	*H*	*H*	*M*	-	-	-	-	-	-	-	-	-	-	-	-

		Locating and Clamping Principles	Design of Jigs	Design of Fixtures	Press Working Terminologies and Element of Cutting Dies	Bending, Forming and Drawing Dies
Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Objective of tool design, Function, features and advantages of jigs and fixture.*	*Types of jigs – Template and Plate Jigs*	*Introduction to fixture, type of fixtures*	*Press working terminology, types of presses*	*Types of Bending dies, press capacity*
S-2	SLO-1	*Locating Principle, Locating methods and devices,*	*Channel, Pot, Turnover, Box and Post Jig*	*Design Principles of milling fixture*	*Press accessories and press working operation.*	*Spring back, knockout, direct and indirect, pressure pads, ejectors*
S-3	SLO-1	*Pin and Button locator, Rest pads and plates, Diamond pin locator*	*Indexing Jigs*	*Lathe fixture*	*Shearing action, clearances, press work materials.*	*Variables affecting metal flow in drawing operation*
S-4	SLO-1	*Clamping Principles, types of clamps, mechanical actuation clamps*	*Drill Bushes and Jig Buttons*	*Design Principles of boring fixture, and Broaching Fixture*	*Center of pressure, design of various elements of dies*	*Draw die insert, draw beads, ironing*
S-5	SLO-1	*Pneumatic actuation clamping*	*method of construction of drill jigs*	*Design Principles of Grinding Fixture*	*Accessories of blanking dies – punch, punch holder, die set, stripper, pilots*	*Design and development of bending and forming*
S-6	SLO-1	*Hydraulic actuation clamping*	*General consideration in the design of Drill jigs*	*Assembly, Inspection and welding fixtures*		*Drawing reverse re-drawing and combination die*
S-7	SLO-1	*Vacuum and magnetic clamping*	*Drill jigs and modern manufacturing*	*Modular fixturing system,*	*Selection of standard parts*	*Blank development for axisymmetric, rectangular and elliptic parts, single and double action dies*
S-8	SLO-1	*Standard parts in jigs and fixtures*	*Design and development of jigs and for*	*Design and development of fixtures and for*	*Design and preparation of four standard*	*Bulging, swaging, Embossing, coining,*

			given component 1	*given component 1*	*views of simple blanking and piercing die*	*curling*
S-9	SLO-1	*Limits, fits, Tolerances and types of tolerances*			*Shaving, notching, compound and progressive dies*	*Hole flanging, shaving, and sizing, assembly, fine blanking dies*

Learning Resources	*1. Donaldson, Lecain and Goold "Tool Design " , 3rd edition Tata McGraw hill ,2007* *2. Joshi, P.H. "Jigs and Fixtures" second edition, Tata McGraw hill publishing co., ltd., New delhi,2004* *3. K.Venkataraman, "Design of Jigs Fixtures and Press tool", Tata McGraw hill New delhi,2005* *4. Kempster, "jigs and fixtures design" Hoddes and Stoughton – third edition 1974*	*5. Joshi, P.H "Press tool – Design and Construction", S.Chand &company, 2010.* *6. Hoffman "Jigs and Fixtures Design" – Thomson Delmar learning, Singapore, 2004.* *7. ASTME fundamentals of tool design prentice hall of India.* *8. P.S.G tech…, "design data book", kalaikathir Achchagam, 2012.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate Create	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. R. Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in, rkpearls@yahoo.com	*1. Dr. P. Hariharan, Anna University, hari@annauniv.edu, hariharan2311@gmail.com*	*1. Kolli Balasivarama Reddy* *Asst. Professor, ME* *SRM Institute of Science and Technology, Kattankulathur,*
2. Dr. A. Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*2.Dr.N.Arunachalam, IIT Madras, chalam@iitm.ac.in*	

Course Code	18MEE341T	Course Name	REFRIGERATION AND AIR CONDITIONING SYSTEMS	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*18MEC107T*	Co-requisite Courses	*NIL*	Progressive Courses	*NIL*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes/Standards		*Refrigerant and Psychrometric Properties Tables &Charts/M.L.Mathur &F.S.Mehta*	

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1 :	*Be familiar with vapour compression system*
CLR-2 :	*Be familiar with the refrigeration cycles and methods for improving Performance*
CLR-3 :	*Understand the working of components of refrigeration systems.*
CLR-4 :	*Be familiar with design of air conditioning systems*
CLR-5 :	*Be familiar with air conditioning systems for various applications.*
CLR-6 :	*Be familiar with refrigeration and air conditioning system s*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)													
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Recognize and analyze the vapour compression systems*	*1&2*	*90*	*80*	*H*	*H*		*M*			*H*							*H*	
CLO-2 :	*Acquire knowledge on refrigeration cycles and methods for improving Performance*	*1,2,3*	*90*	*80*	*H*	*M*		*M*			*L*							*H*	
CLO-3 :	*Understand the working of refrigeration systems.*	*1,2*	*90*	*80*	*H*						*H*							*H*	
CLO-4 :	*Analyze and design ofair conditioning systems.*	*1,2,3*	*90*	*80*	*H*	*H*	*H*	*M*			*M*							*H*	
CLO-5 :	*Appreciate the need and applications of air conditioning systems.*	*1&2*	*90*	*80*	*H*					*L*								*H*	
CLO-6 :	*Understand and analyze the refrigeration and air conditioning system s*	*1&2*	*90*	*80*	*H*	*M*		*M*			*H*							*H*	

		Vapour Compression Refrigeration Systems	Absorption Refrigeration Systems	Refrigeration Equipment's & Contro	Design of Air Conditioning Systems	Applications of Refrigeration And Air Conditioning Systems
Duration (hour)		9	9	9	9	9
S-1	SLO1	*Review of thermodynamic principles of refrigeration*	*Ideal vapour absorption refrigeration system*	*Construction features of reciprocating compressors, Rotary and screw compressors*	*Different heat sources-sensible heat load, Latent heat load*	*Preservation of different products*
S-2	SLO1	*Simple vapour compression refrigeration system*	*Absorbent refrigerant combination - Properties of refrigerant absorbent pair*	*Type of Condenser, heat transfer in condensers*	*Heating and Cooling Load - Occupants load, equipment load, fresh air load, infiltration air load*	*Construction and working of Ice factory*
S-3	SLO1	*Problem on COP of VCR system*	*Vapour absorption refrigeration system based on Water-lithium bromide.*	*Types of cooling towers- Construction features of Natural, Mechanical draft.*	*Design of air conditioning system-cooling load and air quantities*	*The heating and cooling requirements for different dairy products and processes in Dairy plant*
S-4	SLO1	*Methods to improve the COP of VCR system*	*Problems based on Water - lithium bromide systems*	*Type of Evaporators-working of dry expansion and flooded evaporator.*	*Bypass factor(BPF) of heating and cooling coil, Effective sensible heat factor(ESHF)*	*Application of non-conventional refrigeration method in vortex and pulse tube refrigeration. system*
S-5	SLO1	*Multiple evaporator and compressor system*	*Vapour absorption refrigeration system based on Aqua Ammonia*	*Working of automatic (or) constant pressure expansion valve and thermostatic expansion valve*	*Room sensible heat factor(RSHF).Grand sensible heat factor*	*Application of non-conventional refrigeration method in Solar Refrigeration system*
S-6	SLO1	*Cascade system*	*Problems based on Aqua -Ammonia Systems*	*Properties of refrigerants*	*Factors affecting Human comfort*	*Application of air conditioning in hotels and restaurants*
S-7	SLO1	*COP comparison with sub cooling*	*Single effect absorption refrigeration*	*Selection of refrigerants-alternate refrigerants*	*Problems on –RSHF, and GSHF*	*Application of air conditioning in theatres*

		and super heating	*system*			
S-8	SLO1	*Problems based on sub cooling*	*Comparison of vapour compression refrigeration system versus vapour absorption refrigeration system*	*thermostatic control-operating and safety controls*	*Problems on design of air conditioning system*	*Application of air conditioning in auditorium and hospitals*
S-9	SLO1	*Problems based on super heating*	*Advantage and disadvantage of vapour absorption system*	*Refrigerant charging procedure, methods for measuring a Refrigerant Charge*	*Cooling coils and dehumidifier, air washers*	*Cryogenics-low temperature applications*

Learning Resources	1. *Arora, S. C. and Domkundwar, S., A course in Refrigeration and Air conditioning, DhanpatRai (P) Ltd., New Delhi, 2012* 2. *Ananthanarayanan.P.N, "Basic Refrigeration and Air Conditioning" ,Tata McGraw Hill ,3rd Edition,New Delhi,2006* 3. *Manohar Prasad, Refrigeration and A* 4. *Air conditioning, New Age International (P) Ltd, New Delhi, 2010* 5. *Roy J. Dossat, Principles of Refrigeration, Pearson Education Asia, 4th edition, 2001*	6. *Arora, C. P., Refrigeration and Air Conditioning, Tata McGraw Hill, New Delhi, 2006* 7. *Andrew D. Althouse,Modern Refrigeration and Air Conditioning,Goodheart-Willcox Company, Incorporated, 2016* 8. *G F Hundy Refrigeration, Air conditioning and heat pumps, McGraw-Hill Book company(UK) Ltd, fifth edition 2016* 9. *S.N.Sapali,Refrigeration and Air conditioning ,published by asoke K.Ghosh,PHI Learning Private Limited, Second edition 2014* 10. *Ml Mathur Fs Mehta, Refrigerant & Psychrometric Properties Tables & Charts,Published by Jain Brothers,2010*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,
SLO – Session Learning Outcome

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. R. Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in, rkpearls@yahoo.com	*Dr P.Balachander Assistant Professor Thermal Sciences Block Refrigeration & Air Conditioning Department of Mechanical Engineering, College of Engineering, Guindy campus, Anna University, Chennai-600025 Email:p_balachander@annauniv.edu*	*Mr.J.Thavamani Assistant Professor, Department of Mechanical Engineering SRM IST Email: thavamani.j@ktr.srmuniv.ac.in*
2. Dr. A. Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*Mr. K. LAKSHMIKANTH M.E (Refrigeration and Air conditioning system) MANAGER Frick India Limited Seshadri Puram, Bangalore - 560020 Email:bng@frickmail.com*	*Mr. D. kathirkaman Assistant Professor Department of Mechanical Engineering SRM IST Email: kathirkaman.d@ktr.srmuniv.ac.in*

Course Code	18MEE342T	Course Name	INTERNAL COMBUSTION ENGINES	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*18MEC101T,18MEC102T*	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:*	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	*familiarizewith the I.C.enginebasics, analyze the ideal cycles and performance characteristics*			
CLR-2 :	*Study about carburetors, fuel injection systems, ignition, lubrication and cooling systems.*			
CLR-3 :	*Understand the combustion in S.I. engines, combustion chambers and knocking phenomena*			
CLR-4 :	*Understand the combustion in C.I. engine, diesel combustion chambers and abnormal combustion;*			
CLR-5 :	*Study about the emissions from the I.C. engines, alternative fuels and new combustion concepts*			
CLR-6 :	*Understand the design principles of I.C. engines*			

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Performance calculations of I.C. engines, Interpret the ideal and fuel-air cycles; performance maps*	*1,2&3*	*90*	*80*	*H*	*H*	*H*	*H*	*L*	*L*	*M*						*M*	*H*	*M*
CLO-2 :	*Evaluate the functioning of various auxiliary systems*	*1&2*	*90*	*80*	*H*	*H*	*H*	*M*	*M*	*L*	*M*						*M*	*H*	*M*
CLO-3 :	*Analyze SI engine combustion, knocking and the design principles of combustion chamber.*	*1&2*	*90*	*80*	*H*	*H*	*M*	*H*	*M*	*L*	*M*						*M*	*H*	*M*
CLO-4 :	*Analyze CI engine combustion, design principles of combustion chamber and abnormal combustion*	*1&2*	*90*	*80*	*H*	*H*	*M*	*H*	*M*	*L*	*M*						*M*	*H*	*M*
CLO-5 :	*Recognize the need for reducing the emission from I.C. engines, and alternate fuels*	*1&2*	*90*	*80*	*H*	*M*	*M*	*H*	*H*	*M*	*H*						*M*	*H*	*M*
CLO-6 :	*Evaluate the performance, combustion and emissions of I.C. engines from thermodynamic principles*	*1,2&3*	*90*	*80*	*H*	*H*	*M*	*M*	*M*	*M*	*H*						*M*	*H*	*M*

		Performance of I.C. Engines	Engine Auxiliary systems	Combustion in S.I. Engines	Combustion in C.I. Engines	Emissions and Alternative fuels
Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Engine operating cycle, terminology and components, four stroke and two stroke engines and their comparison*	*Carburation, mixture requirements at different loads and speeds, simple carburetor*	*Combustion in spark ignition engines, Stages of combustion in SI engine, flame front propagation*	*Combustion in Compression Ignition engines, Stages of combustion in CI engines,*	*Air pollution due to IC engines, Emissions standards, hydrocarbon and CO emissions,*
S-2	SLO-1	*Operation of SI and CI engines, their p-v diagrams and comparison, classifications and applications IC engines,*	*Problems on simple carburetor*	*Analysis of cylinder pressure data*	*Analysis of cylinder pressure data and heat-release analysis*	*Oxides of nitrogen and soot, aldehydes, sulphur, lead and phosphorus emissions*
S-3	SLO-1	*Volumetric efficiency, and its variation with respect to engine speed, supercharging and turbocharging of engines*	*Functional requirements and classification of an injection systems, injection pump*	*Factors influencing the flame speed,*	*Factors affecting the delay period*	*Exhaust gas recirculation and catalytic converter*
S-4	SLO-1	*First law applied to engine, thermal, mechanical efficiencies, pumping work, mean effective pressure*	*Nozzle types, EFI systems: MPFI, PFI, GDI*	*Rate of pressure riseAbnormal combustion, knocking in SI engines,*	*Basics of fuel sprays: Fuel flow rate through injector nozzle, Overall spray structure*	*Basics of selective catalyst reduction, diesel particulate filter*
S-5	SLO-1	*Engine parameter measurements.*	*Functional requirements of ignition systems, Battery ignition system*	*Effect of engine variables on engine knock*	*Atomization and spray penetration*	*Flame ionization detector, non-dispersive infrared detector*
S-6	SLO-1	*Problems on engine performance.*	*magneto ignition system, Ignition timing and engine parameters*	*Combustion chambers for SI engines*	*Phenomenon of knock in CI engines, comparison of knock in CI and SI engine*	*Chemiluminescence analyzer, smoke types, Bosch smoke meter*
S-7	SLO-1	*Concept of heat balance and problems*	*Functional requirements of lubrication system, properties of lubricants, mist*	*Smooth engine operation, High power output and thermal efficiency*	*Combustion chambers for CI engine: Direct injection engines*	*Fuels for IC engines: Liquid fuels: Alcohol, methanol, ethanol, vegetable oil*

			lubrication system			
S-8	SLO-1	*Review of ideal cycles and fuel-air cycles significance*	*Wet and dry sump lubrication system*	*Concept of hybrid electric drive trains*	*Gasoline Direct Injection (GDI) Engines: Direct injection Vs port injection, classification of GDI eninges*	*Bio diesel advantages and disadvantages; Gaseous fuels: CNG, LPG, Hydrogen*
S-9	SLO-1	*Engine performance characteristics*	*Liquid and air cooling systems, properties of the coolant and antifreeze solutions*	*Architectures of hybrid electric drive trains*	*Spray, wall and air guided combustion systems for GDI engines*	*Advanced concepts: Stratified charge and HCCI engines*

Learning Resources	1. *Ganesan. V, "Internal Combustion Engines", Tata McGraw-Hill, New Delhi, 2015* 2. *Heywood, J.B., "Internal Combustion Engine Fundamentals", McGraw-Hill International, New York, 2017* 3. *Ramalingam, K.K., "Internal Combustion Engines-Theory and Practice", SciTech Publications India Pvt Ltd, Chennai 2016.* 4. *Thipse, S.S., "Internal Combustion Engines", Jaico Publication House, 2010.*	5. *Sharma, M.L., and Mathur R.P., "A Course in Internal Combustion Engines" DhanpantRai& Sons, New Delhi, 2014.* 6. *Fuquan Zhao, David L.Harrington and Ming-Chia D. Lai, "Automotive Gasoline Direct-Injection Systems", SAE International Publisher, 2002* 7. *Mehrdad Ehsani, Yimin Gao, Stefano Longo and Kambiz Ebrahimi "Modern Electric, Hybrid Electric and Fuel Cell Vehhicles", CRC Press, 2018*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,
SLO – Session Learning Outcome

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
K. SaratChander Prasad, Sr. Lead Engineer, Mahindra & Mahindra Pvt Ltd	*Dr. ShamitBakshi, Professor, Indian Institute of Technology Madras*	*Dr. D. Siva Krishna Reddy, Assistant Professor, SRM IST*
Ramesh K.J., Kistler, Product Manager, Instruments India Pvt Ltd	*Dr. Maha Lakshmi, Professor, Anna University*	*Dr. G. Balaji, Associate Professor, SRM IST*

Course Code	18MEE343T	Course Name	ELEMENTS OF SPACE TECHNOLOGY	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:*	Learning		
		1	2	3
CLR-1 :	*Develop a basic knowledge on earth's atmosphere.*			
CLR-2 :	*Learn the different orbit bodies. & Understand the aspects of satellite injection.*			
CLR-3 :	*Know the interplanetary and missile trajectories and materials for Spacecraft.*			

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLO-1 :	*Develop a basic knowledge on earth's atmosphere.*	*1&2*	*100*	*95*
CLO-2 :	*Learn the different orbit bodies. & Understand the aspects of satellite injection.*	*1*	*100*	*95*
CLO-3 :	*Know the interplanetary and missile trajectories and materials for Spacecraft.*	*1*	*100*	*95*

Program Learning Outcomes (PLO)														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
H														
H	*H*		*H*											
H			*H*											

Duration (hour)		9	9	9	9	9
S-1	SLO-1	*The solar system*	*The Many body problem – Lagrange, Jacobi identity*	*General aspects of satellite injections The*	*Two-dimensional interplanetary trajectories*	*Introduction to Hypersonic Aerodynamics, thin shock layers, Entropy layer, Viscous interaction, High temperature flow, Low density flow.*
S-2	SLO-1	*Reference frames and coordinate systems*	*The circular restricted three body problem*	*Launch Phase, The Orbit Injection Phase*	*Fast interplanetary trajectories*	*High temperature gas dynamics- Importance of high temperature flows.*
S-3	SLO-1	*Motion in Acceleration Reference Frames*	*Libration points*	*Satellite orbit transfer - Various cases*	*Three dimensional interplanetary trajectories Launch of interplanetary spacecraft*	*Atmospheric entry of blunt nosed body.*
S-4	SLO-1	*The celestial sphere*	*Relative Motion in the N-body problem*	*Orbit deviations due to injection errors*	*Trajectory Characteristics*	*Spacecraft acoustics and shock loads*
S-5	SLO-1	*The ecliptic, Motion of vernal equinox*	*The two body problem*	*Special and general perturbations - Cowell's Method ,*	*Trajectory about the target plant.6*	*Thermal environment and Thermal Balance*
S-6	SLO-1	*Precession and Equatorial Coordinates*	*Satellite orbits ,Relations between position and time*	*Encke's method*	*The boost phase, The ballistic phase*	*Thermal analysis and Thermal design*
S-7	SLO-1	*Sidereal time, Solar time, Standard time*	*Orbital elements.*	*Cowell's Method ,*	*Trajectory geometry - Optimal flights*	*Thermal active & passive control and thermal control coatings.*
S-8	SLO-1	*The earth's atmosphere.*	*Parameters used to describe the orientation in space*	*Method of variations of orbital elements*	*Time of flight, Reentry phase*	*Requirements and material selection*
S-9	SLO-1	*Troposphere, Stratosphere, Mesosphere, Thermosphere,& Exosphere*	*Examples of orbits*	*General perturbations approach.*	*The position of the impact point , Influence coefficients*	*Spacecraft materials and composite materials.*

Learning Resources	1. *Sutton. G.P, "Rocket Propulsion Elements", 7th Edition, John Wiley & Sons, NewYork, 2011* 2. *Cornelisse.J.W, "Rocket Propulsion and Space Dynamics", W.H. Freeman & Co., New York, 2005* 3. *Rudolph X. Meyer., "Elements of Space Technology", Academic press, London, 2003.*	4. *Parker.E.R, "Materials for Missiles and Spacecraft", McGraw Hill Book Co., NewYork, 2000.* 5. *Ramamurthi. K, "Rocket Propulsion", MacmillanPublishers India Ltd. 2010.*

Learning Assessment											
	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,
SLO – Session Learning Outcome

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. R. Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in, rkpearls@yahoo.com	*Dr.Raju Abraham, Scientist –F, National Institute of Ocean Technology Chennai – 600 100*	*Mr. P.Udayakumar Assistant Professor (O.G) Department of Mechanical Engineering SRM IST*
2. Dr. A. Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*Dr. R.Velraj, Professor, Institute for Energy Studies, Anna University, Chennai, India - 600025*	*Dr. M. Cheralathan, SRMIST*

Course Code	18MEE344T	Course Name	ENERGY ENGINEERING AND MANAGEMENT	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 Environmental aspects of energy utilization.*
CLR-2 :	*Understand Energy conservation concepts.*
CLR-3 :	*Understand concepts of energy savings in various thermal systems.*
CLR-4 :	*Energy management techniques*
CLR-5:	*Energy economics concepts*
CLR-6:	*Know about the importance of energy management systems and its utilization.*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)															
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Recognize the importance of energy usage as per the requirements*	*1&2*	*90*	*80*	*H*	*L*	*L*	*L*	*L*	*M*	*H*	*M*			*L*				
CLO-2 :	*Acquire knowledge on the energy conservations and acts*	*1&2*	*90*	*80*	*H*	*L*	*L*	*L*	*L*	*M*	*H*	*M*	*M*		*L*				
CLO-3 :	*Knowledge of the working of various heat exchangers and various energy storage systems.*	*1&2*	*90*	*80*	*H*	*L*	*L*	*L*	*L*	*L*	*H*	*L*			*L*				
CLO-4 :	*Recognize the cost involved for energy systems*	*1,2&3*	*90*	*80*	*H*	*L*	*L*	*L*	*L*	*L*	*M*	*M*	*H*	*M*	*H*				
CLO-5:	*Implementation of energy management systems in industries*	*1,2&3*	*90*	*80*	*H*	*L*	*L*	*L*	*L*	*L*	*M*	*M*	*H*	*M*	*H*				
CLO-6:	*Get the knowledge about the various energy sources and its management systems*	*1,2&3*	*90*	*80*	*H*	*L*	*L*	*L*	*L*	*L*	*H*	*M*	*H*	*H*	*L*				

		Energy And Environment	Energy Conservation	Energy Savings In Thermal Systems	Energy Management	Energy Economics
Duration (hour)		09	09	09	09	09
S-1	SLO-1	*Introduction to Energy and Environment*	*Introduction to energy conservation*	*Fuels and its consumption*	*Energy management principles.*	*Introduction to engineering economics*
S-2	SLO-1	*Represent World energy consumption*	*Energy conservation schemes*	*Energy savings in Boiler.*	*Energy resource management.*	*Costing techniques in energy engineering*
S-3	SLO-1	*Effect of Greenhouse gases*	*Industrial energy conservation methods*	*Firing methodology in boilers*	*Energy management levels.*	*Cost factors*
	SLO-2	*Global warming*				*Break even analysis*
S-4	SLO-1	*Renewable energy sources*	*Energy surveying for industries.*	*Waste heat recovery systems*	*Energy management information systems.*	*Cost optimization for energy engineering techniques*
	SLO-2		*Energy auditing for industries.*			*Optimal target investment schedule*
S-5	SLO-1	*Environment aspects utilization*	*Energy index and cost*	*Energy saving system in HVAC*	*Energy instrumentation.*	*Financial appraisal and profitability*
S-6	SLO-1	*Energy prices*	*Energy conservation in engineering and process industry*	*Energy savings in Refrigeration systems*	*Energy measurement in energy management*	*Investment decisions*
S-7	SLO-1	*World energy reserves*	*Simple case study of energy auditing in process industries*	*Energy Storage systems*	*Energy management Techniques.*	*Method of investment appraisal*
	SLO-2					*Discounted cash flow*
S-8	SLO-1	*World energy polices*	*Energy conservation in Buildings*	*Energy saving methodologies by using*	*Computerized energy management*	*Summary investment appraisal*

				Insulated pipe work systems		*techniques*
	SLO-2					*Optimization with one variable*
S-9	SLO-1	*The energy future and the role of renewable energy*	*Concept of Green building*	*Heat exchangers*	*Importance of energy management*	*Optimization with multiple variable.*

Learning Resources	1. *Murphy.W.R and McKay G, "Energy Management", Butterworths, London, 2007.* 2. *Reay.D.A, "Industrial Energy Conservation", Pergamon Press, 2003.* 3. *Steve Doty, Wayne C. Turner, "Energy Management Handbook", Fairmont Press, 7th edition, 2009.* 4. *Barney L. Capehart, Wayne C. Turner, William J. Kennedy, "Guide to Energy Management", The Faimont Press, 6th edition, 2008.*	5. *Callaghan.P.W.O, "Design and Management for Energy Conservation", Pergamon Press, Oxford, 2003.* 6. *Hamies, "Energy Auditing and Conservation; Methods", Measurements, Management and Case study", Hemisphere, 2003.* 7. *Trivedi.P.R and Jolka.K.R, "Energy Management", Common Wealth Publication, 2002.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate Create	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr.R.Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*Dr.M.VENKATA RAMANAN Professor Institute for Energy Studies venkat@annauniv.edu*	*S.PANNEERSELVAM Department of Mechanical Engineering SRM IST Email: panneerselvam.s@ktr.srmuniv.ac.in*
2. Dr. A. Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*Dr.S.KUMAR MRT TNEB CHENNAI.*	*Dr. M. Cheralathan, SRMIST*

Course Code	18MEE345T	Course Name	TURBOMACHINES	Course Category	E	*Professional elective*	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*18MEC102T*	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 basic flow concepts in turbo machines*
CLR-2 :	*Understand the performance of centrifugal flow machines.*
CLR-3 :	*Understand the performance of axial flow machines*
CLR-4 :	*Familiarize the performance of axial flow turbines*
CLR-5 :	*Know the Working and performance of hydraulic turbines.*
CLR-6 :	*Understand the performance and design of turbomachines.*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)													
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Acquire the knowledge on basic flow concepts in turbomachines.*	*1& 2*	*90*	*85*	*H*	*M*	-	-	-	-	-	-	-	-	-	-	-	-	-
CLO-2 :	*Appreciate the working and performance of centrifugal flow machines.*	*1& 2*	*90*	*85*	*H*	*H*	-	*M*	-	-	-	-	-	-	-	-	-	-	-
CLO-3 :	*Analyze the working and performance of axial flow machines.*	*1&2*	*90*	*85*	*H*	*H*	-	*M*	-	-	-	-	-	-	-	-	-	-	-
CLO-4 :	*Recognize the working and performance of axial flow turbines*	*1&2*	*90*	*85*	*H*	*H*	-	*M*	-	-	-	-	-	-	-	-	-	-	-
CLO-5 :	*Analyze the working and performance of hydraulic turbines.*	*1&2*	*90*	*85*	*H*	*H*	-	*M*	-	-	-	-	-	-	-	-	-	-	-
CLO-6 :	*Acquire the knowledge on performance and design of turbomachines.*	*1&2*	*90*	*85*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

		Basic flow concepts in turbomachines	Centrifugal flow machines	Axial flow machines	Axial flow turbines	Hydraulic turbines
Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Definition, classification and stages of turbo machines*	*Fans - different impeller sizes, shapes, blade angles, speed and construction*	*Aero-Thermodynamics of flow through an Axial flow Compressor stage.Blade profile, lift and drag coefficients*	*Introduction:Turbinestage: Turbine blade 2-D (cascade)analysis Work done.*	*Pelton turbine- impulse wheel, single jet and multiple jet units*
S-2	SLO-1	*Estimation of specific work for incompressible and compressible flow machines*	*Blade shape, blade number,designcalculations*	*Compressors - brief introduction to two-dimensional cascade and its application to design*	*Degree of reaction; Losses and Efficiency.*	*Velocity triangles at inlet and exit of buckets*
S-3	SLO-1	*Internal and external losses, various efficiencies*	*Performance in series and parallel*	*Flow deflection and stagnation pressure loss across blade rows*	*Flowpassage:Subsonic, transonic and supersonic turbines,Multi-staging of Turbine.*	*Performance calculations considering losses in the nozzle and buckets*
S-4	SLO-1	*Representation of specific work on T-s and h-s diagrams*	*Compressor - slip, inducers, designs without inducer but with inlet guide vanes (IGV)*			*Francis turbine - reaction, impeller shapes for different shape Numbers/heads*
S-5	SLO-1	*Velocity triangles - centrifugal and axial flow machine impellers*	*problems with inducer and IGV's - blade angles,temperature rise and static pressure rise across the impeller*	*Expression for pressure rise coefficient in terms of flow angles and loss coefficient*	*Exit flow conditions:Turbine cooling*	*Calculations on impeller dimensions, blade angles and performance using velocity triangles, draft tubes*
S-6	SLO-1	*Euler's energy equation across the impeller as applicable to all machines,*			*Turbine blade design*	*Kaplan / Propeller Turbine - reaction, impeller (adjustable and fixed) blades and guide blades*
S-7	SLO-1	*Slip and its estimation*	*Vaned and vaneless diffuser and volute casing.Surging; Chocking; Rotating stall*	*Design of impeller blades for free vortex and forced vortex*	*Turbine profiles, Testing of turbine - test rigs - standard instrumentation- operational*	

					characteristics	
S-8	SLO-1	*Degree of reaction*	*Pump - system head, priming of pumps, net positive suction head, minimum starting speed and cavitations.Testing of pumps - test rigs – standard instrumentation- operational characteristics*	*Design and performance calculations. Stall and surgephenomenon. Noise problem in Axial Compressorsand Fans.*	*Airfoil data and Profile construction.*	*Calculation of performance using velocity triangles / blade angles at different radii for free vortex flow, its suitability for low heads*
S-9	SLO-1	*Blade angles and their effects, calculations considering slip.*				

Learning Resources	1. *.Gopalakrishnan.G, PrithviRaj.D, "Treatise on Turbomachines", 1st Edition, Chennai, SciTechPublications, 2006.* 2. *.Seppo A. Korpela., "Priniciple of Turbomachinery", John Wiley and Sons Ltd, 2012.* 3. *.Yahya.S.M, "Turbines, Fans and Compressors", 3rd Edition, Tata McGraw Hill Publications, 2010.*	4. *.Dixon.S.L, "Fluid mechanics and Thermodynamics of Turbomachinery", 5th edition, ElsevierButterworth Heinemann, 2005.* 5. *.Venkanna. B.K, "Fundamentals of Turbomachinery", 4th Edition, New Delhi, PHI Learning Pvt. Ltd,2011.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr.R.Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*Dr.RavindranS,Professor,Hindustan University Padur,Chennai E-mail: drravimepco@gmail.com*	*Mr. N. Vijay Krishna Assistant Professor (O.G) Department of Mechanical Engineering SRM IST Email: vijaykrishna.n@ktr.srmuniv.ac.in*
2. Dr.A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*Vanjeswaran MN, Engineer. Tata Steels Ltd, Jamshedpur Email:mechvanje@gmail.com*	*Mr. P. Sudhakar Assistant Professor(S.G) Department of Mechanical Engineering SRM IST Email: sudhakar.p@ktr.srmuniv.ac.in*

Course Code	18MEE346T	Course Name	THERMAL POWER SYSTEMS	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CLR-1 :	*Know the functions of various auxiliary combustion equipment's.*	Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLR-2 :	*Understand the various Thermal power systems.*																		
CLR-3 :	*Analyze the performance of boiler and condenser. Familiarize with operation of cooling towers.*																		
CLR-4 :	*Familiarize with operation of Nuclear, Diesel and Gas turbine power plants.*																		
CLR-5 :	*Know the power plant economics.*																		
Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*																		
CLO-1 :	*Familiarize with the combustion equipment of Thermal power plants.*	*12*	*90*	*80*	*H*														
CLO-2 :	*Familiarize with the Boilers, accessories and mountings in thermal power system.*	*12*	*90*	*80*	*H*	*H*		*M*											
CLO-3 :	*Familiarize with the working principle of cooling tower and condensers*	*12*	*90*	*80*	*H*	*H*													
CLO-4 :	*Familiarize with the working principle of Nuclear power plant and Diesel power plant.*	*12*	*90*	*80*	*H*						*M*								
CLO-5 :	*Familiarize with economics in power plant*	*12*	*90*	*80*	*H*										*L*				

		Fuel Combustion	Thermal Power	Performance Of Thermal Power System	Nuclear, Diesel And Gas Turbine Power Plants	Power Plant Economics
Duration (hour)		09	09	09	09	09
S-1	SLO-1	*equipmentIntroduction to power plant-Layout of Thermal power plant*	*Systems classification of steam generators.*	*Selectionof Boilers*	*Fuels for Nuclear power plants*	*Power load factor*
	SLO-2	*Combustion equipment's and its types.*			*Moderator for Nuclear power plants*	*Utilization factor*
S-2	SLO-1	*Solid fuel firing method*	*Working principle of high pressure boilers*	*Boiler capacity rating*	*Control rods for Nuclear power plants*	*Power plant cost economics*
	SLO-2				*Coolants for Nuclear power plant.*	
S-3	SLO-1	*Classification and working of stokers*	*Working principle of high pressure boilers*	*Boiler testing and performance*	*Types of Nuclear reactor*	*Tariff rates for electricity*
	SLO-2			*Boiler Energy Balance*		
S-4	SLO-1	*Fuel and ash handling system*	*Working principle of supercritical boilers*	*Condenser design factors*	*Boiling water reactor*	*Demand changes for electricity*
	SLO-2				*Pressurized water reactor.*	*Load distribution*
S-5	SLO-1	*Working principle of draft system its type*	*Working of fluidized bed boilers.*	*Air removal rate and performance of condenser*	*Radiation hazards*	*Effect of Variable load on plant design*
	SLO-2				*Radioactive waste disposal.*	*Energy conservation in power plant*
S-6	SLO-1	*Heat recovery equipmments: Economiser, preheaters and reheaters*	*Boiler mountings*	*Cooling towers range and*	*Classification of Diesel power plant*	*Energy audit in power plant*
	SLO-2					
S-7	SLO-1	*Types of superheaters*	*Boiler accessories*	*Cooling towers approach*	*Components of Diesel power plant*	*Maintenance aspects of power plant*

	SLO-2	*Types of desuperheaters.*	*Feed water Treatment*		*Selection of Engine type.*	
S-8	SLO-1	*Emission control methods-Flue gas cleaning*	*Working of Condensers*	*Cooling towers load and performance*	*Closed cycle Gas Turbine plant*	*Maintenance aspects of power plant*
	SLO-2		*Types of Condensers. Factors affecting condenser. Theory and Design of Condenser*		*Open cycle gas turbine plant.*	
S-9	SLO-1	*Particulate and gaseous emission control methods.*	*Working of cooling towers.*	*Selections of condenser and cooling towers.*	*Combined power cycles.*	*Natural and global energy scenario.*
	SLO-2		*Types of cooling towers.Factors affecting cooling Tower*			

Learning Resources	1. *El Wakil MM "Power plant Technology" McGraw Hill Inc 2010.* 2. *Nag P K " Power plant Engineering" Tata McGraw-Hill, New Delhi, 4th Edition, 2014* 3. *Ramalingam K K "Power plant engineering", Scitech publications Pvt Ltd, 2015*	4. *Arora S C and Domkundwar S "Power plant Engineering",DhanapatRai& sons, New Delhi, 2015* 5. *Rai G D " Non-Conventional Energy sources, "Khanna publishers, 5thEdition, New Delhi, 2014*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr.R.Kalimuthu, ISRO, Mahendragirir_kalimuthu@vssc.gov.in	*Dr. K Karuppasamy Assistant Professor Department of Mechanical Engineering Anna University Regional Campus Tirunelveli - 627 007*	*Mr. S.Malarmannan Assistant Professor, Department of Mechanical Engineering SRM IST Email: malarmannan.s@ktr.srmuniv.ac.in*
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Course Code	18MEE347T	Course Name	SOLAR ENERGY SYSTEMS	Course Category	E	Professional Elective	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*18MEC101T-Thermodynamics*	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:*	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	*be familiar with basics of solar radiation*			
CLR-2 :	*understand the working of solar collectors*			
CLR-3 :	*be familiar with the solar thermal energy systems and their applications*			
CLR-4 :	*understand the solar thermal energy storage and solar cooling systems*			
CLR-5 :	*be familiar with the solar photovoltaic energy conversion systems*			
CLR-6 :	*be familiar with the solar energy conversion systems*			

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)															
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*understand the fundamentals of solar radiation*	*1,2*	*90*	*80*	*H*			*M*			*M*							*H*		
CLO-2 :	*understand the basic principles of solar collector systems*	*1,2*	*90*	*80*	*H*		*H*											*H*		
CLO-3 :	*analyze and design solar thermal energy systems*	*1,2,3*	*90*	*80*	*H*	*M*	*H*			*L*	*H*							*H*		
CLO-4 :	*acquire knowledge on solar thermal energy storage and solar cooling systems*	*1,2*	*90*	*80*	*H*	*H*		*M*			*H*							*H*		
CLO-5 :	*acquire knowledge and analyze solar photovoltaic energy conversion systems*	*1,2,3*	*90*	*80*	*H*			*M*		*M*	*H*							*H*		
CLO-6 :	*acquire knowledge on solar energy conversion systems*	*1,2,3*	*90*	*80*	*H*			*H*		*L*	*M*							*H*		

		Solar Radiation	Solar Thermal Collectors	Design of Solar Thermal Systems	Solar Thermal Energy Storage and Solar Cooling	Solar Photovoltaic Energy Conversion
Duration (hour)		9	9	9	9	9
S-1	SLO-1	*The sun and the earth, electromagnetic spectrum*	*Cassification of solar collectors and solar flat plate collectors*	*Design of solar flat plate collector systems*	*Need for solar thermal energy storage*	*Photovoltaic effect , advantages and disadvantages of solarphotovoltaic technology and classification,*
S-2	SLO-1	*Laws of thermal radiation*	*Solar evacuated tube collectors*		*Sensibleand latent heat storage, its advantages and disadvantages*	*Semiconductors, p-n junction, photo generation of charge carriers*
S-3	SLO-1	*Solar radiation:beam and diffuse radiations, terrestrial radiation*	*Advantages and disadvantages of concentrators over flat plate collectors*	*Problems on solar flat plate collector systems*	*Stratified thermal energy storage*	*I-V characteristics of solar cell*
S-4	SLO-1	*Sun and earth geometry*	*Solar concentrators and receiver geometries, concentrationratio*	*Design of solar active systems using f-chart method*	*PCM based solar thermal energy storage*	*Losses in solar cells and solar module*
S-5	SLO-1	*Solar angles*	*Compound parabolic concentrators, fresnel lens collectors*	*Design of solar cooker*	*Selection of latent heat storage materials*	*Maximum power point tracking in solar photovoltaic system*
S-6	SLO-1	*Sunrise, sunset and day length*	*Solar parabolic concentrators: trough systems*	*Solar air heater and solar dryer*	*Solar cooling systems and its advantages*	*Photovoltaic modules in series and parallel*
S-7	SLO-1	*Solar radiation on tilted surfaces*	*Solar parabolic concentrators: dish systems*	*Solar desalination: types, and operation*	*Vapour compression refrigeration systems and its solar operation*	*Concentrated photovoltaic cells*
S-8	SLO-1	*Measurement of solar radiation:*	*Solar central receiver system*	*Solar pond: types, principles and*	*Vapour absorption cooling systems*	*Temperature dependencies and multi junction*

		pyranometer		*applications*		*solar cells*
S-9	SLO-1	*Measurementof solar radiation: pyrheliometer, sunshinerecorder*	*Solar collector orientation and sun tracking systems*	*Solar thermal power plants and solar furnace*	*Solar thermoelectric cooling systems*	*Grid connected and standalone photovoltaic system*

Learning Resources	1. *Duffie.J.A, &Beckman.W.A, "Solar Engineering of Thermal Processes", 3ro Edition, John Wiley & Sons, Inc.,2006* 2. *Sukhatme.K, Suhas P. Sukhatme, "Solar energy: Principles of thermal collection and storage", Tata McGraw* 3. *Hill publishing Co. Ltd, 8th Edition, 2011.* 4. *Green MA. Solar cells: operating principles, technology, and system applications. Englewood Cliffs, NJ, Prentice-Hall, Inc., 2009.* 5. *Garg. H.P, Prakash.J, "Solar energy fundamentals and applications", Tata McGraw Hill publishing Co. Ltd, 2006.*	6. *Yogi Goswami.D, Frank Kreith, Jan F.Kreider, "Principle of solar engineering", Taylor and Francis, 2nd Edition, 2000.* 7. *Chetan Singh Solanki, "Solar Photovoltaic technology and systems: A manual for Technicians, Trainers and* a. *Engineers", PHI Learning private limited, 2013.* 8. *G. N. Tiwari and M. K. Ghosal, "Renewable Energy Applications", Narosa Publications, 2004.*

Learning Assessment											
	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate Create	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

 # CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
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Course Code	18MEE348T	Course Name	GAS TURBINE TECHNOLOGY	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		*Approved Gas Tables are permitted*	

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	*Familiarize the functions of components of gas turbine.*			
CLR-2 :	*Analyze the power cycles for optimum thermal performance.*			
CLR-3 :	*Understand axial flow compressor characteristics.*			
CLR-4 :	*Understand combustion systems and axial flow turbine operation*			
CLR-5 :	*Familiar with the performance predictions.*			
CLR-6:	Familiar with gas turbine technologies and their performances			

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Appreciate the functions of components of gas turbine.*	*1& 2*	*90*	*80*	*H*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CLO-2 :	*Appreciate the analysis knowledge of the power cycles for optimum thermal performance.*	*1,2,3*	*90*	*80*	*H*	*H*	*H*	-	-	-	-	-	-	-	-	-	-	-	-
CLO-3 :	*Appreciate the understanding of the axial flow compressor characteristics.*	*1,2, 3*	*90*	*80*	*H*	*H*	*H*	-	-	-	-	-	-	-	-	-	-	-	-
CLO-4 :	*Appreciate the understanding of the combustion systems and axial flow turbine operation*	*1,2,3*	*90*	*80*	*H*	*H*	*H*	-	-	-	-	-	-	-	-	-	-	-	-
CLO-5 :	*Appreciate the familiarity with the performance predictions of gas turbines.*	*1,2,3*	*90*	*80*	*H*	*H*	*H*	*L*	*L*	-	-	-	-	-	-	-	-	-	-
CLO-6 :	*Appreciate the familiarity with gas turbine technologies and their performances*	*1,2,3*	*90*	*80*	*H*	*H*	*H*	*L*	*L*	-	-	-	-	-	-	-	-	-	-

Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Definition, classification of gas turbines*	*Ideal cycle operation and thermal performance*	*Centrifugal compressor, Principle of operation, work done. Pressure rise and the diffuser*	*Operation requirements*	*Prediction performance of gas turbines component characteristics*
S-2	SLO-1	*Open cycle single shaft and twin shaft multi speed arrangement, Closed cycle, aircraft propulsion*	*Methods of determining component losses*	*Compressibility effects, Non dimensional quantities*	*type of combustion – Factors affecting combustion process, Combustion chamber performance*	*Off design operation and its relative performance*
S-3	SLO-1	*Gas turbine components and their description*	*Design point performance calculations, Comparative performance of actual and practical cycles.*	*Computerized design procedure. Axial flow compressor basic operation*	*Different types of combustion chambers and their relative merits and demerits*	*Equilibrium running of gas generator*
S-4	SLO-1	*Representation of specific work on T-s and h-s diagrams*	*Analysis of polytropic efficiency (Infinitesimal stage efficiency) of a gas turbine and Velocity triangles*		*Turbine construction – Performance, Impeller blade fixing*	*Off design operation of free turbine – Methods of displacing of the equilibrium running line*
S-5	SLO-1	*Comparison of steam and gas turbines*	*Closed cycle gas turbine and Combined cycle and Cogeneration schemes, Integrated gasification combined cycle.*	*Elementary theory, Factors effecting stage pressure ratio, Blockage in compressor annulus*	*Cooling of turbine blades – Blade vibration*	*Incorporation of variable pressure losses*
S-6	SLO-1	*Applications of gas turbine in various fields.Industrial applications of gas turbines.*			*Protective coating – Gas turbine turbo chargers - Power expanders*	*Matching procedure for two spool engines – Principle of control systems.*
S-7	SLO-1	*Gas Turbine in Co- Generation - Heat recovery and steam generation scheme.*	*Reheat, intercooling and Regenerator cycles for improved thermal performance.*	*Degree of reaction, Blade fixing details, Sealing materials, Material selection for compressor blades, Stage performance*		

S-8	SLO-1	*Gas turbine fuels and their properties*	*Optimum pressure ratio for maximum thermal efficiency, work ratio, air rate, effect of operating variables on thermal efficiency, work ratio, and air rate*	*Design and off design performance characteristics.*	*Vortex theory – Estimation of stage performance.*	*Factors influence the gas turbine performance and the improvement methods.*
S-9	SLO-1	*Environmental issues related to the operation and maintenance, Future of gas turbine engines and the new possibilities*				

Learning Resources	1. *Ganesan.V, "Gas Turbines", Tata McGraw Hill, 3rd Edition, 2010.* 2. *Mattingly.J.D, "Elements of Propulsion: Gas turbines and Rockets", McGraw Hill, 2012* 3. *Yahya S.M, "Turbines, Fans and Compressors", 3rd Edition, Tata McGraw Hill Publications, 2010.* 4. *Irwin E. Treager, 'Gas Turbine Engine Technology ', Mc Graw Hill Education,3rd edition, 2013.* 5. *Saravanamuttoo. H.I.H, Rogers.G.F.C, Henry Cohen, "Gas Turbine Theory",Pearson Prentice Hall, 6th Edition, 2009.*	6. *Gopalakrishnan.G, Prithvi Raj D, "Treatise on Turbomachines", 1st Edition, Chennai, SciTech Publications, 2006.* 7. *Horlock.J.H, "Advanced Gas Turbine Cycles", Elsevier Science Ltd, 2003.* 8. *Venkanna.B.K, "Fundamentals of Turbomachinery", 4th Edition, New Delhi, PHI Learning Pvt. Ltd, 2011.* 9. *Yahya.S.M, "Gas Tables for compressible flow calculations", New Age International (P) Ltd, NewDelhi, 6th Edition, 2011*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr.R.Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*Dr.K. Karunamurthy, Associate Professor, School of Mechanical and Building Sciences, VIT, Chennai. Email: karunamurthy.k@vit.ac.in*	*Dr. R. Senthil Associate Professor Department of Mechanical Engineering SRM IST. Kattankulathur Campus. Email: senthil.r@ktr.srmuniv.ac.in*
2. Dr.A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*Mr.M.Periyasamy Chief Manager, NLC Limited, Neyveli.Tamil Nadu Email: mpsamy34912@gmail.com*	*Dr. M. Cheralathan Professor, Department of Mechanical Engineering SRM IST Email: cheralathan.m@ktr.srmuniv.ac.in*

Course Code	18MEE349T	Course Name	SOLAR ENERGY UTILIZATION	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 :	*Be familiar with basics of solar radiation data and its measurement*
CLR-2 :	*Be familiar with construction and operation of solar thermal energy systems*
CLR-3 :	*Understand the operation of solar thermal power plants*
CLR-4 :	*Be familiar with basics and design of solar photovoltaic systems*
CLR-5 :	*Be exposed to the concept solar architecture in buildings and green buildings*
CLR-6 :	*Be familiar with solar energy concepts and various applications of solar energy like thermal systems, photovoltaic systems and building architecture*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Understand solar radiation, solar angles and recognize and analyze the working of solar radiation measuring instruments*	*1&2*	*85*	*75*	*H*	*M*					*H*							*H*	
CLO-2 :	*Understand the components and working of low temperature solar thermal systems*	*1*	*85*	*75*	*M*					*M*	*H*						*M*	*H*	
CLO-3 :	*Acquire knowledge on basic components and working of concentrated solar thermal systems for power generation*	*1*	*85*	*75*	*M*					*M*	*H*						*M*	*H*	
CLO-4 :	*Comprehend the solar cell working and manufacturing and can design a solar system for buildings*	*1&2*	*85*	*75*	*M*	*M*				*M*	*H*						*M*	*H*	
CLO-5 :	*Recognize the various solar architecture in buildings and gain a basic knowledge in green buildings*	*1*	*85*	*75*	*M*					*L*	*H*						*M*	*H*	
CLO-6 :	*Understand solar radiation and its seasonal variations along with understanding of the practical application of solar energy powered systems in the three main domains of thermal, photovoltaic and building architecture*	*1*	*85*	*75*	*M*						*H*						*M*	*H*	

		Solar Radiation and its measurement	Low Temperature Systems	High Temperature systems	Photovoltaics	Solar Systems for Buildings
Duration (hour)		18	18	18	18	18
S-1	SLO-1	*The Sun and the Earth, Electromagnetic spectrum*	*Solar flat plate collectors*	*Solar concentrators and receiver geometries, Concentration ratio*	*Photovoltaic effect, Classification, Advantages and disadvantages of Solar photovoltaic technology*	*Need for passive architecture, Thermal comfort*
S-2	SLO-1	*Laws of radiation*	*Basic design of solar flat plate collectors, example problems*	*Advantages and disadvantages of concentrated collectors over non-concentrated collectors*	*Semiconductors, p-n junction, Photo generation of charge carriers*	*Sun's motion, Orientation and design of buildings*
	SLO-2	*Solar radiation: beam and diffuse radiations, Terrestrial radiation*				
S-3	SLO-1	*Depletion of Solar radiation in atmosphere*	*Solar evacuated tube collectors*	*Rankine power cycle*	*Photovoltaic cell manufacture: Czochralski, Zone refining and ribbon growth*	*Thermal capacity, Sensible and latent heat storage in buildings, Insulation*
S-4	SLO-1	*Solar angles, example problems*	*Domestic hot water systems: Integral collector storage, Thermosiphon system, Drain back system, Drain down system, Anti-freeze system*	*Compound parabolic concentrators, Fresnel lens collectors*	*I-V characteristics of solar cell*	*Solar Passive architecture : Heating of Buildings*
S-5	SLO-1		*Solar Cooker : Box type and Dish type*	*Solar parabolic concentrators: trough system*	*Losses in solar cell*	*Solar Passive architecture : Cooling of Buildings*
S-6	SLO-1	*Sunrise, sunset and day length, example problems*	*Solar Cooking application problems*	*Solar parabolic concentrators: dish system*	*Solar Module manufacturing*	*Air conditioning : Solar vapour compression refrigeration system*

S-7	SLO-1	*Solar radiation on tilted surfaces*	*Solar air heater, Solar dryer and its types*	*Central receiver plant / Power tower*	*Photovoltaic system for power generation : Standalone system and grid connected system*	*Air conditioning : Solar vapour absorption refrigeration system*
S-8	SLO-1	*Measurement of solar radiation: Pyranometer*	*Solar desalination, solar still design, example problems*	*Solar furnaces: types, principle and application*	*Photovoltaic system design for a building: DC system and AC system, example problems*	*Green buildings, Zero energy buildings, Rating systems*
S-9	SLO-1	Measurement of solar radiation: Pyrheliometer, Sunshine Recorder	Solar Pond: types, principle and application	Orientation and sun tracking systems		

Learning Resources	1. *Duffie.J.A, &Beckman.W.A, "Solar Engineering of Thermal Processes", 4th Edition, John Wiley & Sons, Inc., 2013.* 2. *Sukhatme.K, Suhas P. Sukhatme, "Solar energy: Principles of thermal collection and storage", Tata McGraw Hill publishing Co. Ltd, 8th Edition, 2011.* 3. *Chetan Singh Solanki,"Solar Photovoltaic: Fundamentals, Technologies and Applications", PHI Learning private limited, 2015.* 4. *Jan F. Kreider, "The solar heating design process: active and passive systems, McGraw-Hill, 2007.* 5. *G.D. Rai, "Solar Energy Utilisation", Khanna Publishers, 5th Edition, 2014.* 6. *Yogi Goswami.D, Frank Kreith, Jan F.Kreider, "Principle of solar engineering", Taylor and Francis, 2nd Edition, 2000. Andy Walker, "Solar Energy", John Wiley & Sons, 2013.* 7. *Garg. H.P, Prakash.J, "Solar energy fundamentals and applications", Tata McGraw Hill publishing Co. Ltd, 2006.* 8. *Tiwari.G.N, "Solar energy: Fundamentals, Design, Modeling and Applications", Alpha Science International, Limited, 2013.* 9. *David A Bainbridge, Ken Haggard, "Passive solar architecture: Heating, Cooling, Ventilation and more use of natural flows", Chelsea Green Publishing, 2011.*

Learning Assessment											
	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr.R.Kalimuthu, ISRO, Mahendragirir_kalimuthu@vssc.gov.in	*Dr. G Kumaresan Associate Professor Institute for Energy StudiesCollege of Engineering Guindy Anna University E-Mail : gkumaresan@annauniv.edu*	*Mr. Joji Johnson Assistant Professor, Department of Mechanical Engineering SRM ISTEmail: joji.j@ktr.srmuniv.ac.in*
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Course Code	18MEE350T	Course Name	GAS DYNAMICS AND SPACE PROPULSION	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*18MEC201T, 18MEC202T*	Co-requisite Courses	*NIL*	Progressive Courses	*NIL*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes/Standards		*Gas Tables*	

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLR-1 :	*Familiarize the compressible fluid flow concepts*																		
CLR-2 :	*Understand the isentropic flow through variable area ducts and normal shocks.*																		
CLR-3 :	*Familiarize with the oblique shock and expansion waves*																		
CLR-4 :	*Understand the flow through constant area duct with friction and heat transfer*																		
CLR-5 :	*Understand the aircraft and rocket propulsion*																		
CLR-6 :	*Familiarize with the gas dynamics and space propulsion*																		
Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*																		
CLO-1 :	*Analyse and evaluate the compressible flow problems*	*123*	*90*	*80*	*H*	*H*		*M*											
CLO-2 :	*Analyse and solve the engineering flow problems through the nozzles and diffusers with and without Normal shock.*	*123*	*90*	*80*	*H*	*H*		*M*											
CLO-3 :	*Analyse and solve problems related to oblique shock and expansion waves.*	*123*	*90*	*80*	*H*	*H*		*M*											
CLO-4 :	*Analyse and solve problems related to flow through constant area ducts with friction and heat transfer..*	*123*	*90*	*80*	*H*	*H*		*M*											
CLO-5 :	*Analyse and evaluate the performance of Aircraft and Rocket Engines.*	*123*	*90*	*80*	*H*	*H*		*M*											
CLO-6 :	*Understand the gas dynamics and space propulsion.*	*123*	*90*	*80*	*H*	*H*		*M*											

		Fundamentals of Compressible Flow	Isentropic Flow Through Variable Area Ducts	Oblique Shock And Expansion	Flow Through Constant Area Ducts	Aircraft and Rocket Propulsion
Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Energy equation for compressible fluid flow*	*T-s and h-s diagrams for nozzles and diffusers*	*Introduction and oblique shock relations*	*Flow in constant area ducts with friction (Fanno flow), Fanno curves*	*Types of aircraft engines and Propulsion theory*
	SLO-2					
S-2	SLO-1	*Stagnation state and Mach number*	*Area ratio as a function of Mach number, Impulse function*	*Relation between wave angle and deflection angle*	*Fanno flow equations,*	*Performance of Turbojet, Turbofan ,Turboprop engines*
	SLO-2					
S-3	SLO-1	*Various regimes of flow*	*Mass flow rate through nozzles and diffusers*	*Supersonic flow over a wedge and weak oblique Shock*	*Variation of flow properties (no derivation)*	*Ramjet and pulse jet engine – construction and working.*
	SLO-2					
S-4	SLO-1	*Reference velocities , Critical states*	*Problems on variable area duct*	*Problems on the oblique shock wave*	*Variation of Mach number with duct length*	*Problems on Aircraft Engine Performance*
	SLO-2					
S-5	SLO-1	*Problems on energy equations*	*Flow with normal shock – Development, governing equations*	*Supersonic compression and expansion, Prandtl-Meyer expansion*	*Flow in constant area duct with heat transfer - Rayleigh line & curves*	*Types and applications of rocket engines*
	SLO-2					
S-6	SLO-1	*Equivalent of Bernoulli's equation for compressible flow*	*Derivation of Prandtl – Meyer equation*	*Problems on Prandtl-Meyer expansion and compression*	*Rayleigh flow equations*	*Solid ,Liquid and Hybrid propellant rockets – construction and fuels-oxidizers*
	SLO-2					
S-7	SLO-1	*Effect of Mach number on compressibility*	*Variation of flow parameters -static pressure & temperature, density, stagnation pressure and entropy across the shock (no derivations)*	*Detached shock waves, reflection and intersection of shocks and expansion waves*	*Variation of flow properties (no derivate ion)*	*Performance of Rocket engines.*
	SLO-2					
S-8	SLO-1	*Velocity of sound and wave propagation- subsonic, sonic and supersonic waves*	*Impossibility of shock in subsonic flows, strength of a shock wave*	*Problems on intersection of shocks and expansion waves*	*Maximum heat transfer concept*	*Problems on Rocket engines*
	SLO-2					

S-9	SLO-1	*Problems on energy equations*	*Problems on Normal shock*	*Underexpanded and overexpanded nozzles*	*Tables and charts for Fanno flow and Rayleigh flow.*	*Types and applications of rocket engines*
	SLO-2					

Learning Resources	1. *Yahya.S.M, "Fundamentals of Compressible Flow with Aircraft and Rocket Propulsion", New Age International (P) Ltd, New Delhi, 3rd edition, 2012.* 2. *Radhakrishnan.E, "Gas Dynamics", PHI Learning Pvt. Ltd, 4th edition, 2012.* 3. *Mattingly.J.D, "Elements of Propulsion: Gas turbines and Rockets", McGraw Hill, 2012.* 4. *Balachandran.P, "Fundamentals of compressible fluid dynamics", PHI Learning, 2012*	5. *Robert.D.Zucker, "Oscar Biblarz, Fundamentals of Gas Dynamics",John Wiley and Sons, 2nd edition, 2011.* 6. *Ascher H.Shapiro , 'The dynamics and thermodynamics of compressible flow",R.R.Kreiger Publishers, Volume 2, 1983.* *Databook* 7. *Yahya.S.M, "Gas Tables for compressible flow calculations", New Age International (P) Ltd, New Delhi, 6th edition, 2011.*

Learning Assessment											
	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate Create	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr.R.Kalimuthu, ISRO, Mahendragiri,r_kalimuthu@vssc.gov.in	*Dr. R.Velraj, Professor, Institute for Energy Studies, Anna University, Chennai, India - 600025*	*Dr. P.Chandrasekaran, Associate Professor, SRMIST*
2. Dr.A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*Dr.Raju Abraham, Scientist –F, National Institute of Ocean Technology Chennai – 600 100*	*Mr.G.Manigandaraja, Assistant Professor, SRMIST*

Course Code	18MEE441T	Course Name	COMPUTATIONAL FLUID DYNAMICS	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*18MEC101T,18MEC105T*	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 basic governing equations of fluid mechanics and behavior of PDE.*
CLR-2 :	*Be familiar with the different discretization techniques*
CLR-3 :	*Know the CFD solution techniques in compressible flow*
CLR-4 :	*Be familiar with incompressible fluid flow problems solution techniques*
CLR-5 :	*Be familiar with the basics of turbulence modeling.*
CLR-6 :	*Be familiar to solve fluid flow problems*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Understand and apply basic governing equations to different problems.*	*1& 2*	*90*	*85*	*H*	*H*	*H*	*H*			*L*		*M*						
CLO-2 :	*Choose and apply different discretization techniques in solving problems.*	*1*	*90*	*85*	*H*	*H*	*H*	*H*			*L*		*H*						
CLO-3 :	*Choosing different solution techniques to solve numerical problems.*	*123*	*90*	*85*	*H*	*H*	*H*				*L*		*H*						
CLO-4 :	*Solving different incompressible flow problems with appropriate pressure correction and solution techniques.*	*123*	*90*	*85*	*H*	*H*	*H*				*L*		*H*						
CLO-5 :	*Apply turbulence modeling in solving high Reynolds number flows*	*1&2*	*90*	*85*	*H*	*H*	*H*				*L*		*H*						
CLO-6 :	*Choose and apply different discretization and solution techniques to solve fluid flow problems*	*123*	*90*	*85*	*H*	*H*	*H*				*L*		*H*						

		Governing Equations	Dicretisation Techniques	Soluton Techniques And Numerical Methods For Compressible Flow	Finite Volume Method And Techniques For Incompressible Flow	Turbulence Modeling
Duration (hour)		9	9	9	9	9
S-1	SLO 1	*Introduction, various application of computational fluid dynamics*	*Discretization techniques and principles*	*Solution techniques for linear system of equations- Gauss elimination method.*	*Introduction to finite volume method(FVM)*	*Concept of boundary layer*
S-2	SLO 1	*Conservation and Non conservation form of governing equations. Models of fluid flow*	*Finite difference method – Forward, Backward difference methods*	*Numerical solution – Gauss Siedel and Tri-diagonal matrix algorithm*	*Discretization of one dimensional steady state heat conduction convection equation using FVM*	*Laminar sub layer logarithmic layer Velocity defect law*
S-3	SLO 1	*Continuity equation derivation in all forms*	*Finite difference method – central difference methods*	*Numerical solution – Jacobie and relaxation techniques*	*Discretization of incompressible Naviers Stokes Equations using finite differences*	*Concept of turbulence, Reynolds averaging*
S-4	SLO 1	*Momentum equation derivation*	*One dimensional steady state heat conduction problem -Explicit method*	*Solution techniques for ordinary differential equations, Linear multistep method*	*Concept of staggered grid.*	*Time average equations for turbulent flow*
S-5	SLO 1	*Energy equation derivation*	*One dimensional steady state heat conduction problem -Implicit method*	*Predictor and corrector scheme – McCormack technique*	*Pressure correction method*	*Boissuniq approximation method, Types of turbulence models –*
S-6	SLO 1	*Different types of boundary conditions – Dirichlet, Neumann ,Cauchy and Robbins boundary conditions with examples*	*Discretization of one dimensional wave equation*	*Solution of supersonic flow through converging-diverging nozzle with predictor and corrector method: Governing equations*	*SIMPLE algorithm and boundary conditions*	*Prandtl mixing length model, One-equation models*
S-7	SLO 1	*Classification of Partial differential equations –elliptic ,parabolic, hyperbolic*	*Stability analysis of different equations, consistency and convergence*	*Numerical method*	*Solution of Couette flow using SIMPLE algorithm*	*Two-equation models*

S-8	SLO 1	*Mathematical behavior of Partial differential equations - Elliptic ,Parabolic equation*	*Problems on stability analysis*	*Boundary conditions, case set-up and results*	*Problems in Couette flow using SIMPLE algorithm*	*Energy cascade mechanism in turbulent flows*
S-9	SLO 1	*Mathematical behavior of Partial differential equations - Hyperbolic equations –well posed problems*	*Discussion on CFL condition*	*Problems in supersonic flow through converging-diverging nozzle*	*Alternating direction implicit method and application to unsteady two dimensional heat conduction*	*Comparison of merits and demerits of different turbulent models*

Learning Resources	*1. Anderson J.D., "Computational Fluid dynamics", McGraw Hill Int., New York, 2010.* *2. Versteeg H.K., and Malalasekera W., An introduction to computational fluid dynamics, "The finite volume method", Longman, 2007.* *3. Suhas.V. Patankar, "Numerical Heat Transfer and Fluid Flow", Hemisphere Publishing Corporation, 2009.*	*4. Muralidhar.K, and Sundararajan.T, "Computational Fluid Flow and Heat Transfer", Narosa Publishing House, New Delhi, Second Edition, 2008.* *5. Ghoshdasdidar.P.S, "Computer simulation of fluid flow and heat transfer", Tata McGraw Hill Publishing Company Ltd., 1998.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr.R.Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*Dr.R.Sivakumar ,Professor and Dean SMBS, VIT, Chennai*	*P.Sudhakar, SRMIST*
2. Dr.A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*Mr.P.Sivaganga kumar,Support Manager,Siemens Industry software Compiutational Dynamics India(P) ltd Bengaluru*	*Dr.D.Siva Krishna reddy SRMIST*

Course Code	18MEE442T	Course Name	ADVANCED ENGINEERING THERMODYNAMICS	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Engineering Thermodynamics (18MEC101T)*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes/Standards		*Steam tables, Mollier and generalized compressibility chart*	

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1 :	*Familiarize with entropy, exergy and thermodynamics properties.*
CLR-2 :	*Be familiar with the relationship between thermodynamic properties*
CLR-3 :	*To attain the knowledge about chemical thermodynamics*
CLR-4 :	*To attain the knowledge about statistical thermodynamics*
CLR-5 :	*To attain the knowledge of irreversibility in Thermodynamics*
CLR-6 :	*To attain the knowledge of thermodynamics for various engineering systems*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Understand the application of exergy and entropy in varies engineering devices.*	*1, 2, 3*	*95*	*85*	*H*	*H*	*L*	*H*										*H*	
CLO-2 :	*Understand the concept of Real gas behaviour and multicomponent systems.*	*1, 2, 3*	*95*	*85*	*H*	*H*	*L*	*M*										*H*	
CLO-3 :	*Understand the concept Chemical thermodynamics and equilibrium.*	*1, 2, 3*	*95*	*85*	*H*	*H*	*L*	*M*										*H*	
CLO-4 :	*Understand the concept Statistical thermodynamics.*	*1, 2, 3*	*95*	*85*	*H*	*H*	*L*	*M*										*H*	
CLO-5 :	*Understand the concept of irreversible thermodynamics.*	*1, 2, 3*	*95*	*85*	*H*	*H*	*L*	*M*										*H*	
CLO-6 :	*Understand the concept of thermodynamics to various engineering systems.*	*1, 2, 3*	*95*	*85*	*H*	*H*	*L*	*M*										*H*	

		Entropy, Exergy Analysis And Property Relations	Real Gas Behaviour And Multicomponent Systems	Chemical Thermodynamics And Equilibrium	Statistical Thermodynamics	Irreversible Thermodynamics
Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Entropy principle and its applications, Entropy transfer mechanisms phase diagram, phase changes, various properties diagram, 1st order phasetransition and 2nd order phase transition*	*Law of corresponding states, Generalized compressibility chart, Reduced coordinate Phase transition, types of equilibrium and stability, multi-component and multi-phase systems, equations of state.*	*Degree of reaction, reaction equilibrium, law of mass action, heat reaction Chemical equilibrium, Thermodynamic equation for phase*	*Statistical thermodynamics: Introduction, energy states and energy levels*	*Introduction to Steady-state thermodynamics,*
S-2	SLO-1	*Exergy transfer by heat, work and mass*	*Stability of thermodynamic systems, Le Chatelier's Principle, Other equation of state: Vander Waals equation of state, Beattie-Bridgeman equation of state*	*Temperature dependence of the heat of reaction and equilibrium constant, thermal ionization of a monatomic gas*	*Micro and Macro state, Maxwell-Boltzmann statistics*	*Irreversibility and causes of irreversibility*
S-3	SLO-1	*Exergy destruction, exergy balance in closed and open systems*	*Benedict-Webb-Rubin equation of state, Virial equation of state*	*Gibbs function change, Fugacity and Activity, heat capacity of reacting gases in equilibrium*	*Sterling's approximation, Maxwell-Boltzmann distribution function*	*Thermodynamics forces and thermodynamics velocities*
S-4	SLO-1	*Exergy analysis of industrial systems: power system and refrigeration systems*	*Use of generalized charts for enthalphy and entropy departure*	*Enthalpy of formation, 1st law for reactive system*	*Bose-Einstein statistics, Femi-Dirac statistics*	*Onsager's reciprocal relations*
S-5	SLO-1	*Maxwell relations, Generalized relations for changes in entropy, internal energy and enthalpy.*	*Fugacity coefficient, lee-kesler generalized three parameter tables*	*Adiabatic flame temperature, Enthalpy and energy of combustion*	*Distribution of particles over energy levels, partition function*	*Calculation of entropy production*
S-6	SLO-1	*General thermodynamic consideration an*	*Fundamental property relations for systems of*	*Entropy change for reactive system*	*Microscopic interpretation of heat and*	*Thermoelectricity: Application*

		equations of state, Evolution of thermodynamics properties from equation of state	*variable composition.*		*work*	*of irreversible thermodynamics to a thermocouple*
S-7	SLO-1	*Type of equilibrium, local equilibrium condition*	*Partial molar properties, Real gas mixture.*	*Absolute entropy, third law of thermodynamics*	*Statistical interpretation of entropy*	*Uncoupled effects in thermoelectricity*
S-8	SLO-1	*condition of equilibrium for a heterogeneous system, Gibbs phase rule*	*Ideal solution of real gases and liquid, activity, equilibrium in multi-phase systems*	*2nd law analysis for reactive system*	*Application of statistics to gases-mono-atomic ideal gas*	*The coupled equations of thermoelectricity*
S-9	SLO-1	*Condition of stability and Third law of thermodynamics*	*Gibbs phase rule for non-reactive components.*	*chemical exergy, 2nd law efficiency of a reactive system*	*Principle of equipartition of energy, thermodynamics properties, specific heat of solids*	*Other effects in Thermocouples*

Learning Resources	1. *Yunus, A. C., and Boles, A.," Thermodynamics-An engineering approach, 8th edition", Tata McGraw Hill-Education New Delhi, 2015.* 2. *Nag, P. K., "Engineering Thermodynamics", 5th edition, Tata McGrew Hill education New Delhi, 2013.* 3. *Bejan, A., "Advance Engineering Thermodynamics, 3rd edition, John Wiley and sons, 2006.*	4. *Smith, J. M. etal, "Introduction to chemical engineering thermodynamics" Tata McGrew Hill, 2005* 5. *Puri, I. K., and Annamalai, K., "Advance Engineering Thermodynamics", CRC Press, 2001.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Expert from Industry	Experts from Higher Technical Institute	Internal Experts
1. Dr.R.Kalimuthu, ISRO, Mahendragiri,r_kalimuthu@vssc.gov.in	*1. Dr. Laltu Chandra Indian Institute of Technology (BHU)*	*1. Dr. Piyush Sharma, Asst. Prof.*
2. Dr.A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*Dr. Amit Gupta (ABSTC) Aditya Birla Science and Technology Company*	*Dr. Pankaj Kumar Research Asst. Prof.*

Course Code	18MEE443T	Course Name	ADVANCED FLUID MECHANICS	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Fluid Mechanics (18MEC102T)*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Mechanical Engineering*	Data Book / Codes/Standards			

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1 :	*Familiarize with fundamental fluid flow pattern*
CLR-2 :	*Be familiar with the concept of potential flow*
CLR-3 :	*To attain the knowledge about the exact solution of Navier-Stokes Equations*
CLR-4 :	*Be familiar with laminar boundary layers, turbulent flows, turbulence modeling and equations, Basic discretization method*
CLR-5 :	*To attain the knowledge of the various types of flow stability theory*
CLR-6 :	*Be familiar with the applications of N-S equation in internal and external flows*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)													
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Analyze the different flow patterns, difference in rotational and irrotational flow, Stream and velocity potential function.*	*1, 2, 3*	*90*	*80*	*H*	*H*	*L*	*H*										*H*	
CLO-2 :	*Acquire knowledge on Source and Sink; Vortex flow, Doublet, Superposition of basic plane potential flows*	*1, 2, 3*	*90*	*80*	*H*	*H*	*L*	*M*										*H*	
CLO-3 :	*Understand the basic calculations for force and momentum calculations using N-S equations, understand the Couette flows, Poiseuille flows*	*1, 2, 3*	*90*	*80*	*H*	*H*	*L*	*M*										*H*	
CLO-4 :	*Understand the Integral form of boundary layer equations, Turbulent boundary layer equation, major turbulence modeling, finite element method, finite volume method*	*1, 2, 3*	*90*	*80*	*H*	*H*	*L*	*M*										*H*	
CLO-5 :	*Understand the concept of the Linear Stability theory*	*1, 2, 3*	*90*	*80*	*H*	*H*	*L*	*M*										*H*	
CLO-6 :	*Able to apply and solve N-S equation for different flow conditions.*	*1, 2, 3*	*90*	*80*	*H*	*H*	*L*	*M*										*H*	

		Analyze the different flow patterns, difference in rotational and irrotational flow, Stream and velocity potential function	Acquire knowledge on Source and Sink; Vortex flow, Doublet, Superposition of basic plane potential flows	Understand the basic calculations for force and momentum calculations using N-S equations, understand the Couette flows, Poiseuille flows	Understand the Integral form of boundary layer equations, Turbulent boundary layer equation, major turbulence modeling, Discretization	Understand the concept of the Linear Stability theory
Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Continuity Equation, Streamlines, and Stream Function*	*Uniform flow, source flow, sink flow*	*Solutions to the Steady-State Navier-Stokes Equations*	*Boundary layer on a flat plate*	*Concept of small-disturbance stability,*
S-2	SLO-1	*Vorticity and Circulation*	*Free vortex flow*	*Problems based on Steady-State Navier-Stokes Equations*	*Similarity solutions, Integral form ofboundary layer equations Approximate Methods*	*Linear Stability Theory of Fluid Flows*
S-3	SLO-1	*Problem based on vorticity and circulation*	*Super imposed flow, source and sink pair*	*Poiseuille Flow in a Rectangular Conduit*	*General equations of turbulent flow, Turbulent boundary layer equation*	*Orr-Sommerfeld equation,*
S-4	SLO-1	*Irrotational Flows and the Velocity Potential*	*Doublet*	*Couette Flow Between Concentric Circular Cylinders*	*Flat plate turbulent boundary layer*	*Boundary layer stability*
S-5	SLO-1	*Problems based on irrotational Flows and the Velocity Potential*	*Flow past a Rankine oval body*	*Creeping flows*	*Turbulent Models-zero, one and two*	*Thermal Instability*
S-6	SLO-1	*Lagrangian and Eulerian description*	*doublet in a uniform flow*	*Fully developed flows in non- circular cross-sections*	*Prandtl mixing hypothesis,*	*Transition to turbulence*
S-7	SLO-1	*Reynolds transport theorem*	*Flow past a cylinder with circulation*	*Unsteady Flows: Impulsive Motion of a Plate—Stokes's First Problem*	*Basic discretization – Finite difference method*	*Inviscid stability theory*

S-8	SLO-1	*Derivation of continuity and momentum equations using Reynolds transport theorem*	*Magnus effect; Kutta-Joukowski lift theorem*	*Oscillation of a Plate—Stokes's Second Problem*	*Finite volume method*	*Problems based on Navier-Stoke's equation for steady incompressible flows*
S-9	SLO-1	*Problem based on Reynolds transport theorem*	*Concept of lift and drag.*	*Flow in Convergent and Divergent Channels*	*Finite element method*	*Favorable and adverse pressure gradients, flow separation*

Learning Resources	1. *Graebel. W.P, "Advanced Fluid Mechancis", 1st Edition, Academic Press, Elsevier Inc., 2007* 2. *Muralidhar and G. Biswas, " Advanced Engineering Fluid Mechanics", 3rd Edition, Narosa Publishers, 2015* 3. *Stevan A Jones, "Advanced Methods for Practical Applications in Fluid Mechanics", InTech Publishers, 2012*	4. *Kundu P., Cohen I and Dowling D,"Fluid Mechanics" 6th edition,2015* 5. *Schlichting H., K. Gersten, Boundary Layer Theory, 8/e, Springer 2000*

Learning Assessment											
	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate Create	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Expert from Industry	Experts from Higher Technical Institute	Internal Experts
1. Dr.R.Kalimuthu, ISRO, Mahendragiri,r_kalimuthu@vssc.gov.in	*Dr. Dhiman Chatterjee, Professor, Dept. of Mechanical Engineering, IIT Madras*	*1. Dr. Pankaj Kumar*
2. Dr.A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*1. Dr Parag Deshpande, senior scientist,NAL*	*Dr. M. Cheralathan, SRMIST*

Course Code	18MEE444T	Course Name	DESIGN OF PUMPS AND TURBINES	Course Category	E	Professional Elective	L	T	P	C
							3	0	0	3

Pre-requisite Courses	18MEC102T	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 :	Acquire the knowledge on basic flow concepts in turbines and pumps
CLR-2 :	Understand the design principles of simple radial flow pumps
CLR-3 :	Know the design principles of various turbines
CLR-4 :	Understand the phenomenon of cavitation in hydraulic machines
CLR-5 :	Know the hydro machine applicability from the cavitation point of view.
CLR-6:	Familiarize with the performance and design of turbines and pumps

Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	Appreciate the basic flow concepts in turbines and pumps.	1&2	90	85	H	H	H	-	-	-	-	-	-	-	-	-	-	-	-
CLO-2 :	Know the design principles of simple radial flow pumps	1	90	85	H	H	H	M	-	-	-	-	-	-	-	-	-	-	-
CLO-3 :	Appreciate the design principles of various turbines	123	90	85	H	H	H	M	-	-	-	-	-	-	-	-	-	-	-
CLO-4 :	Familiarize with the effects of cavitation in hydraulic machines	123	90	85	H	H	H	-	-	-	-	-	-	-	-	-	-	-	-
CLO-5 :	Become familiar with hydro machine applicability from the cavitation point of view.	1&2	90	85	H	H	H	-	-	-	-	-	-	-	-	-	-	-	-
CLO-6 :	To solve practical fluid flow problems in turbines and pumps	123	90	85	H	H	H	-	-	-	-	-	-	-	-	-	-	-	-

		Basic principles of fluid machinery	Theory of Pumps	Design of pumps	Theory and design of turbines	Cavitation
Duration (hour)		9	9	9	9	9
S-1	SLO 1	Definition, classification and stages of turbines and pumps	Introduction to mixed flow centrifugal pumps	Design procedure for pumps	Theory of turbines , specific speed, Euler's turbine equation	Introduction to cavitation
S-2	SLO 1	Basic equations of energy transfer between the fluid and the rotor	Calculation of thrust In mixed flow centrifugal pumps	Thermal design of pumps -	Introduction to Pelton wheel (impulse turbine) - single jet and multiple jet units	Cavitation in pumps
S-3	SLO 1	Performance characteristics of various turbines and pumps	Impellers, Pump casings – volute casing and vortex casing	Selection of materials for withstanding high temperature and corrosive fluids	Velocity diagrams at the inlet and exit of the buckets	Cavitation in turbines
S-4	SLO 1	Dimensional analysis	Velocity diagrams for mixed flow centrifugal pumps	Hydraulic design of pumps	Performance calculations considering the losses in the nozzle and the buckets	Thomas cavitation factor
S-5	SLO 1	Dimensionless parameters in turbines and pumps	Calculation of work input to mixed flow centrifugal pumps	Selection of the impeller for pumps	Introduction to reaction turbine (mixed flow and axial flow) and Degree of reaction	Net positive suction head (NPSH)
S-6	SLO 1	Specific speed in turbines and pumps	Head, Losses and efficiency of mixed flow centrifugal pumps	Calculation of casing dimension	Francis turbine – Velocity diagrams and Design procedure	Effects of cavitation on the performance of turbines and pumps
S-7	SLO 1	Velocity triangles of a stage	Specific speed, Power requirement and operating characteristics	Introduction to computer programs for iterative and interactive design	Introduction to Kaplan / Propeller Turbine – axial flow reaction type	Cavitation – damage to equipments
S-8	SLO 1	Calculation of work output of turbine	Minimum starting speed of centrifugal pump	System head, Net positive suction head,	Velocity diagrams and design procedure for Kaplan turbine	Design considerations to avoid cavitation
S-9	SLO 1	Computation of efficiency	Multi stage pump	Priming of pumps	Governing of turbines	Cavitation and energy harvesting

Learning	1. Dixon.S.L, "Fluid Mechanics and Thermodynamics of Turbomachinery", 6th Edition, Butterworth	4. Seppo A. Korpela., "Priniciple of Turbomachinery", John Wiley and Sons Ltd, 2012

Resources	2. *Heinemann, U.K.,2010* 3. *Viktor Gelpke, "Hydraulic turbines their design and installation", Research press, 2010*	5. *Yahya.S.M, "Turbines, Fans and Compressors", 3rd Edition, Tata McGraw Hill Publications, 2010* 6. *Venkanna. B.K, "Fundamentals of Turbomachinery", 4th Edition, New Delhi, PHI Learning Pvt. Ltd, 2011.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate Create	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr.R.Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*Dr K KARUNAMURTHY Associate Professor School of Mechanical and Building Sciences VIT Chennai*	*Mr. S.Bharath Subramaniam, Assistant Professor, SRMIST*
2. Dr.A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*Mr. Udhayakumar Balaji Senior Piping Engineer Petrofac Engineering services India ltd*	*Dr. M. Cheralathan, SRMIST*

Course Code	18MEE445T	Course Name	THERMAL ENERGY STORAGE SYSTEMS	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*18MEC101T-Thermodynamics*	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 with the techniques used for storing various forms of energy*
CLR-2 :	*Understand the sensible thermal energy storage systems and materials*
CLR-3 :	*Understand the latent and thermochemical energy storage systems.*
CLR-4 :	*Understand the properties of storage materials and heat transfer fluids*
CLR-5 :	*Know the various techniques used for storing thermal energy in heating/cooling applications and energy savings*
CLR-6 :	*Be familiar with the Thermal energy storage systems and its applications.*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Familiarize with the techniques used for storing various forms of energy*	*1*	*90*	*80*	*H*						*L*							*H*	
CLO-2 :	*Understand the sensible thermal energy storage, material and methodology*	*12&3*	*90*	*80*	*H*	*M*					*L*							*H*	
CLO-3 :	*Understand the latent and thermochemical energy storage systems.*	*12&3*	*90*	*80*	*H*	*M*					*M*							*H*	
CLO-4 :	*Understand the properties of storage materials and heat transfer fluids*	*1&2*	*90*	*80*	*H*				*H*		*M*							*H*	
CLO-5 :	*Know the various techniques used for storing thermal energy in heating/cooling applications and energy savings*	*1&2*	*90*	*80*	*H*	*L*			*L*		*H*							*H*	
CLO-6 :	*Be familiar with various techniques used for storing thermal energy in heating/cooling applications and energy savings*	*12&3*	*90*	*80*	*H*	*L*			*M*		*M*							*H*	

		Energy Storage	Sensible Thermal Energy Storage Systems	Latent Thermal And Thermochemical Energy Storage Systems	Thermal Energy Storage Materials	Thermal Storage Applications And Energy Savings
Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Basics of Energy storage and its types*	*Sensible Thermal Energy Storage (STES) system and its types*	*Latent Thermal Energy Storage (LTES) system and its types*	*Thermal energy storage materials - Classification, thermosphysical properties*	*Cool Thermal Energy Storage (CTES) concept and comparison of storage technologies*
S-2	SLO-1	*Energy storage by mechanical medium*	*Selection of sensible thermal energy storage materials and methodologies*	*Types and properties of latent heat storage materials and cooling/Heating load calculations*	*Various methods to improve the thermophysical properties of PCM*	*Cool thermal energy storage in process cooling*
S-3	SLO-1	*Energy storage by chemical medium*	*Properties of sensible heat storage materials*	*Encapsulation techniques of LTES (PCM) materials*	*selection criteria for thermal energy storage materials*	*CTES systems building air conditioning applications*
S-4	SLO-1	*Low and Medium temperature thermal storage systems*	*Sensible cooling and heating load calculations*	*Performance assessment of LTES system in building*	*Phase Change Materials – classifications and properties*	*Solar energy storage – passive heating and cooling, green house heating*
S-5	SLO-1	*High temperature thermal storage systems*	*STES Technologies, storage tanks using water and rock bed thermal storage*	*Passive and active LTES systems*	*PCM selection for heating and cooling applications*	*Drying and heating for process industries*
S-6	SLO-1	*Necessity of TES, types of TES technologies and Comparison of thermal energy storage technologies*	*Solar pond thermal storage and building structure thermal storage*	*Thermochemical energy storage principles and materials*	*Heat transfer fluids and properties*	*Solar power plant applications.*

S-7	SLO-1	*Seasonal thermal energy storage Principle*	*Passive solar heating storage*	*Thermochemical energy storage systems - open adsorption energy storage system and closed adsorption energy storage system*	*Selection of heat transfer fluid for heating and cooling applications*	*TES and Energy Savings - utilization of waste or surplus energy, reduction of demand charges and deferring equipment purchases*
S-8	SLO-1	*Seasonal (Source) TES technologies - aquifer thermal storage, borehole thermal storage and cavern thermal storage*	*Active solar heating storage*	*Closed absorption energy storage system solid/gas, thermochemical energy storage system and thermochemical accumulator energy storage system*	*Measuring instruments for thermophysical properties*	*Additional energy savings considerations for TES*
S-9	SLO-1	*Earth-to-air thermal storage, energy piles thermal storage, sea water thermal storage, rock thermal storage and roof pond thermal storage*	*High temperature Sensible Thermal Energy Storage system*	*Floor heating system using thermochemical energy storage and thermochemical energy storage for building heating applications*	*Necessity of improving thermophysical properties*	*Case studies for TES energy savings*

Learning Resources	1. *R. Parameshwaran and S. Kalaiselvam, "Thermal Energy Storage Technologies for Sustainability: Systems Design, Assessment and Applications", Academic Press Inc, 23 September 2014.* 2. *Ibrahim Dincer and Marc A. Rosen, "Thermal Energy Storage Systems and Applications", 2nd Edition, John Wiley and Sons Ltd., 2011.* 3. *Luisa F. Cabeza, "Advances in Thermal Energy Storage Systems: Methods and Applications", October 31, 2014* 4. *Charles E. Dorgan, James S. Elleson, "Design Guide for Cool Thermal Storage", ASHRAE, Atlanda, 1993.*	5. *R. Velraj"Sensible heat Storage for solar heating and cooling systems" in the book titled "Advances in Solar Heating and Cooling - Pages 399 - 428, Elsevier Publication, 2016* 6. *ASHRAE, "Handbook of Fundamentals", American Society of Heating Refrigeration and Air Conditioning Engineers, New York, 1993.* 7. *Alternate fuels for IC Engines: Liquid fuels, Gaseous fuels - properties, advantages and disadvantages, Emissions from engines – Emission standards – Euro, BS*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr.R.Kalimuthu, ISRO, Mahendragiri,r_kalimuthu@vssc.gov.in	*VELRAJ R Professor Institute for Energy Studies, Anna University Chennai 600 025Email: velrajr@annauniv.edu*	*Mr. A.Sathishkumar Assistant Professor, Department of Mechanical Engineering SRM IST Email: sathishkumar.a@ktr.srmuniv.ac.in*
2. Dr.A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*Raju Abraham,Sc-F National Institute of Ocean Technology Chennai 600 100 Ph 044-6678 3339 Email: abraham@niot.res.i*	*Dr. M. Cheralathan Professor, Department of Mechanical Engineering SRM IST Email: cheralathan.m@ktr.srmuniv.ac.in*

Course Code	18MEE446T	Course Name	Design of Heat exchangers	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*NIL*	Co-requisite Courses	*Heat and mass Transfer*	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 :	*Gain knowledge on the basics of Heat Exchanger*
CLR-2 :	*Familiarize with Design Aspects of heat exchangers*
CLR-3 :	*Acquire the basic skills acquired to design the double pipe and shell and tube heat exchangers*
CLR-4 :	*Acquire the basic skills acquired to design the compact and plate heat exchangers*
CLR-5	*familiarize with the condensers and evaporators*
CLR-6	*familiarize with the design of heat exchangers*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)															
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3	
CLO-1 :	*understand the fundamentals of heat exchanger*	*1 2 3*	*90*	*85*	*H*			*M*												
CLO-2 :	*Understand the various design aspects of heat exchangers*	*1 2 3*	*90*	*85*	*H*		*H*	*M*												
CLO-3 :	*Evaluate the design of double pipe and shell and tube heat exchangers*	*1 2 3*	*90*	*85*	*H*	*H*	*H*	*M*												
CLO-4 :	*Evaluate the design of compact and plate type heat exchangers*	*1 2 3*	*90*	*85*	*H*	*H*	*H*	*M*												
CLO-5:	*Familiarize with design of various types of condensers and evaporators*	*1 2 3*	*90*	*85*	*H*	*H*	*H*	*M*												
CLO-4:	*To understand with the design of heat exchangers*	*1 2 3*	*90*	*85*	*H*	*H*	*H*	*M*												

		Fundamentals Of Heat Exchanger	Design Aspects Of Heat Exchangers	Double Pipe Heat Exchangers And Shell & Tube Heat Exchangers	Compact And Plate Heat Exchanger	Condensers And Evaporators
Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Introduction, classification of heat exchangers, Recuperator and Regenerator*	*Introduction, effect of turbulence,*	*Introduction, Thermal design and analysis of inner tube and outer tube*	*Classification of compact heat exchangers, Merits and Demerits of Compact heat exchangers*	*Types of Condensers,*
S-2	SLO-1	*Geometry of Construction, Tubular, Plate heat exchangers*	*Effect of friction factor, pressure drop in tube side,*	*hydraulic design and analysis of inner tube and outer tube*	*Design of compact heat exchangers*	*Design of surface condensers- Down-flow*
S-3	SLO-1	*Effect of Extended Surface Heat Exchangers Heat transfer Mechanisms,*	*Effect of Pressure drop in tube bundles.*	*Design of Double Pipe Heat Exchangers-parallel flow & counter flow-problems*	*Factors affecting of compact heat exchangers*	*Types of Condensers, Design of surface condensers- Central-flow*
S-4	SLO-1	*Flow arrangements, Application, Selection of Heat Exchangers.*	*Heat Transfer and pumping power relationship*	*Design of Double Pipe Heat Exchangers-cross flow heat exchanger-*	*Design of plate heat exchangers*	*Design of evaporative condensers-Inverted flow &Regenerative*
S-5	SLO-1	*Overall Heat transfer coefficient, LMTD method for Heat Exchanger analysis for parallel flow heat exchanger*	*Pressure Drop in Bends and fittings*	*Basic components of shell & tube heat exchangers*	*Factors affecting Design of plate heat exchangers*	*Design of evaporative condensers*
S-6	SLO-1	*Overall Heat transfer coefficient, LMTD method for Heat Exchanger analysis for COUNTER flow heat exchanger*	*Effect of fins arrangement ant its geometry on heat transfer*	*Design of shell & tube heat exchangers*	*Operational characteristics of plate heat exchanger*	*Types of Evaporators,*
S-7	SLO-1	*Overall Heat transfer coefficient, LMTD method for Heat Exchanger analysis for CROSS heat exchanger*	*Fouling of Heat exchangers, effect on heat transfer*	*Factors affecting in shell & tube heat exchangers*	*flow arrangements in plate heat exchangers*	*calculation of Evaporator surface and multiple evaporator*

S-8	SLO-1	*ε NTU method for Heat Exchanger analysis*	*Problems in pressure drop and fouling in Heat exchangers*	*Shell side heat transfer. Pressure drop*	*Heat transfer and pressure drop calculations*	*calculation of Evaporator multiple effect*
S-9	SLO-1	*Heat Exchanger design considerations - Material requirement Design codes and its requirement*	*Factors affecting performance of HE/PHE/Condensers/Evaporator*	*Problems on design of shell and tube heat exchangers and its applications*	*Applications of compact and plate heat exchanger*	*Factors affecting in condensers and evaporators of heat changers*

Learning Resources	1. *SadikKakac and Hongtan Liu, "Heat Exchangers Selection, Rating and Thermal Design", CRC Press,2002* 2. *Kern D.Q, "Process Heat Transfer", Tata McGraw Hill , 1997, Reprint 2008* 3. *Ramesh K. Shah, "Fundamentals of Heat Exchanger Design", John Wiley & Sons,2003* 4. *Arthur. P Frass, "Heat Exchanger Design", John Wiley & Sons, 1988.*	5. *Taborek.T, Hewitt.G.F and Afgan.N, "Heat Exchangers, Theory and Practice", McGraw-Hill Book Co.2018* 6. *Kuppan T, "Heat Exchanger design handbook", Marcel Dekker INC, 2000.* 7. *Standards of Tubular Exchanger Manufacturers Association(TEMA), 9th Edition,2007 – www.tema.org* 8. *Wolverine Heat Transfer Data book – III by Wolverine Tube Inc.,*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr.R.Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	Dr. K Karuppasamy Assistant Professor Department of Mechanical Engineering Anna University Regional Campus Tirunelveli - 627 007	Mr. G.Manikandaraja Assistant Professor, Department of Mechanical Engineering SRM IST Email: manikandaraja.g@ktr.srmuniv.ac.in
2. Dr.A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	K.Pasupathi Deputy manager – mechanical- AQUATHERM Engineering Consultants(India) Pvt. Ltd.,	Mr. S. Malarmannan Assistant Professor, Department of Mechanical Engineering SRM IST Email: malarmannan.s@ktr.srmuniv.ac.in

Course Code	18MEE447T	Course Name	COMBUSTION ENGINEERING	Course Category	E	*Professional elective*	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*18MEC101T Thermodynamics*	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:*	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	*Acquire the fundamental knowledge of combustion*			
CLR-2 :	*Gain knowledge on thermodynamics of combustion*			
CLR-3 :	*Understand the kinetics of combustion*			
CLR-4 :	*Understand the types of flames*			
CLR-5 :	*Familiarize with combustion aspects in SI and CI engines*			
CLR-6 :	*Acquire knowledge on combustion reactions and its stages in internal combustion engines*			

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Acquire the knowledge of combustion equations for different air fuel ratios*	*1&2*	*90*	*80*	*H*	*M*												*H*	
CLO-2 :	*Analyzecombustions based on first law and second law of thermodynamics in reacting systems*	*1*	*90*	*80*	*H*	*H*												*H*	
CLO-3 :	*Evaluate the kinetic of combustion and reaction order and its theory*	*1*	*90*	*80*	*H*	*H*		*M*										*H*	
CLO-4 :	*Acquire the knowledge of flames characteristics and its types*	*1&2*	*90*	*80*	*H*	*H*		*M*										*H*	
CLO-5 :	*Understand the stages of combustion in SI and CI engines and acquire knowledge with normal and abnormal combustion.*	*1&2*	*90*	*80*	*H*													*H*	
CLO-6 :	*Understand the emission norms and its control method*	*1*	*90*	*80*	*H*						*H*							*H*	

		Combustion Of Fuels	Thermodynamics Of Combustion	Kinetics Of Combustion	Flames	Engine Combustion
Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Combustion engineering and its importance*	*Thermo-chemistry first law analysis of reacting systems*	*Rates of reaction*	*Different types of flames Laminar and turbulent*	*Combustion in SI and CI engines*
S-2	SLO-1	*Combustion behavior with different air composition*	*To understand the reacting system and calculations on first law of thermodynamics*	*Determination of rates of reaction*	*Premixed and diffusion flames*	*Stages of combustion in SI and CI engines,*
S-3	SLO-1	*Combustion equations for Theoretical air*	*Acquire knowledge on Adiabatic combustion Temperature*	*Reaction order and molecularity complex reactions*	*Laminar Jet Flame Height – Turbulent flame Lift-Off Height and Blowout Limit.*	*Advanced techniques of combustion in IC engines-learn burn engine –HCCI engine*
S-4	SLO-1	*Combustion equations for excess air*	*Adiabatic combustion Temperature calculations*	*Determination of reaction order and molecularity complex reactions*	*Fuel burning velocity, Determination of Burning velocity, Factors affecting burning velocity*	*Normal combustion and abnormal combustion*
S-5	SLO-1	*Proper Air fuel ratio for combustion*	*Second law analysis of reacting systems*	*Chainreactions - Arrhenius rate equation, collection theory*	*Droplet Evaporation and Combustion*	*Emission norms in Heavy duty and light duty vehicles and its standards BS and Euro norms*
S-6	SLO-1	*Equivalence Ratio*	*Criterion for chemical Equilibrium*	*Calculation on Chain reactions - Arrhenius rate equation, collection theory*	*Flame Quenching, flammability*	*Emissions from premixed combustion*
S-7	SLO-1	*Exhaust gas composition*	*Determination of equilibrium constant for gaseous mixtures*	*Activated complex theory*	*Flame by ignition*	*Emission from non-premixed combustion*
S-8	SLO-1	*Air fuel ratio from exhaust gas composition*	*Evaluation of equilibrium composition*	*Explosive and general oxidative*	*Flame stabilization in open burners*	*Reasons of HC, sulphur , PM, $NO_x$and CO emissions in engines*
S-9	SLO-1	*Heating value of fuels*	*Chemical availability*	*Characteristics of fuels on Explosive and general oxidative*	*Methods to stabilize the flame in open burner*	*Control of HC, sulphur , PM, NO_x and CO emissions in engines*

Learning Resources	1. *Stephen.R.Turns, "An Introduction to Combustion concepts and applications", 2nd Edition, McGraw Hill Book Company, Boston, Edition 3,2011.* 2. *Ganesan.V, "Internal Combustion Engines", Tata McGraw-Hill, New Delhi,2009.* 3. *Ramalingam.K.K, "Internal Combustion Engines - Theory and practice",SciTech Publications India Pvt. Ltd., Chennai, 2010.* 4. *Thipse.S.S, "Internal Combustion Engines", Jaico Publication House, 2010.*	5. *Thipse.S.S, "Alternate Fuels", Jaico Publication House., 2010.* 6. *Mathur.M.L, and Sharma.R.P, "A course in Internal Combustion Engines",Dhanpat Rai & Sons, New Delhi, 2010.* 7. *Heywood.J.B, "Internal Combustion Engine Fundamentals", McGraw Hill International, New York, 2008.* 8. *Domkundwar.V.M, "A course inInternal Combustion Engines", Dhanpat Rai & Sons, 2010.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr.R.Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*Dr. K.KarunamurthyAssociate Professor, Department of Mechanical Engineering VIT –Chennai campus*	*Mr. M.Sivashankar Assistant Professor, Department of Mechanical Engineering SRM IST –KTR campus*
2. Dr.A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*Mr.P.Balaji Manager Product Development HVAC Division Ashok LeylandChennai*	*Dr. M. Cheralathan, SRMIST*

Course Code	18MEE448T	Course Name	SUSTAINABLE ENERGY SYSTEMS	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	The purpose of learning this course is to:	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	*be familiar with the energy scenario*			
CLR-2 :	*be familiar with environmental impactof energy generation*			
CLR-3 :	*understand the various energy conservation options and measures*			
CLR-4:	*be familiar with the energy policies*			
CLR-5:	*be familiarwith the sustainable development and life-cycle analysis*			
CLR-6:	*be familiar with energy conservation, policies and sustainability of energy systems.*			

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*acquire knowledge on the energy scenario.*	*1&2*	*90*	*80*	*H*						*M*								
CLO-2 :	*acquire knowledge on environmental impactof energy generation*	*1,2&3*	*90*	*80*	*H*			*M*			*H*								
CLO-3 :	*acquire knowledge on basic the energy conservation measures*	*1,2&3*	*90*	*80*	*H*			*M*			*H*					*L*			
CLO-4:	*understand the basic energy policies*	*1*	*90*	*80*	*H*						*H*					*L*			
CLO-5:	*acquire knowledge on basic the sustainable development and life-cycle analysis*	*1*	*90*	*80*	*H*						*H*					*L*			
CLO-6:	*acquire knowledge on energy conservation, policies and sustainability of energy systems.*	*1,2&3*	*90*	*80*	*H*			*M*			*H*								

		Energy scenario	Environmental impact ofenergy generation and utilization	Energy conservation	Sustainable development and Energy policies	Life-cycle assessment and Ecology
Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Basics of sustainability and sustainable energy sources*	*Global warming and acid precipitation,*	*Energy conservation measures*	*Sustainable energy strategies*	*General description of LCA*
S-2	SLO-1	*Introduction to conventional energy resources*	*Analysis of modeling of earth's climate,*	*Improvement Factors of Energy Conservation*	*Key expectations from implementation of green energy strategies and policies*	*LCA methodology*
S-3	SLO-1	*Introduction to non-conventional energy resources*	*Radiation balance of earth planet*	*Energy conservationcase studies*	*Interdependence of the factors affecting sustainable development*	*Energetic life-cycle analysis*
S-4	SLO-1	*World energy scenario – Conventional energy sources.*	*Greenhouse gases and radiative forcing Concept*	*Energy management-understanding energy costs, Bench marking,Energy performance*	*Modeling instruments and case studies*	
S-5	SLO-1	*World energy scenario – Non-Conventional energy sources.*	*Global warming potentials*	*Energy management policies*	*Sustainable assessment of solar energy*	*LCA of solar PV and thermal systems*
S-6	SLO-1	*Indian energy scenario – Conventional energy sources.*	*Anthropogenic effect on climate and its control*	*Energy conversation in thermal systems*	*Sustainable assessment of fossil fuel*	*LCA of hydrogen-fuel cell vehicles*
S-7	SLO-1	*Indian energy scenario – Non-Conventional energy sources.*	*Impact of energy efficiency*	*Energy conversation in electrical systems*	*fossil fuelcombustion*	*LCA of gasoline vehicles*
S-8	SLO-1	*Energy forecasting*	*other environmental impact aspects and cogeneration*	*Introduction to energyaudit*	*Assessment of green energy strategies*	*Case study, comparative LCA of hydrogen-fuel cells vsgasoline*

						vehicles
S-9	SLO-1	*Energy security*	*Problems in cogeneration*	*Case study in energyaudit*	*Green energy–based sustainability ratio*	*Case study, comparative LCA of conventional and alternative vehicles*

Learning Resources	1. *Dincer, C. Zamfirescu, "Sustainable Energy Systems and Applications", Springer, 2012.* 2. *Frank Kreith, Susan Krumdieck , "Principles of Sustainable Energy Systems", 2nd Edition, Taylor & Francis, 2014.* 3. *Muthu, Subramanian Senthilkannan, "Social Life Cycle Assessment An Insight", Springer, 2015.*	4. *Demirel, Yaşar, "Energy Production, Conversion, Storage, Conservation, and Coupling", Springer, 2016.* 5. *https://beeindia.gov.in/sites/default/files/1Ch1.pdf* 6. *http://www.mospi.nic.in/sites/default/files/publication_reports/Energy_Statistics_2017r.pdf*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate Create	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr.R.Kalimuthu, ISRO, Mahendragiri,r_kalimuthu@vssc.gov.in	*Dr. R.Velraj, Professor, Institute for Energy Studies,Anna University, Chennai, India - 600025*	*S. Arul Kumar, SRMIST.*
2. Dr.A.Velayutham, DRDO, Avadi, velayudham.a@cvrde.drdo.in	*Dr.Raju Abraham, Scientist –F, National Institute of Ocean Technology Chennai – 600 100*	*Dr.S. Manikandan, SRMIST.*

Course Code	18MEE449T	Course Name	FUEL CELL TECHNOLOGY	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 learn:
CLR-1:	The basics of fuel cell technology
CLR-2:	The concepts of fuel cell electrochemistry
CLR-3:	The major types of fuel cells and their modes of operation
CLR-4:	The methods of production, storage and utilization of hydrogen as a fuel
CLR-5:	The application of fuel cells in power cogeneration
CLR-6:	The Safety issues and cost expectation

Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	Learning 1: Level of Thinking (Bloom)	Learning 2: Expected Proficiency (%)	Learning 3: Expected Attainment (%)	PLO 1: Engineering Knowledge	PLO 2: Problem Analysis	PLO 3: Design & Development	PLO 4: Analysis, Design, Research	PLO 5: Modern Tool Usage	PLO 6: Society & Culture	PLO 7: Environment & Sustainability	PLO 8: Ethics	PLO 9: Individual & Team Work	PLO 10: Communication	PLO 11: Project Mgt. & Finance	PLO 12: Life Long Learning	PSO 1	PSO 2	PSO 3
CLO-1:	Understand the basics of fuel cell and fuel cell thermodynamics	1&2	90	80	H														
CLO-2:	Understand the fuel cell electrochemistry&Implications and use of fuel cell polarization curve.	1&2	90	80	H						H								
CLO-3:	The major types of fuel cells and their modes of operation such as Polymer electrolyte membrane fuel cell,Direct methanol fuel cells,Alkaline fuel cell,Molten Carbonate fuel cell&Solid oxide fuel cell	1&2	90	80	H						H								
CLO-4:	The methods of production, storage and utilization of hydrogen as afuel	1&2	90	80	H														
CLO-5:	The methods of production, storage and utilization of hydrogen as afuel	1&2	90	80	H														
CLO-6:	Understand the Fuel Processor &Safety issues and cost expectation	1	90	80	H						H								

		Introduction to Fuel Cells And Fuel Cell Thermodynamics	Fuel Cell Electrochemistry	Types Of Fuel Cells	Hydrogen Production, Storage And Utilization	Application Of Fuel Cells In Power Cogeneration
Duration (hour)		9	9	9	9	9
S-1	SLO-1	Introduction and overview of fuel cell technology: A simple fuel cell, fuel cell advantages and disadvantages	Fuel cell reaction kinetics	Classification of fuel cells	Hydrogen: Its merit as a fuel, Production methods: from fossil fuels, electrolysis, thermal decomposition	Fuel cell power plant, Balance of fuel cell power plant.
S-2	SLO-1	Basic fuel cell operation, Layout of a Real Fuel Cell: The Hydrogen–Oxygen Fuel Cell with Liquid Electrolyte.	Introduction to electrode Kinetics.	Polymer electrolyte membrane fuel cell (PEMFC)	Production method from photochemical.	Fuel cell power plantstructure.
S-3	SLO-1	Difference between fuel cell and batteries, fuel choice.	Electro Chemical Energy Conversion – Factors affects Electro Chemical Energy Conversion.	Direct methanol fuel cells (DMFC)	Production method from photocatalytic, hybrid.	Cogeneration
S-4	SLO-1	Overview of types of fuel cells (with emphasis on PEMFC and DMFC technology)	Conversion of chemical energy to electricity in a fuel cell	Alkaline fuel cell (PAFC)	Hydrogen storage methods: Onboard hydrogen storage.	Benefits and Drawbacks of fuel cell power plant.
S-5	SLO-1	Fuel cell thermodynamics: Thermodynamics review, Application of first and second law to fuel cells	Reaction rate	Molten Carbonate fuel cell (MCFC)	Chemical storage & physical storage.	Fuel cell electric vehicles.
S-6	SLO-1	Heat Potential of a fuel: Enthalpy of reaction,	Butler -Volmer equation.	Solid oxide fuel cell (SOFC)	In metal and alloy hydrides.	Motor cycles and bicycles, airplanes

		Work potential of a fuel: Gibbs free energy				
S-7	SLO-1	*Predicting reversible voltage of a fuel cell under nonstandard-stateconditions.*	*Fuel cell charge*	*Comparison of fuel cell,*	*Carbon nanotubes.*	*Fueling stations.*
S-8	SLO-1	*Basic Parameters of Fuel Cells. Fuel cell efficiency.*	*Mass transport.*	*Performance behavior*	*Glass capillary arrays - pipeline storage and hydrogenutilization.*	*Fuel processor and fuel cell stack.*
S-9	SLO-1	*Basic Parameters of Fuel Cells. Fuel cell efficiency., Comparison with Carnot efficiency.*	*Implications and use of fuel cell polarization curve.*	*Proton Exchange Membrane Fuel Cells.*	*Glass capillary arrays - pipeline storage and hydrogenutilization.*	*Safety issues and cost expectation.*

Learning Resources	*1. O'Hayre, R. P., S. Cha, W. Colella, F. B. Prinz, "Fuel Cell Fundamentals", Wiley, NY 2006.* *2. Viswanathan. B, AuliceScibioh, M, "Fuel Cells – Principles and Applications", Universities Press (India) Pvt., Ltd., 2009.* *3. Bagotsky .V.S, "Fuel Cells",Wiley, 2009.*	*4. DetlefStolten, "Hydrogen and Fuel Cells: Fundamentals, Technologies and Applications", 2010* *5. Larminie .J, Dicks A. "Fuel Cell Systems", 2nd Edition, Wiley, 2003.* *6. Barclay .F.J. "Fuel Cells, Engines and Hydrogen", Wiley, 2009.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
Babu C Chief Consultant Conserve Consultant private Limited Hyderabad	*Dr,Joseph Daniel, Associate Professor, School of Mechanical and Building Sciences, VIT Chennai*	*Mr. S. Rajendra Kumar, SRMIST*
C. Anand Raj, Head Green Initiative, Infosys Chennai	*Dr. Rayapati Subbarao, Associate Professor, NITTR Kolkata*	*Mr. V. Thirunavukkarasu, SRMIST*

Course Code	18MEE450T	Course Name	MODELING OF THERMAL SYSTEMS	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Thermodynamics Fluid Mechanics Heat Transfer*	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 the thermal system design*
CLR-2 :	*DevelopMathematical models for the thermal systems*
CLR-3 :	*Apply numerical analysis to solve the mathematical models*
CLR-4 :	*Familiarize with different optimization methods*
CLR-5 :	*Apply optimization methods in problem solving of thermal systems*
CLR-6 :	*Evaluate the economic factors involved in design and application of thermal systems*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)													
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Understand system design and steps involved in the formulation of the design process*	*1& 2*	*85*	*75*	*H*	*M*	*M*	*M*							*L*				
CLO-2 :	*Development of mathematical models from the physical system*	*1&2*	*85*	*75*	*H*	*H*	*M*	*H*							*M*				
CLO-3 :	*Solve the mathematical models using numerical analysis*	*1&2*	*85*	*75*	*H*	*H*	*M*	*H*							*M*				
CLO-4 :	*Explore optimization methods to provide feasible solutions in the design of thermal systems*	*1&2*	*85*	*75*	*H*	*H*	*M*	*H*							*H*				
CLO-5 :	*Evaluate the economic factors in the design and application of thermal systems*	*1,2& 3*	*85*	*75*	*H*	*H*	*H*	*H*							*H*				
CLO-6 :	*familiarize with design and analysis of the thermal systems*	*12&3*	*85*	*75*	*H*	*H*	*M*	*H*							*H*				

Title of the module		Introduction to Thermal System Design	Mathematical Modeling of Thermal systems	Numerical Analysis of Thermal Systems	Optimization Methods	Economics and Financial Aspects of thermal system
Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Engineering design;Design Versus Analysis, Synthesis for Design*	*Importance of Modeling in Design, Basic Features of Modeling*	*Numerical Model for a System*	*Optimization; basic concepts, optimization methods*	*Calculation of Interest, Simple Interest, Compound Interest, Effective Interest Rate*
S-2	SLO-1	*Need for optimization; Thermal system design*	*Types of Models; Analog Models, Mathematical Models, Physical Models, Numerical Models, Interaction Between Models*	*Modeling of Individual Components*	*Optimization of Thermal Systems, Practical Aspects in Optimal Design*	*Profitability estimate; Cost of return earnings*
S-3	SLO-1	*Basic Characteristics of thermal design; Analysis Types*	*Development of Mathematical Modeling, General Procedure, Final Model and Validation*	*System Simulation, Importance of Simulation Methods for Numerical analysis*	*The Lagrange Multiplier Method, Basic Approach, and Physical Interpretation,*	*Data requirements for calculation of various cash flow techniques*
S-4	SLO-1	*Formulation of the Design Problem, Variables, Constraints and Limitations*	*Physical Modeling, Dimensional Analysis, Modeling and Similitude*	*Simulation: Steady& Lumped Systems*	*Significance of the Multipliers, Optimization of Unconstrained Problems*	*Financial analysis; Discounted & non discounted cash flow techniques*
S-5	SLO-1	*Design Types; Conceptual Design, Innovative Conceptual Design ; Modifications in the Design of Existing Systems*	*Development of a Numerical Model Solution Procedures*	*Dynamic Simulation of Lumped Systems*	*Search Methods, Basic Considerations, Importance of SearchMethods,*	*Pay back period method; Average rate of return (ARR) method*
S-6	SLO-1	*Steps involved in the Design Process*	*Curve Fitting; Exact Fit, Best Fit*	*Distributed systems, simulation of large systems*	*Golden Search method and typical exercise problem*	*Simple problems on pay back and ARR*
S-7	SLO-1	*Problems on Thermal Resistance and*	*Problems on exact fit*	*Numerical Simulation Versus*	*Fibonacci Search method*	*Net present value method (NPV);*

		Capacitance		*Real System,*		*Profitablity Index method (PI) ; Simple problems*
S-8	SLO-1	*Problems on Building Heating with variable temperatures*	*Problems on best fit*	*Design of Systems for Different Application*	*Problems on Fibonacci Search method*	*Internal rate of return method (IRR) & Benefit cost method (BCR); Simple Problems*
S-9	SLO-1	*Problems on unsteady state heat transfer*	*Problems on nonlinear least squares*	*Problem on numerical modeling of fluid flow systems*	*Steepest Ascent/Descent Method*	*Comparison between NPV and IRR methods*

Learning Resources	1. *Y Jaluria, "Design and optimization of thermal systems", Tata McGraw Hill, 3rd Edition, New Delhi,2007* 2. *W F Stoecker, "Design of thermal systems", Tata McGraw Hill, 3rd Edition, New Delhi, 1989.* 3. *C Balaji, "Essentials of Thermal System Design and Optimization,", Ane Books, New Delhi 2014*	4. *J S Arora, "Introduction to optimum design", ElesiverPublication , 3rd Edition, 2012* 5. *Bender.E.A , "Introduction to Mathematical Modeling", Dover Publication, 2000*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Expert
R. Mohan Prabhu Senior Engineer, Compression GEA Group, Pune, India	*Dr. VenkataRamanan Professor, Institute of Energy Studies Anna University, Guindy Campus, Chennai – 600025*	*Dr. S. Shashi Kumar, SRMIST*
Joseph ShekharSanthappan Faculty Mechanical Section, Engg. Dept. Shinas College of Technology, Al-Agur, Shinas, Sultanate of Oman.	*Dr. R. Chandrasekhar Research Scientist Dept. of Electrical and Computer Engineering, Colorado State University Fort Collins, Colorando Area, USA*	*Dr. M. Cheralathan, SRMIST*

Course Code	18MEE331J	Course Name	SENSORS AND ACTUATORS FOR AUTOMATION	Course Category	E	*Professional Elective*	L	T	P	C
							2	0	2	3

Pre-requisite Course	*Nil*	Co-requisite Course	*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 :	*Expose the basics of various sensors used in automation*
CLR-2 :	*Impart the fundamental concept of electro-mechanical and fluid power systems*
CLR-3 :	*Provide exposure on practical knowledge of sensors and its measurements*
CLR-4 :	*Impart knowledge in mechanical, magnetic and electromechanical sensors*
CLR-5 :	*Provide the knowledge on the working principle of hydraulic, pneumatic, mechanical and electrical actuators*
CLR-6 :	*Impart the fundamental concept of drives and control system*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLO-1 :	*Understand the different types of sensors used in automation*	*1*	*85*	*80*
CLO-2 :	*Identify suitable sensor for the developments of automation processes*	*2*	*90*	*85*
CLO-3 :	*Develop the automation system by integration of electromechanical sensors and fluid power systems*	*3*	*90*	*80*
CLO-4 :	*Identify the type of actuators and its associated drivers for different application*	*2*	*85*	*80*
CLO-5 :	*Demonstrate effective use of actuators, its elements for the generation, control and conversion of energy for the typical automation system*	*2*	*90*	*80*
CLO-6 :	*Build real time automation system within realistic constraints such as industrial, economic, environmental, ethical, social, health and safety*	*3*	*95*	*85*

Program Learning Outcomes (PLO)														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
H	-	*M*	-	*H*	-	-	-	-	-	-	-	*L*	-	*L*
H	*M*	*L*	*L*	*H*	-	-	-	-	-	-	-	*M*	-	*M*
H	*H*	*H*	*M*	*H*	-	-	-	-	-	-	*M*	*H*	-	*H*
H	*M*	-	-	*H*	-	-	-	-	-	-	*M*	*M*	-	*M*
H	-	-	-	*H*	-	-	-	-	-	-	*M*	*L*	-	*L*
H	*M*	*M*	*M*	*H*	*M*	*M*	*L*	*L*	-	-	*M*	*H*	-	*H*

Duration (hour)		12	12	12	12	12
S-1	SLO-1	*Role of sensors in manufacturing: Importance of estimation in sensing*	*Resistive sensors: Potentiometer*	*Fiber optic sensors – Temperature sensors*	*Pneumatic systems – Types, components*	*Mechanical systems – Types of motion*
	SLO-2	*Role of sensors in manufacturing: Innovative sensor technologies*	*Resistive sensors: Strain gauge*	*Fiber optic sensors – Liquid level sensing*	*Pneumatic systems – working principle*	*kinematics chains*
S-2	SLO-1	*Physical transduction principles: Mechanical, Thermal*	*Inductive sensors: Methods of achieving inductance*	*Fluid flow level sensing*	*Hydraulic systems – Types, components*	*Cams, gears, ratchet and pawl*
	SLO-2	*Physical transduction principles: Electrical, Magnetic*	*Ferromagnetic plunger type, Transformer type*	*Micro bend sensing*	*Hydraulic systems – working principle*	*belt and chain drives*
S-3	SLO-1	*Classification of sensors: property based*	*Capacitive sensors: parallel plate capacitive sensor*	*Film sensors – Thick film sensors*	*Directional control of valves*	*Electrical systems – mechanical switches*
	SLO-2	*Classification of sensors: applications based*	*Serrated plate capacitive sensor*	*Thin film sensors*	*Valve symbols*	*solid state switches*
S-4	SLO-1	*Characterization: Electrical*	*Force/stress sensors using Quartz Resonators*	*Nano sensors - Introduction*	*Pressure control valves*	*Solenoids*
	SLO-2	*Characterization: Mechanical*	*Various beam designs*	*Nano structure, operation mechanism*	*Cylinders*	*DC motors*
S-5	SLO-1	*Characterization: Thermal, Optical*	*Ultrasonic sensors: introduction*	*Smart sensors –Introduction, properties*	*Rotary Actuators (Hydraulic type) components*	*Stepper motors – introduction, specifications*
	SLO-2	*Characterization: Biological and Chemical*	*Principles, Materials, Applications*	*Smart sensors – primary sensors, Compensation*	*Working principle*	*Stepper motors – types*

S-6	SLO-1	*Static characteristics of sensors*	*Magnetic sensors: Types*	*Functional integration of sensors*	*Rotary Actuators (Pneumatic type) components*	*Stepper motor – control*
	SLO-2	*Dynamic characteristics of sensors*	*Magnetic sensors: working principles*	*Smart sensors – information coding/processing*	*Working principle*	*Stepper motor - characteristics*
S 7-8	SLO-1	*Lab 1: Measurement of speed and displacement using linear and rotary sensors*	*Lab 4: Temperature measurement using RTD and thermocouple*	*Lab 7: Study on eddy current sensor for thickness measurement*	*Lab 10: Simulation of single and double acting cylinder circuits using different directional control valves*	*Lab 13: Speed and torque characterization and sequence control of stepper motor*
	SLO-2					
S 9-10	SLO-1	*Lab 2: Force and Torque measurement using strain gauge*	*Lab 5: Experimentation on voltage, current, power, and frequency measurement*	*Lab 8: Study on ultrasonic sensors for material fault diagnosis*	*Lab 11: Sequencing of pneumatic circuits*	*Lab 14: Closed loop position and velocity control of a DC servo motor*
	SLO-2					
S 11-12	SLO-1	*Lab 3: Pressure measurement system using sensors*	*Lab 6: Experimentation with tactile sensor for force and touch detection*	*Lab 9: Simulation of hydraulic circuits in a hydraulic trainer*	*Lab 12: Simulation of logic and electro-pneumatic circuits*	*Lab 15: Speed and torque characterization and control of DC motors*
	SLO-2					

Learning Resources	1. *Patranabis D., "Sensor and Actuators", Prentice Hall of India (Pvt) Ltd., 2013.* 2. *Bolton W., "Mechatronics", Fourth edition, Pearson publishers, 2010.* 3. *Andrzej M. Pawlak., "Sensors and Actuators in Mechatronics – Design and Applications", CRC press, Taylor and Francis group, 2007.*	4. *Clarence W de Silva, "Sensors and Actuators – Engineering system instrumentation", second edition, CRC press, Taylor and Francis group, 2016.* 5. *Ian R. Sinclair, "Sensors and Transducers", third edition, Newnes, 2001.* 6. *R.K.Rajput, "A text book of Mechatronics", S.Chand & Company Limited, Second edition, 2009.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% Weightage)								Final Examination (50% Weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*20%*	*20%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*
	Understand										
Level 2	Apply	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*
	Analyze										
Level 3	Evaluate	*10%*	*10%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*
	Create										
	Total	100%		100%		100%		100%		100%	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr. P.Kartikeyan, Head – Operations Improvement, Nokia India, kartikeyan.p@nokia.com*	1. *Dr.K.Senthilkumaran, Assistant professor, IIITDM, Kancheepuram. skumaran@iiitdm.ac.in*	*1. P.Haja Syeddu Masooth, SRM IST*
2. *Dr. R. Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in*	2. *Dr.B.Mohan, Professor, Anna University, mohan@mitindia.edu*	*2. Dr.R.Rajaraman, SRM IST*
3. *Dr. A. Velayutham, DRDO, Avadi, velayutham.a@cvrde.drdo.in*		

Course Code	18MEE332J	Course Name	MICROPROCESSOR AND MICROCONTROLLERS	Course Category	E	*Professional Elective*	L	T	P	C
							2	0	2	3

Pre-requisite Course	*Nil*	Co-requisite Course	*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 :	*Expose the basics of microprocessors*
CLR-2 :	*Introduce the need and use of Interrupt structure*
CLR-3 :	*Impart the applications of microprocessor*
CLR-4 :	*Enable to understand the architecture of microcontroller*
CLR-5 :	*Expose the instruction set and register set of microcontroller*
CLR-6 :	*Impart knowledge about different peripheral interfacing devices*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Understand the basics of microprocessors*	*1*	*95*	*90*	*H*	*L*	*M*	*L*	*H*	-	-	-	-	-	-	-	*M*	-	*M*
CLO-2 :	*Use the processors for various applications*	*3*	*90*	*85*	*H*	*L*	*L*	*M*	*M*	-	-	-	*L*	-	-	*L*	*M*	-	*H*
CLO-3 :	*Develop the assembly language programs*	*1*	*85*	*80*	*H*	*L*	*L*	*L*	*M*	-	-	-	*M*	-	-	*L*	*M*	-	*L*
CLO-4 :	*Understand the interfacing techniques*	*3*	*80*	*75*	*H*	*L*	*L*	*M*	*H*	-	-	-	*M*	-	-	*L*	*M*	-	*M*
CLO-5 :	*Understand the internal architecture of microcontroller*	*2*	*80*	*75*	*H*	*L*	*L*	*M*	*M*	-	-	-	*M*	-	-	*L*	*M*	-	*L*
CLO-6 :	*Use microcontroller with different peripherals*	*3*	*90*	*85*	*H*	*L*	*M*	*M*	*H*	-	-	-	*H*	-	-	*L*	*H*	-	*M*

Duration (hour)		12	12	12	12	12
S-1	SLO-1	*Introduction to 8086 microprocessor- Internal Architecture*	*Peripherals and Interfacing-Interfacing I/O Ports*	*Application of Microprocessor- Microprocessor based Aluminium Smelter Control, Process Description*	*Introduction to 8051 Microcontroller- Microcontroller Block Diagram*	*Microcontroller Interfacing and Applications- System Design - Traffic Light Control*
	SLO-2	*Physical Memory Organization*	*Interfacing I/O Ports*		*Microcontroller Block Diagram*	*Switching Circuit*
S-2	SLO-1	*Addressing Modes*	*8086 Interrupts*	*Microprocessor based Aluminium Smelter Control, Process Description*	*Instruction Set*	*8051 Hardware Interface - Operation Sequence*
	SLO-2		*Interrupt Responses*			
S-3	SLO-1	*Instruction Set*	*Direct Memory Access (DMA)*	*Lab 7: Program to perform following conversion : BCD to ASCII BCD to hexadecimal*	*Register Set*	*System Design - Washing Machine Control*
	SLO-2		*I/O Mode*			*Washing Cycle*
S-4	SLO-1	*Lab1: Basic arithmetic operations*	*Lab 4: Sorting of array in: Ascending order*		*Lab 10: A/D and D/A converter interface*	*Lab 13: Fabrication of 8-bit LED interfaces for 8085 kit through 8155 and 8255*
	SLO-2					
S-5	SLO-1		*Lab 4: Sorting of array in: Descending order*	*Design of Microprocessor based Pattern Scanner System BCD to hexadecimal*		
	SLO-2					
S-6	SLO-1	*I/O Addressing Capability*	*Interfacing Analog to Digital Data Converters*	*Design of Microprocessor based Pattern Scanner SystemBCD to hexadecimal*	*Memory*	*LCD Interfacing*
	SLO-2				*I/O Addressing*	*Keyboard Interfacing*
S-7	SLO-1	*General Bus Operation*	*Interfacing Digital to Analog Converters*	*Lab 8: Program to demonstrate decision making and looping operation*	*Interrupts*	*Relays and opt Isolators*
	SLO-2					*Stepper Motor Interfacing*
S-8	SLO-1	*Lab2: Basic Logical operations*	*Lab 5: Program to demonstrate string*		*Lab 11: Key board and Display*	*Lab 14: Interfacing and programming*

	SLO-2		*manipulations*			*of 8255. (E.g. traffic light controller)*
S-9	SLO-1			*Design of an Electronic Weighing Bridge*		
	SLO-2					
S-10	SLO-1	*Assembler Directives*	*Stepper Motor Interfacing*	*Design of an Electronic Weighing Bridge*	*Design of Microcontroller based Length Measurement System for Continuously Rolling Paper*	*DC motor Interfacing*
	SLO-2	*Operators*				*PWM*
S-11	SLO-1	*Lab 3: Transfer of block to another location in reverse order*	*Lab 6: Program to demonstrate Factorial of given numbers*	*Lab 9: Program to demonstrate parameter passing methods*	*Lab 12: Stepper motor interface*	*Lab 15: Interfacing DC motor and Servo motor*
	SLO-2					
S-12	SLO-1					
	SLO-2					

Learning Resources	1. *A K Ray and K M Bhurchandi, "Advanced Microprocessor and Peripherals", McGraw Hill Education private Limited , 2011.* 2. *Krishna Kant, "Microprocessors and Microcontrollers", Eastern Economy Edition, PHI learning private ltd, 2012.* 3. *Douglas V Hall and SSSP Rao, "Microprocessors and Interfacing", Pearson Education, 2012.*	4. *Muhammad Ali Mazidi, Janice Gillispie Mazidi, Rolin D.Mckinlay, "The 8051 Microcontroller and Embedded Systems", McGraw Hill Education private Limited, 2008.* 5. *Ramesh S. Gaonkar, Microprocessor Architecture. Programming and Applications with the 8085, 5th ed., Penram International Publishing (India) Private Limited. 2005*

Learning Assessment											
	Bloom's Level of Thinking	Continious Learning Assessment (50% Weightage)								Final Examination (50% Weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*20%*	*20%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*
	Understand										
Level 2	Apply	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*
	Analyze										
Level 3	Evaluate	*10%*	*10%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*
	Create										
	Total	100%		100%		100%		100%		100%	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. P.Kartikeyan, Head – Operations Improvement, Nokia India, kartikeyan.p@nokia.com	1. Dr.K.Senthilkumaran, Assistant professor, IIITDM, Kancheepuram. skumaran@iiitdm.ac.in	1. Eastus Russel, SRMIST
2. Dr. R. Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	2. Dr.B.Mohan, Professor, Anna University, mohan@mitindia.edu	2. Dr.R.Rajaraman, SRMIST
3. Dr. A. Velayutham, DRDO, Avadi, velayutham.a@cvrde.drdo.in		

Course Code	18MEE333T	Course Name	INDUSTRIAL ROBOTICS AND AUTOMATION	Course Category	E	Professional Elective	L	T	P	C
							3	0	0	3

Pre-requisite Course	Nil	Co-requisite Course	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 :	Introduce the basics of robotic technology and its applications
CLR-2 :	Impart knowledge on robot motion analysis and control
CLR-3 :	Explore the application of robot in manufacturing and assembly
CLR-4 :	Impart knowledge on automation and control technologies in manufacturing
CLR-5 :	Introduce the concept of automated material transport systems
CLR-6 :	Impart knowledge on fundamentals and applications of automated production lines

Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	Understand the basics of robot anatomy, control and sensing system	1	90	85	M	L	L	L	M	-	L	-	M	L	L	-	H	-	H
CLO-2 :	Gain knowledge on robot manipulator kinematics, path control and dynamics	2	90	85	H	M	L	M	M	-	M	-	L	M	L	-	H	-	L
CLO-3 :	Understand the application of robot in manufacturing and assembly	2	90	85	M	M	M	L	M	L	M	-	M	H	L	-	H	-	M
CLO-4 :	Gain knowledge on various elements of automations in manufacturing	2	90	85	L	M	L	M	H	-	L	-	L	L	M	-	H	-	H
CLO-5 :	Understand the concept of automated guided vehicle system for shop floor application	2	90	85	M	L	L	M	H	-	L	-	L	L	M	-	H	-	M
CLO-6 :	Gain knowledge on automated storage and retrieval system and automated assembly system	2	90	85	M	M	L	M	M	-	L	-	M	H	M	-	H	-	H

Duration (hour)		9	9	9	9	9
S-1	SLO-1	Introduction to Robotics	Introduction to manipulator kinematics – position representation	Robot Applications in Manufacturing:	Automation in production systems	Automated material transport systems, storage system and assembly system : Introduction
	SLO-2	History of Robots	forward and reverse transformation of the 2 degree of freedom arm	General consideration in Robot Material Handling	Automated manufacturing system	Automated Guided Vehicle system
S-2	SLO-1	Robot Anatomy	3 degree of freedom arm in two dimensions	Material Transfer Application – pick and place operations	Computerized manufacturing and support systems	AGV types
	SLO-2	Components	4 degree of freedom manipulator in three dimensions	Palletizing and related operations	Reasons for automating	Applications
S-3	SLO-1	Work Volume	Homogeneous transformations and Robot kinematics, parallel kinematics	Machine Loading and unloading	Automation principles and strategies – The USA principle	Vehicle Guidance
	SLO-2	Polar, cylindrical and cartesian	Kinematic equations using Homogeneous transformations	Die casting, plastic moulding	Strategies for Automation and process improvement	Routing
S-4	SLO-1	Robot drive systems	Solving the kinematic equations	Forging and related operations	Automation Migration strategy	Traffic Control
	SLO-2	Hydraulic drive	Examples	Machining operations, Stamping press operations	Manual, automated and automated integrated production	Safety
S-5	SLO-1	Electric drive	A discussion on orientation	Robots used in Spot welding	Basic elements of an Automated System	System Management

	SLO-2	*Pneumatic drive*	*Roll, pitch and yaw for a manipulator wrist mechanism*	*Application and benefits*	*Power to accomplish the Automated Process*	*Autonomous intelligent vehicle*
S-6	SLO-1	*Control systems*	*Manipulator path control – motion types*	*Robots used in Continuous Arc welding*	*Program of instructions*	*Automated storage Systems*
	SLO-2	*Dynamic performance*	*joint space schemes*	*Problems for Robots in Arc welding, applications, features of the welding robot, sensors, advantage and benefits*	*Control system*	*Retrieval Systems*
S-7	SLO-1	*Precision of Movement, Spatial resolution*	*Robot dynamics analysis,*	*Robots used in Spray Coating, and additive manufacturing*	*Advanced automation functions –*	*Carousel Storage Systems.*
	SLO-2	*Accuracy, Repeatability*	*Static analysis,*	*Application and benefits*	*Safety monitoring,*	
S-8	SLO-1	*End Effectors – grippers*	*Compensating for gravity,*	*Other Processing operation using Robots*	*Maintenance and repair diagnostics,*	*Automated assembly system –*
	SLO-2	*tools*	*Robot arm dynamics*	*Drilling, Grinding, Riveting*	*Error detection and recovery*	*system configuration,*
S-9	SLO-1	*Robotic sensors*	*Configuration of a Robot controller*	*Assembly system configurations - Single work station assembly,*	*Levels of automation*	*parts delivery at work stations,*
	SLO-2	*Types of sensors*	*General robot controller elements*	*series assembly system, parallel assembly system*	*Device, machine, cell or system, plant, enterprise levels.*	*applications.*

Learning Resources	1. *"Industrial Robotics Technology, Programmming, and Applications" - Mikell P Groover, Mitchell Weiss, Rogen N Nagel, Nicholas G Odrey, AshishDutta, Tata McGraw Hill Special Indian Edition, 2012.* 2. *"Computer Aided Design and Manufacturing" - K.Lalit Narayan, K.MallikarjunaRao, Prentice Hall of India, 2008.* 3. *"Automation, Production systems, and Computer intergrated Manufacturing"- Mikell P. Groover, Prentice Hall of India, 2008.*	4. *"Industrial Robotics Technology, Programming, and Applications"- Mikell P Groover, Mitchell Weiss, Roger N Nagel 2008* 5. *"Robotics Technology & Flexible Automation" - S.R.Deb, S.Deb 2012* 6. *"Introduction to Robotics in CIM system" - James A Rehg 2002*

Learning Assessment

	Bloom's Level of Thinking	Continious Learning Assessment (50% Weightage)								Final Examination (50% Weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*40%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
Level 2	Apply Analyze	*40%*	-	*40%*	-	*40%*	-	*40%*	-	*40%*	-
Level 3	Evaluate Create	*20%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Total	100%		100%		100%		100%		100%	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. P.Kartikeyan, Head – Operations Improvement, Nokia India, kartikeyan.p@nokia.com	*1. Dr.K.Senthilkumaran, Assistant professor, IIITDM, Kancheepuram. skumaran@iiitdm.ac.in*	*1. E. Sankar, SRMIST*
2. Dr. R. Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*2. Dr.B.Mohan, Professor, Anna University, mohan@mitindia.edu*	*2. Dr.R.Rajaraman, SRMIST*
3. Dr. A. Velayutham, DRDO, Avadi, velayutham.a@cvrde.drdo.in		

Course Code	18MEE334T	Course Name	PLC AND ITS APPLICATIONS	Course Category	E	Professional Elective	L	T	P	C
							3	0	0	3

Pre-requisite Course	Nil	Co-requisite Course	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 :	Impart PLC principle to reduce the human efforts by means of automation
CLR-2 :	Identify the main parts of PLC and hardware components
CLR-3 :	Analyze and interpret typical PLC timer ladder logic programs
CLR-4 :	Acquire knowledge on HMI remote control monitoring in industrial automation
CLR-5 :	Learn PLC process – control design and PID configuration
CLR-6 :	Design PLC control system I/O and its applications

Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	Learning			Program Learning Outcomes (PLO)													
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	Utilize the parts of machine controller diagram including rungs, branches of PLC	2	85	80	M	-	-	-	M	-	-	-	-	-	-	-	L	-	L
CLO-2 :	Understand the equipment used to program a PLC and mnemonic code	2	90	85	M	-	-	-	-	-	-	-	-	-	-	-	M	-	L
CLO-3 :	Gain knowledge on hardwired and Human Machine Interface communicate with PLC	2	85	80	H	-	M-	M	-	-	-	-	-	-	-	-	L	-	M
CLO-4 :	Learn the functions of PLC process – control design and elements	2	85	80	H	-	-	-	-	-	-	-	-	-	-	-	L	-	L
CLO-5 :	Understand basic knowledge of PLCs concepts and its application in industries	3	90	85	H	-	M	M	-	-	-	-	-	-	-	-	M	-	H
CLO-6 :	Develop complete system of PLC to meet industrial tasks	2	85	80	H	M	H	H	M	-	-	-	M	-	M	-	H	-	H

Duration (hour)		9	9	9	9	9
S-1	SLO-1	Introduction	Control system classifications	Advanced program techniques-Introduction	Introduction: level of lontrol & automation	Case studies of manufacturing and process automation
	SLO-2	History of the PLC	Manual and auto control system	Physical components vs program components	Components of control system	PLC interface to a robot
S-2	SLO-1	Principles of operation	Automated system building block	RS Flip Flop, one shot,	Control elements of industrial automation	Case studies of on - off control
	SLO-2	Benefits of PLC	Requirements for industrial control	D Flip Flop, T Flip Flop	Examples of control requirements	Automatic control in manufacturing
S-3	SLO-1	Various parts of PLC	Motor magnetic starter	Forms of counters	Selection criteria for control elements	Water tank level control
	SLO-2	Hardwired system replacement	Process control choices	Counter application	Standardization	Irrigation - Canal water level control & logic diagram
S-4	SLO-1	Functions of PLC	Components of modularized PLC	Sequencers	Signal conversion	Filling of bottle - Case study
	SLO-2	Need for PLCs and its advantages	PLC configuration	Sequential functional chart	Quantification errors and resolution	
S-5	SLO-1	Inputs & Outputs of PLC	Introduction to human machine interface	NAND logic function	Process control system	Conveyor System Speed Control - Case Study
	SLO-2	Common types of mechanical design for PLCs	Device and PLC / HMI configuration	NOR logic function	Control Strategy and types	
S-6	SLO-1	PLC Architecture and Wiring Diagrams	Fundamentals of human machine interfacing	AND ladder Rung	PLC Selection factors	Coal Handling System- Case Study
	SLO-2	Internal structure Architecture of PLC	HMI-PLC application	OR ladder Rung	PLC Families	
S-7	SLO-1	Basic components and their symbols of	Network standards	Types of timer	Feedback control of continuous systems	Multi-Unit Chemical Process- Case

		Ladder diagram				*Study*
	SLO-2	*Functions & function blocks of Ladder diagram*	*Network systems role in industry*	*On/off cyclic timer*	*PLC systems and safety*	
S-8	SLO-1	*Switches& Its types*	*Number systems*	*Simple and complex branches*	*PID control configuration*	*Commissioning of PLC systems*
	SLO-2	*Relay systems*	*PLC data*	*standard format program*	*PID control systems*	*Fault Finding Techniques*
S-9	SLO-1	*PLC size and Applications*	*PLC in automation technology*	*Logical Actuators: solenoid, valves cylinders*	*Design cases: Oven temperature control, supervisory control and data acquisition*	*Power Plant Monitoring and Control*
	SLO-2	*PLCs versus other technologies*	*Examples of commercial systems involving PLC*	*Logical Actuators: hydraulics and pneumatics*	*Position measurement*	*Other Applications of PLC*

Learning Resources	1. *Khaled Kamel, Eman Kamel, "Programmable Logic Controllers, Industrial C", Mc Graw Hill private Ltd, 2014.* 2. *Gar Dunning, "Programmable Logic Controllers, Industrial Control", Mc Graw Hill private Ltd, 2009.* 3. *John R. Hackworth, Federick D. Hackworth , Jr., "Programmable Logic Controllers : Programming Methods and Applications" Prentice Hall Publishing, 2003* 4. *W. Bolton, "Programmable Logic Controllers", Newnes Education private Limited, 2009.* 5. *Frank D, Petruzella, "Programmable Logic Controllers", Mc Graw Hill private Ltd, 2011.* 6. *Hugh Jack, "Automating Manufacturing Systems with PLCs" Mc Graw Hill private Ltd 2007.*	7. *Kelvin T. Erickson, "Programmable Logic Controllers: An Emphasis on Design and Application" Mc Graw Hill private Ltd 2007.* 8. *R. Bliesener, F. Ebel, C. Loffler, "Programmable Logic Controllers", Festo Dicactic, Ltd, 2002.* 9. *Kevin Collins, "PLC Programming for Industrial Automation", Newnes Education private Limited, 2009.*

Learning Assessment

	Bloom's Level of Thinking	Continious Learning Assessment (50% Weightage)								Final Examination (50% Weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*40%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
Level 2	Apply Analyze	*40%*	-	*40%*	-	*40%*	-	*40%*	-	*40%*	-
Level 3	Evaluate Create	*20%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Total	100%		100%		100%		100%		100%	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. P.Kartikeyan, Head – Operations Improvement, Nokia India, kartikeyan.p@nokia.com	*1. Dr.K.Senthilkumaran, Assistant professor, IIITDM, Kancheepuram. skumaran@iiitdm.ac.in*	*1. A. Arunnath, SRMIST*
2. Dr. R. Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*2. Dr.B.Mohan, Professor, Anna University, mohan@mitindia.edu*	*2. Dr.R.Rajaraman, SRMIST*
3. Dr. A. Velayutham, DRDO, Avadi, velayutham.a@cvrde.drdo.in		

Course Code	18MEE335T	Course Name	FLEXIBLE MANUFACTURING SYSTEM	Course Category	E	Professional Elective	L	T	P	C
							3	0	0	3

Pre-requisite Course	*Nil*	Co-requisite Course	*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 :	*Introduce the concepts that can be flexible to the modern competitive environment.*
CLR-2 :	*To impart knowledge of Group Technology*
CLR-3 :	*To impart knowledge about flexible manufacturing systems and its concepts*
CLR-4 :	*Introduce the concepts of manufacturing cell and its systems*
CLR-5 :	*Introduce the concepts JIT and KANBAN system*
CLR-6 :	*To impart knowledge about FMS software structure and description*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Understand the concepts of FMS in the modern competitive environment*	*1*	*90*	*85*	*M*	-	*H*	*L*	*M*	-	*L*	-	*M*	-	*M*	-	*H*	-	*H*
CLO-2 :	*Understand the concepts about Group Technology and various coding schemes*	*2*	*90*	*85*	*H*	-	-	*L*	*M*	-	*M*	-	-	*M*	*M*	-	*H*	-	*H*
CLO-3 :	*Understand the need of FMS layout, applications with scheduling concepts*	*2*	*90*	*85*	*M*	-	*M*	*L*	*M*	-	*M*	-	*M*	*H*	*L*	-	*H*	-	*H*
CLO-4 :	*Understand the concepts of cell, Unattended machining, JIT in detail*	*2*	*90*	*85*	*L*	-	*L*	*L*	*L*	-	-	-	*L*	*L*	*M*	-	*H*	-	*H*
CLO-5 :	*Understand the FMS software modules, ideas in data exchanges*	*2*	*90*	*85*	*M*	-	*H*	*L*	*H*	-	-	-	*L*	-	*H*	-	*H*	-	*H*
CLO-6 :	*Ability to perform Planning, Scheduling and control of FMS*	*2*	*90*	*85*	*M*	-	*H*	*L*	*M*	-	-	-	*M*	*H*	*H*	-	*H*	-	*H*

Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Traditional production planning, forecasting, process planning*	*Introduction to Group Technology*	*Introduction to FMS*	*Manufacturing Cell, Product flow from cell to cell*	*FMS software – Introduction*
	SLO-2	*Estimating, master scheduling, and various steps involved in planning and control*	*Part families*	*Basic components of FMS*	*Classification of Cell*	*General structure and requirements*
S-2	SLO-1	*Problems in production planning and control*	*Introduction to parts classification and coding*	*Application Characteristics of FMS*	*Unattended machining*	*Advantages of FMS software*
	SLO-2	*Cycle of activities*	*Coding system architecture*	*Significance of FMS*	*Features and requirement*	*Activities and functions to be performed by FMS software, within the system*
S-3	SLO-1	*Computer Integrated production management systems*	*Opitz system structure, classification system*	*Types of FMS*	*Differences between FMS and FMC*	*Types of FMS software modules*
	SLO-2	*Cycle of activities in CIPMS*	*MICLASS system*	*Types of FMS layouts*	*Introduction to JIT, Goals*	*Work-order processing*
S-4	SLO-1	*Cost Planning*	*Code system*	*Factors influencing FMS layout*	*Objectives of JIT, Ingredients*	*Data distribution and collection*
	SLO-2	*Cost Control*	*Group Technology machine cells*	*Objectives, AIMS of FMS*	*Quality and Quantity Principles of JIT*	*System diagnostics and maintenance*
S-5	SLO-1	*Inventory types*	*Types of GT machine cells*	*Advantages of FMS*	*Primary quantity JIT principles*	*Tool management*
	SLO-2	*Inventory Management*	*Benefits of Group technology*	*Disadvantages of FMS*	*Benefits of JIT*	*Traffic management and control*
S-6	SLO-1	*Material Requirements Planning*	*Product design benefits, tooling and*	*Area of Application of FMS in an Industry*	*JIT implementation*	*Quality control management*

			setups			
	SLO-2	*Basic MRP concepts*	*Material handling*	*Various equipment and their functions required for an FMS*	*KANBAN/CARD system introduction*	*Fixtures and work piece control*
S-7	SLO-1	*Inputs to MRP*	*Production and inventory control*	*CIM technology*	*Push Vs pull system*	*Planning scheduling and simulation*
	SLO-2	*Master production schedule, bill of materials, Inventory record file*	*Employee satisfaction*	*Hierarchy of CIM*	*Dual card KANBAN*	*Computer simulation*
S-8	SLO-1	*Principles of MRP*	*Process planning procedures*	*Direct Real Time schedule control*	*Dual card KANBAN for milling and drilling*	*General phases of simulation analysis*
	SLO-2	*MRP output reports*	*System planning-objective, guideline,*	*Major functions of FMS host*	*Single card KANBAN concept*	*Functions*
S-9	SLO-1	*Benefits of MRP*	*System definition and sizing-*	*FMS concepts*	*Single card KANBAN- Example*	*FMS hosts*
	SLO-2	*MRP-II*	*Human resources*	*Process routings in an FMS*	*Benefits of KANBAN system*	*Data exchanges*

Learning Resources	1. *"CAD/CAM Computer Aided Design and Manufacturing" - M.Groover&E.Zimmers, Pearson Prentice Hall, 2012* 2. *"Flexible Manufacturing System"- H.K.Shivanand, M.M.Benal, V.Koti, New Age International Pvt Limited, 2006* 3. *"Computer Aided Manufacturing" - P.N RAO, N.K.TIWARI, T.K.KUNDRA, McGraw Hill Education India private Ltd, 2014*	4. *"CAD/CAM Theory and Practice"- Ibrahim Zyed, Sivasubramaniam Tata McGraw Hill International 2011* 5. *"Flexible Manufacturing Cells and Systems" - William .W.LuggenPrentice Hall 1991* 6. *"Automation production Systems & Computer Integrated Manufacturing" - MikellP Groover 1989* 7. *"Handbook of Flexible of Manufacturing Systems" - JHA N.K 1991*

Learning Assessment

	Bloom's Level of Thinking	Continious Learning Assessment (50% Weightage)								Final Examination (50% Weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Understand										
Level 2	Apply	*40%*	-	*40%*	-	*40%*	-	*40%*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Create										
	Total	100%		100%		100%		100%		100%	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. P.Kartikeyan, Head – Operations Improvement, Nokia India, kartikeyan.p@nokia.com	*1. Dr.K.Senthilkumaran, Assistant professor, IIITDM, Kancheepuram. skumaran@iiitdm.ac.in*	*1. M.Kamatchi Hariharan SRMIST*
2. Dr. R. Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*2. Dr.B.Mohan, Professor, Anna University, mohan@mitindia.edu*	*2. Dr.R.Rajaraman, SRMIST*
3. Dr. A. Velayutham, DRDO, Avadi, velayutham.a@cvrde.drdo.in		

Course Code	18MEE432T	Course Name	INTERNET OF THINGS IN AUTOMATION	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

Pre-requisite Course	*Nil*	Co-requisite Course	*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 :	*Acquire knowledge on IoT enabling technologies*
CLR-2 :	*Impart knowledge on work logic of IoT in manufacturing system*
CLR-3 :	*Acquire knowledge on prototyping and production*
CLR-4 :	*To know the role of IoT in laser cutting, 3D printing, CNC milling*
CLR-5 :	*To know the use of smart objects for smart applications*
CLR-6 :	*Track and trace real time manufacturing information*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLO-1 :	*Understand the design principles of connected devices*	*2*	*90*	*80*
CLO-2 :	*Apply IoT models in manufacturing technologies*	*2*	*85*	*80*
CLO-3 :	*Understand the importance of standardization in IoT*	*1*	*90*	*85*
CLO-4 :	*Understand the capabilities and application of IoT*	*2*	*90*	*85*
CLO-5 :	*Become master of IoT for business model*	*1*	*85*	*80*
CLO-6 :	*Acquire the real time manufacturing information*	*2*	*85*	*80*

Program Learning Outcomes (PLO)														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
H	*M*	*M*	*L*	*L*	-	-	-	-	-	-	*M*	*H*	-	*H*
H	*M*	*L*	*L*	-	-	-	-	-	-	-	*M*	*H*	-	*H*
H	*L*	*L*	-	*M*	-	-	-	-	-	-	*M*	*H*	-	*H*
H	*L*	-	-	*L*	-	-	-	-	-	-	*M*	*M*	-	*M*
H	*L*	-	-	-	-	-	-	-	-	*M*	*M*	*M*	-	*M*
H	*L*	-	-	-	-	-	-	-	-	-	*M*	*M*	-	*M*

Duration (Hour)		9	9	9	9	9
S-1	SLO – 1	*Introduction to IoT*	*Existing manufacturing paradigms and their limitations*	*Real time status monitoring and Real time production guiding*	*IoT application for industry value creation and challenges*	*Configuration of smart shop floor*
	SLO – 2	*Definition and characteristic of IoT*	*Agile manufacturing, Networked manufacturing*	*Real time production data sharing, Real time production requeuing*		
S-2	SLO – 1	*Physical design of IoT*	*Reconfigurable manufacturing system*	*Deployment of multi-sensors, multiple sensor selection, multiple sensor manager*	*IoT application requirement and capabilities*	*The logical flow of the prototype system*
	SLO – 2	*Physical design of IoT*	*Product service system and industrial product service system,*	*Multisource manufacturing information capturing and sharing*	*Challenges faced by IoT industries application*	*The framework of the prototype system*
S-3	SLO – 1	*Logical design of IoT*	*Manufacturing grid*	*Information encapsulation*	*Future factory concepts*	*The framework of the prototype system*
	SLO – 2	*Logical design of IoT*	*Cloud manufacturing*	*Case study – hardware device, software system*	*The smart factory initiative*	*Deployment of hardware devices*
S-4	SLO – 1	*IoT enabling technologies*	*Limitations of agile manufacturing system*	*IoT standardization*		*Workflow of the prototype system*
	SLO – 2	*IoT enabling technologies*	*Applications of IoT in manufacturing system*	*Importance of standardization – beginning of everything*	*From technologies to technology concept*	*Task driven manufacturing resource configuration model*
S-5	SLO – 1	*IoT levels and deployment models*	*Key features and limitations of IoT in manufacturing system*	*The need of methods and tools and corresponding research*		*Production scheduling / rescheduling model*
	SLO – 2	*IoT levels and deployment models*	*Integration framework of real time manufacturing information – sharing and integration*	*Gaps between IoT standardization, IoT research, IoT development and IoT innovation*	*Brownfield IoT : Technologies for retrofitting*	*The scheduling and rescheduling method*

S-6	SLO – 1	*Design principles for connected devices*		*M2M service layer standardization*		*IoT enabled smart materials handling module*
	SLO – 2	*Design principles for connected devices*	*Real time manufacturing data processing*	*Prototype and production*	*Smart objects and smart applications*	
S-7	SLO – 1	*Calm and ambient technology*		*Physical prototypes and mass personalization*		*IoT enabled smart station*
	SLO – 2	*Calm and ambient technology*	*Sharing and exchange service*	*Open source versus closed source*	*Four aspects in your business to master IoT*	
S-8	SLO – 1	*Internet principles*	*IoT enabled smart assembly station*	*Prototyping embedded devices, sensors, actuators*		*Operation guidance from the system*
	SLO – 2	*Internet Communication – overview*	*Overall architecture of IoT enabled smart assembly station*	*Embedded computer basics, Arduino, Raspberry Pi, sketch, iterate and explore*	*Value creation from big data and serialization from pharmaceutical industry*	*Real time queuing under exceptions*
S-9	SLO – 1	*Overall architecture of IoT manufacturing system (MS)*	*IoT enabled smart trolley*	*Non digital methods, Laser cutting, 3D printing, types of 3D printing*		*Real time manufacturing information track and trace*
	SLO – 2	*The work logic of IoT MS, Description of core technologies of IoT MS*	*IoT enabled materials handling*	*Moving to manufacture, Moving to manufacture, CNC milling, recycling*	*IoT for oil and gas industries*	*Real time production performances monitor module*

Learning Resources	1. *ArshdeepBahga, Vijay Madisetti, "Internet of Things – A hands on approach", ArshdeepBahga& Vijay Madisetti 2014* 2. *Yingfeng Zhang, Fei Tao, "Optimization of manufacturing using internet of things", Academic Press Elsevier 2017.* 3. *Adrian McEwen, Hakim Cassimally, "Designing the internet of things", Springer International Publishing 2018.*	4. *Dr. Ovidiu Vermesan, Dr. Peter Friess, "Internet of Things – Covering technologies for smart environments and ecosystem", River Publishers 2013.* 5. *Christoph Jan Bartodziej, "The concept of industry 4.0" – An empirical analysis of technologies and applications in production logistics", Springer Gabler 2017* 6. *Francis daCosta, "Rethinking the internet of things – A scalable approach to connecting everything", Apress 2013.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% Weightage)								Final Examination (50% weightage)	
		CLA-1 (10%)		CLA-2 (15%)		CLA-3 (15%)		CLA-4 (10%) #			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*40%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
Level 2	Apply Analyze	*40%*	-	*40%*	-	*40%*	-	*40%*	-	*40%*	-
Level 3	Evaluate Create	*20%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Total	100%	-	100%	-	100%	-	100%	-	100%	-

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from industry	Expert from higher technical institution	Internal Expert
1. Mr. P.Kartikeyan, Head – Operations Improvement, Nokia India, kartikeyan.p@nokia.com	*1. Dr.K.Senthilkumaran, Assistant professor, IIITDM, Kancheepuram. skumaran@iiitdm.ac.in*	*1. N. Dinakar, SRMIST*
2. Dr. R. Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*2. Dr.B.Mohan, Professor, Anna University, mohan@mitindia.edu*	*2. Dr.R.Rajaraman, SRMIST*
3. Dr. A. Velayutham, DRDO, Avadi, velayutham.a@cvrde.drdo.in		

Course Code	18MEE433T	Course Name	VIRTUAL INSTRUMENTATION	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

Pre-requisite Course	*Nil*	Co-requisite Course	*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 :	*Impart knowledge on virtual instrumentation and differentiate it from conventional instruments*
CLR-2 :	*Learn the basic programming concepts*
CLR-3 :	*Learn different Data Acquisition System*
CLR-4 :	*Impart knowledge on interfacing of virtual instrumentation*
CLR-5 :	*Provide knowledge in process analysis by virtual instrumentation tool.*
CLR-6 :	*Develop real time applications using LabVIEW*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Describe about virtual instrumentation*	*1*	*90*	*85*	*M*	-	*M*	*L*	*H*	-	*L*	-	-	-	-	*L*	*H*	-	*H*
CLO-2 :	*Get adequate knowledge on virtual instrumentation tool sets*	*2*	*90*	*85*	*H*	-	-	*L*	*H*	-	*L*	-	-	-	-	*L*	*H*	-	*H*
CLO-3 :	*Describe data acquisition*	*2*	*90*	*85*	*H*	-	*M*	*M*	*H*	-	*L*	-	*M*	-	-	*L*	*H*	-	*H*
CLO-4 :	*Understand virtual instrumentation programming techniques*	*2*	*90*	*85*	*H*	-	*M*	*L*	*H*	-	-	-	*L*	-	-	*L-*	*H*	-	*H*
CLO-5 :	*Gain knowledge on interfacing and networking of virtual instrumentation*	*2*	*90*	*85*	*H*	-	*M*	*M*	*H*	-	-	-	*L*	-	-	-	*H*	-	*H*
CLO-6 :	*Use virtual instrumentation tool for process monitoring*	*2*	*90*	*85*	*H*	-	*M*	*L*	*H*	-	*L*	-	*M*	-	-	-	*H*	-	*H*

Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Historical perspective, advantages of virtual instrumentation*	*Modular Programming in Lab-VIEW*	*Introduction to PC based data acquisition*	*Common Instrument Interfaces*	*Use of Analysis tools*
	SLO-2	*Block diagram of a virtual instrument*	*Building a connector pane*	*Sampling fundamentals*	*Current loop*	*Fourier transforms*
S-2	SLO-1	*Architecture of a virtual instrument*	*VIs and sub-Vis*	*Analog Input/output techniques*	*Serial port Communication*	*Power spectrum*
	SLO-2	*Conventional instruments versus Traditional instruments*	*Opening and editing sub-Vis*	*Digital Input/output techniques*	*Instrument driver VIs*	*correlation methods*
S-3	SLO-1	*Hardware in virtual instrumentation*	*Placing sub-VIs, Saving sub VIs*	*Buses*	*RS 232C/ RS485*	*Windowing and filtering*
	SLO-2	*Software in virtual instrumentation*	*Loops and charts, Terminals inside or outside loops*	*ADC, DAC*	*GPIB*	*Distributed I/O modules*
S-4	SLO-1	*Layers of virtual instrumentation software*	*Shift Registers*	*Counters and timers*	*Using other interfaces*	*Virtual Laboratory, Simulation of level*
	SLO-2	*Graphical system design model*	*Arrays, creating arrays*	*DMA*	*Bus Interfaces: USB, PCMCIA*	*Major equipments- Oscilloscope, Digital Multi-meter*
S-5	SLO-1	*Virtual instrumentation for test*	*Deleting, inserting and replacing elements*	*Software and hardware installation*	*VXI, SCSI*	*Temperature data acquisition system*
	SLO-2	*Virtual instrumentation for industrial I/O and control*	*Clusters and graphs*	*Calibration, resolution*	*PCI, PXI, Fire wire*	*Image acquisition and processing*
S-6	SLO-1	*Virtual instrumentation for design*	*Case and sequence structures*	*Signal conditioning*	*PXI system controllers*	*Image acquisition using line sensor*
	SLO-2	*Graphical programming in data flow*	*formula nodes, feedback nodes*	*Computer based measurements system*	*Ethernet control of PXI.*	*Image acquisition using a single sensor*

S-7	SLO-1	*Comparison with conventional programming*	*Control timing*	*Selecting and configuring data acquisition system*	*Networking basics for office*	*Motion control employing stepper motor*
	SLO-2	*Virtual instrumentation in the engineering processes*	*Local and global variables*	*Concept of universal data acquisition card*	*Networking basis for industrial applications*	*On-Off controller PID Controller*
S-8	SLO-1	*Virtual instrumentation personal computers*	*State machine*	*Data acquisition interface requirements*	*VISA and IVI.*	*PID controller theory*
	SLO-2	*Graphical programming and textual programming*	*String and file I/O*	*Use of timers/counters*	*VISA Programming terminology*	*PID tuning software*
S-9	SLO-1	*Development of Virtual Instrument using Graphical user interface (GUI)*	*Instrument Drivers*	*Signal sources, measurement system*	*VISA and Serial*	*Advantages and Limitations of PID controller*
	SLO-2	*Real-time systems*	*Publishing measurement data in the web, cable news network*	*Increasing the measurement quality*	*IVI software technology*	*Advantages and Limitations of On-Off controller*

Learning Resources	1. *Robert H.Bishop, "Learning with LabVIEW 2009", Pearson Education 2010.* 2. *Jovitha Jerome, "Virtual Instrumentation Using LabVIEW", Eastern Economy Edition,PHI learning private ltd, 2010.* 3. *Sanjay Gupta and Joseph john, "Virtual Instrumentation Using LabVIEW",McGraw Hill Education private Limited, 2013.*	4. *N.Mathivanan, "PC-based Instrumentation: Concepts and Practice", Eastern Economy Edition, PHI Learning private Ltd, 2007.* 5. *Kevin James, "PC Interfacing and Data Acquisition: Techniques for Measurement, Instrumentation and Control", Newnes, 2000.*

Learning Assessment											
	Bloom's Level of Thinking	Continuous Learning Assessment (50% Weightage)								Final Examination (50% Weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*40%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
Level 2	Apply Analyze	*40%*	-	*40%*	-	*40%*	-	*40%*	-	*40%*	-
Level 3	Evaluate Create	*20%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Total	*100%*		*100%*		*100%*		*100%*		*100%*	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. P.Kartikeyan, Head – Operations Improvement, Nokia India, kartikeyan.p@nokia.com	*1. Dr.K.Senthilkumaran, Assistant professor, IIITDM, Kancheepuram. skumaran@iiitdm.ac.in*	*1. Dr.R.Rajaraman, SRMIST*
2. Dr. R. Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*2. Dr.B.Mohan, Professor, Anna University, mohan@mitindia.edu*	*2. Dr.I.Suresh Kannan, SRMIST*
3. Dr. A. Velayutham, DRDO, Avadi, velayutham.a@cvrde.drdo.in		

Course Code	18MEE434T	Course Name	NEURAL NETWORK AND FUZZY SYSTEMS	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

Pre-requisite Course	*Nil*	Co-requisite Course	*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 :	*Acquire knowledge on the fundamental of neural networks*
CLR-2 :	*Apply the neural network recurrence for automation*
CLR-3 :	*Utilize the practical applications of neural networks in automation*
CLR-4 :	*Understand the principles of Clustering approaches to automation*
CLR-5 :	*Understand various applications of fuzzy in automation*
CLR-6 :	*Understand the Neural Network approach to Pattern Recognition*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)													
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Acquire basic understanding of the various algorithms involved in Neural Networks & Fuzzy Systems*	*3*	*90*	*80*	*H*	*H*	*H*	*H*	-	-	-	-	*H*	-	-	*H*	*H*	-	*H*
CLO-2 :	*Analyze the neuron model and fundamentals on learning algorithms*	*3*	*90*	*80*	*M*	-	-	-	-	-	-	-	-	-	-	*H*	*M*	-	*M*
CLO-3 :	*Understand various Fuzzy algorithms.*	*3*	*90*	*80*	*H*	*H*	*L*	*H*	*H*	-	-	-	*M*	-	-	*H*	*H*	-	*M*
CLO-4 :	*Analyze how to apply the concept of fuzzy & neural in automation*	*3*	*90*	*80*	*H*	*M*	*M*	*H*	*H*	-	-	-	*M*	-	-	*H*	*H*	-	*M*
CLO-5 :	*Application of Neural and Neuro fuzzy concepts*	*3*	*90*	*80*	*H*	*L*	*L*	*H*	-	-	-	-	*M*	-	-	*H*	*H*	-	*M*
CLO-6 :	*Analyze and compare a variety of automation techniques to real-world problems*	*3*	*90*	*80*	*H*	*H*	*L*	*H*	-	-	-		*M*	-	-	*H*	*H*	-	*M*

Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Introduction to ANN*	*Counter propagation*	*Introduction to Fuzzy Sets*	*Fuzzy Relations on Sets and Fuzzy Sets*	*Application of neural networks and fuzzy logic*
	SLO-2	*History of neural networks*	*Self-organization Map*	*Crispness, Vagueness, Fuzziness, Uncertainty*		
S-2	SLO-1	*Biological Neurons and its Artificial Models*	*Cognitron and Neocognitron*	*Fuzzy Set Theory*	*Compositions of Fuzzy Relations*	*Applications of Fuzzy Set Theory*
	SLO-2	*Models of Artificial Neural Networks*		*Fuzzy Sets-Basic Definitions*		
S-3	SLO-1	*Learning and Adaptation*	*Hopfield Net- kohonnen Nets*	*Basic Set-Theoretic Operations for Fuzzy Sets*	*Properties of the Min-Max Composition*	*Support Logic Programming and Fril*
	SLO-2	*Neural Network Learning Rules*		*Types of Fuzzy Sets*		
S-4	SLO-1	*Hebbian Learning Rule*	*Mathematical foundations of Discrete-Time hopfield networks*	*Further Operations on Fuzzy Sets*	*Fuzzy Graphs*	*Application in Measurement, Control*
	SLO-2	*Perceptron Learning Rule*		*Algebraic Operations*		
S-5	SLO-1	*Types of activation Functions*	*Mathematical foundations of gradient type hopfield networks*	*Set-Theoretic Operations*	*Fuzzy Functions on Fuzzy Sets*	*Linguistic Evaluation and Ranking of Machine Tools*
	SLO-2			*Criteria for Selecting Appropriate Aggregation Operators*		
S-6	SLO-1	*Multilayer perceptron*	*Grossberg nets*	*Fuzzification and Defuzzification*	*Integration of Fuzzy Functions*	*Application in Flexible Manufacturing Systems*
	SLO-2	*Batch Learning and On-Line Learning*				
S-7	SLO-1	*Supervised Learning Viewed as an Optimization Problem*	*Transient response of continuous-Time Networks*	*Fuzzy Measures and Measures of Fuzziness*	*Performance index – Modification of rule base*	*Adaptive Neural Controllers*
	SLO-2					

S-8	SLO-1	*Back propagation algorithm and its variants*	*Relaxation Modeling in Single-Layer Feedback Networks*	*The Extension Principle and Applications*	*Genetic algorithms*	*Signal Processing and Image Processing*
	SLO-2				*Adaptive fuzzy system*	
S-9	SLO -1	*Different types of learning, examples*	*Art-I, Art-II reinforcement learning*	*Algebraic Operations with Fuzzy Numbers*	*Neuro fuzzy systems*	*Case studies*
	SLO -2					

Learning Resources	1. *Vallum B. R And Hayagriva V.R C++, Neural networks and Fuzzy logic, BPB Publications.* 2. *Simon Haykins, "Neural Networks - A comprehensive foundation", Macmillan College, Proc. Con. Inc. New York, 2005* 3. *Zimmermann.H.J, "Fuzzy set theory and its applications", Allied Publication Ltd.,Chennai, 2001.New Delhi, 1996* 4. *Fuzzy logic &Neural Networks/ Chennakesava R. Alavala/ New Age International, 2008* 5. *Neural Networks for control, Millon W. T, Sutton R.S and Werbos P.J, MIT Press 1992*	6. *Fuzzy sets Fuzzy logic, Klir, G.J anfd Yuan B.B Prentice Hall of India Pvt. Ltd.,, New Delhi* 7. *Neural Networks and Fuzzy systems, Kosko.. Prentice hall of India Pvt. Ltd.,, New Delhi 1994* 8. *Introduction to Fuzzy control, Dirankov D. Hellendoorn H, Reinfrank M., Narosa Publications House, New Delhi 1996* 9. *Introduction to Artificial Neural systems, Zurada J. M Jaico Publishing House, New Delhi 1994*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% Weightage)								Final Examination (50% Weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Understand										
Level 2	Apply	*40%*	-	*40%*	-	*40%*	-	*40%*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Create										
	Total	100%		100%		100%		100%		100%	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. P.Kartikeyan, Head – Operations Improvement, Nokia India, kartikeyan.p@nokia.com	*1. Dr.K.Senthilkumaran, Assistant professor, IIITDM, Kancheepuram. skumaran@iiitdm.ac.in*	*1. S.Thamilarasu, SRMIST*
2. Dr. R. Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*2. Dr.B.Mohan, Professor, Anna University, mohan@mitindia.edu*	*2. Dr.R.Rajaraman, SRMIST*
3. Dr. A. Velayutham, DRDO, Avadi, velayutham.a@cvrde.drdo.in		

Course Code	18MEE435T	Course Name	ELEMENTS OF MECHATRONICS	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

Pre-requisite Course	*Nil*	Co-requisite Course	*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 basic key elements of mechatronics systems*
CLR-2 :	*Have cognizance on performance of sensors and transducers.*
CLR-3 :	*Understand different actuation systems, signal processing and Controllers*
CLR-4 :	*Program the PLC*
CLR-5 :	*Design mechatronics system and its applications*
CLR-6 :	*Case studies*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLO-1 :	*To discuss mechanical systems used in Mechatronics*	*1*	*90*	*85*
CLO-2 :	*To integrate mechanical, electronics, control and computer engineering in the design of mechatronics systems*	*2*	*85*	*80*
CLO-3 :	*Use mathematical methods and tools to analyse and develop electrical and mechanical engineering systems*	*3*	*85*	*80*
CLO-4 :	*Identify, define, formulate and solve complex mechatronics engineering problems*	*2*	*85*	*80*
CLO-5 :	*Ability to work in design, implementation and integration of mechatronics engineering applications*	*2*	*85*	*80*
CLO-6 :	*Conduct feasibility study for using mechatronics systems for solving assistive technology applications*	*2*	*85*	*80*

Program Learning Outcomes (PLO)														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
H	*L*	*H*	*H*	-	-	*L*	-	-	-	-	-	*H*	-	*H*
H	*L*	*H*	*M*	*L*	-	*L*	-	-	*H*	-	-	*M*	-	*M*
L	*M*	*L*	-	*L*	-	-	-	-	-	-	*L*	*M*	-	*H*
H	*M*	*H*	*H*	*H*	-	*L*	-	-	-	*M*	-	*H*	-	*H*
H	-	*H*	-	*M*	-	*L*	-	-	*L*	-	-	*M*	-	*M*
M	*M*	-	*H*	*L*	-	-	-	-	*L*	*M*	*L*	*M*	-	*H*

Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Mechatronics*	*Mathematical models*	*Microprocessor systems*	*Introduction of basic structure*	*Stepper motor*
	SLO-2	*Engineering Design*				
S-2	SLO-1	*Classification of Sensors*	*Building Blocks : Mechanical*	*Basic elements of control systems*	*Input and output processing*	*Stepper motor - types*
	SLO-2	*Classification of transducers*	*Building Blocks : Electrical*			
S-3	SLO-1	*Thermal and electrical sensors*	*Building Blocks : Fluid*	*Microcontrollers*	*Programming*	*Servo motor*
	SLO-2	*Optical sensor*	*Building Blocks : thermal system*			
S-4	SLO-1	*Acoustic sensor*	*System models*	*Microprocessor architecture and terminology*	*Mnemonics*	*Servo motor - types*
	SLO-2	*Pneumatic sensor*				
S-5	SLO-1	*Magnetic sensor*	*Dynamic response of systems*	*Closed loop controllers*	*Timers*	*Case studies of mechatronics system- pick and place robot*
	SLO-2	*Piezo electric sensor*				
S-6	SLO-1	*Transducers: Static characteristics*	*first and second order systems*	*Proportional, derivative and integral controls*	*counters and internal relays*	*automatic car park barrier*
	SLO-2	*Transducers: Dynamic characteristics*		*Derivative and integral controls*		
S-7	SLO-1	*Open loop control systems*	*Modeling dynamic systems*	*PID controller*	*Data handling*	*Engine management system*
	SLO-2	*Closed loop control systems*				
S-8	SLO-1	*Servo mechanism*	*System transfer functions*	*Controllers*	*Selection of PLC*	*Digital camera*
	SLO-2			*Tuning of controller*		
S-9	SLO-1		*Frequency response*	*Adaptive control of machine tools*	*Development of simple ladder programs for specific purposes*	*A PC based computer numerically controlled drilling machine*
	SLO=2					

Learning Resources	1. *W.Bolton, "Mechatronics electronic control systems in mechanical and electrical engineering", Pearson Education 2013.* 2. *Godfrey C.Onwubolu, "Mechatronics principles and applications", Elsevier, 2011.*	3. *Devdas Shetty & Richard A.Kolk, "Mechatronics system design", Indian Edition, Cenage Learning, 2009.* 4. *Nitaigour Premchand Mahalik, "Mechatronics principles, concepts and applications", Tata McGraw-Hill, 2008.* 5. *R.K.Rajput, "A textbook of Mechatronics", Revised Edition, S.Chand Company,2009.*

Learning Assessment											
	Bloom's Level of Thinking	Continious Learning Assessment (50% Weightage)								Final Examination (50% Weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*40%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
Level 2	Apply Analyze	*40%*	-	*40%*	-	*40%*	-	*40%*	-	*40%*	-
Level 3	Evaluate Create	*20%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Total	100%		100%		100%		100%		100%	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. P.Kartikeyan, Head – Operations Improvement, Nokia India, kartikeyan.p@nokia.com	*1. Dr.K.Senthilkumaran, Assistant professor, IIITDM, Kancheepuram. skumaran@iiitdm.ac.in*	*1. S.Benu Deepsun, SRMIST*
2. Dr. R. Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*2. Dr.B.Mohan, Professor, Anna University, mohan@mitindia.edu*	*2. Dr.R.Rajaraman, SRMIST*
3. Dr. A. Velayutham, DRDO, Avadi, velayutham.a@cvrde.drdo.in		

Course Code	18MEE801J	Course Name	ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING	Course Category	E	*Professional Elective*	L	T	P	C
							2	0	2	3

Pre-requisite Course	*Nil*	Co-requisite Course	*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 :	*Learn about Artificial Intelligence and identify the need of AI in Mechanical Engineering*
CLR-2 :	*Learn about different search algorithms*
CLR-3 :	*Learn about Logic controllers, Microprocessors*
CLR-4 :	*Learn about Python Programming*
CLR-5 :	*Apply the concept of Machine Learning for mechanical applications*
CLR-6 :	*Apply Mechanical concepts in AI and build an efficient working environment*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLO-1 :	*Understand the concept of Artificial Intelligence*	*1*	*90*	*85*
CLO-2 :	*Characterize the concepts of Machine Learning*	*1*	*90*	*85*
CLO-3 :	*Identify the different concepts in Heuristic methods*	*1*	*90*	*85*
CLO-4 :	*Understand MATLAB and Python programming*	*2*	*90*	*85*
CLO-5 :	*Solve problems in Genetic programming*	*2*	*90*	*85*
CLO-6 :	*Apply the basic knowledge of Mechanical in smart manufacturing*	*2*	*90*	*85*

Program Learning Outcomes (PLO)														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
H	*L*	*M*	*M*	*H*	-	*M*	*H*	*M*	-	-	*M*	-	-	-
H	-	*M*	*M*	*H*	-	*M*	*L*	*M*	-	-	*M*	-	-	-
H	-	-	*M*	*L*	-	-	*H*	*M*	*L*	-	-	*M*	*L*	*M*
H	*H*	*L*	*M*	*M*	-	*L*	*L*	*M*	*L*	-	*M*	*M*	*L*	*M*
H	*H*	-	*M*	*M*	-	-	*L*	*M*	*L*	-	*L*	*M*	*L*	*M*
H	*M*	-	*M*	*H*	-	*L*	*L*	*M*	*L*	-	*H*	*M*	*L*	*M*

Duration (hour)		12	12	12	12	10
S-1	SLO-1	*Artificial Intelligence and its foundations*	*Lab-4: MATLAB- Optimization methods GA, Fuzzy, Neural & PSO*	*Tutorial 4: Artificial Intelligence in Manufacturing Industry*	*Fuzzy matching techniques*	*Syntax programming for optimization*
	SLO-2	*History of AI, LISP and PROLOG*		*Hebb's Rule, McCulloch and Pitts Neurons*	*Tutorial 6: Microcontrollers*	*Reduced environmental impact by ML*
S-2	SLO-1	*Blind search, Breadth first*	*Formalized symbolic logics*	*Evolutionary Learning: Genetic Algorithm and Problems in GA*	*Lab-12: FLEXSIM Software*	*Harnessing useful data using AI and ML*
	SLO-2	*Lab-1: Python Programming*	*Syntax and semantics for Logics Representing knowledge using rules and rules-based deduction systems*	*Genetic Programming*	*RETE matching algorithm*	*Supply chain Communication*
S-3	SLO-1	*Heuristic search techniques*	*Reasoning under uncertainty*	*Lab-7: Image Processing, Object and Motion detection*	*Object-Oriented representations*	*Cutting waste using AI*
	SLO-2	*Hill climbing technique*	*Bayes' probabilistic inferences*		*Data mining for Mechanical Engineers*	*Integration of man machine system*
S-4	SLO-1	*Best first search technique, A* algorithm,*	*Heuristic methods*	*Markov Chain Monte Carlo (MCMC) methods, Bayesian Networks*	*Lab-13:Hydraulic and Pneumatic simulator*	*Improved customer service using AI*
	SLO-2	*AO* algorithm*	*Fuzzy reasoning*	*Lab:8- Pick and place operation of ABB Robot in Manual Mode*	*Dimensionality Reduction PCA*	*Minimizing Equipment Failures*
S-5	SLO-1	*Lab-2: Machine Learning using python*	*Lab-5: Introduction to SIMULINK & Modelling of problems related to kinematics and dynamics of robot using MATLAB*	*Graphical models Markov Random Fields*	*Single Value Decomposition(SVD), t-Distributed Stochastic Neighbor Embedding (t-SNE) methods*	*Predictive Maintenance*
	SLO-2	*Tutorial:1 Python Programming in Mechanical applications*		*Hidden Markov Models (HMMs)*	*Ensemble Techniques Boosting Bagging*	*Multi-dimensional optimization*

S-6	SLO-1	*Game trees- Numerical*	*Expert system, Relationship between Artificial Intelligence and Mechanical Engineering*	*Lab-9: Pick and place operation of ABB Robot in Teach Pendent method, PLC Controlled material handling system*	*Data visualization in machine learning*	*Artificial Neural network*
	SLO-2	*Minimax algorithm*	*Expert system, Relationship between Artificial Intelligence and Mechanical Engineering*		*Text mining*	*Greedy algorithm*
S-7	SLO-1	*Game playing*	*Diagnosis of rule-based reasoning Case-based reasoning and fault-based tree fault diagnosis*	*Tracking Methods*	*Lab-14:Study on Microcontrollers*	*Greedy algorithm problems*
	SLO-2	*Alpha beta pruning*	*Diagnosis of rule-based reasoning Case-based reasoning and fault-based tree fault diagnosis*	*Python- Basics of coding, Writing and importing code*		*Robotic perception*
S-8	SLO-1	*Lab-3: Basics of MATLAB programming*	*Case study: Manufacturing scheduling*	*Tutorial 5: PLC controllers*	*Case study on driverless vehicles*	*Sensors and effectors*
	SLO-2		*Case study: Manufacturing scheduling*			*Types of sensors and acutators*
S-9	SLO-1	*Definition and importance of Knowledge Representation of knowledge*	*Tutorial 2: Case study in manufacturing industry Case study: Intelligent Diagnostic system for Rotating machinery*	*Lab-10: 8051 Micro controller-Temperature and Traffic control*	*Lab-15: Study on Driverless Vehicles*	*Dynamics and control*
	SLO-2	*Organization and Manipulation Logical Agents*	*Case study: Fault diagnosis to Hot Forging Press*			*Problems in Dynamics*
S-10	SLO-1	*Problems in Genetic Algorithm*	*Lab-6: Sensors and its applications*	*Python coding*	*Application of AI and ML in Inventory control*	*Robotic software architecture*
	SLO-2	*Programming GA in MATLAB*				*Writing Robotic software*
S-11	SLO-1	*Problems in Artificial Neural Network*	*Tutorial 3: Image Processing, Object and Motion detection*	*MATLAB and its applications in Fault detection and Optimization*	*Reducing time of production with AI*	*Robotic programming language*
	SLO-2	*Programming ANN in MATLAB*	*Basics of Machine Learning*		*Cost reduction of production with AI*	*Case study on Humanoid robot*
S-12	SLO-1	*Programming Particle swarm optimization (PSO)*	*Definition & uses of Machine Learning*	*Lab-11: 8051 Micro controller-Temperature and Traffic control*	*Automating quality control using AI and ML*	*Machine Learning in supply chain*
	SLO-2	*Problems in PSO*	*Decision Tree & Practical applications*			

Learning Resources	1. *Russell, Stuart J., and Peter Norvig. Artificial intelligence: a modern approach. Malaysia; Pearson Education Limited,, 2016.* 2. *Patterson, Dan W. Introduction to artificial intelligence and expert systems. Prentice-hall ofIndia, 2010.* 3. *Marsland, Stephen. Machine learning: an algorithmic perspective. Chapman and Hall/CRC, 2009.*	4. *Luger, George F., and William A. Stubblefield. Artificial intelligence and the design of expert systems. Benjamin-Cummings Publishing Co., Inc., 2009.* 5. *Charniak, Eugene. Introduction to artificial intelligence. Pearson Education India, 2000.* 6. *Nilsson, Nils J. Principles of artificial intelligence. Morgan Kaufmann, 2014.*

Learning Assessment

	Bloom,s Level of Thinking	Continuous Learning Assessment (50% Weightage)								Final Examination (50% Weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*20%*	*20%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*
Level 2	Apply Analyze	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*
Level 3	Evaluate Create	*10%*	*10%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*
	Total	100%		100%		100%		100%		100%	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. P.Kartikeyan, Head – Operations Improvement, Nokia India, kartikeyan.p@nokia.com	*1. Dr.K.Senthilkumaran, Assistant professor, IIITDM, Kanchipuram, skumaran@iiitdm.ac.in*	*1. Mr.S.Vignesh, SRMIST*
2. Dr. R. Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*2. Dr.B.Mohan, Professor, Anna University, mohan@mitindia.edu*	*2. Dr. Suresh Kannan I, SRMIST*
3. Dr. A. Velayutham, DRDO, Avadi, velayutham.a@cvrde.drdo.in		

Course Code	18MEE802T	Course Name	DIGITAL IMAGE PROCESSING AND MACHINE VISION	Course Category	E	Professional Elective	L	T	P	C
							3	0	0	3

Pre-requisite Course	Nil	Co-requisite Course	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 image fundamentals transforms necessary for image processing.
CLR-2 :	Study the image enhancement techniques
CLR-3 :	Study basic image processing operations
CLR-4 :	Overview of image restoration techniques.
CLR-5 :	Understand the need for image compression and segmentation
CLR-6 :	Understand the rapid advances in Machine vision.

Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLO-1 :	Review the fundamental concepts of a digital image processing system	2	85	90
CLO-2 :	Analyze images in the frequency domain using various transforms	2	85	80
CLO-3 :	Evaluate the techniques for image enhancement and image restoration	2	80	85
CLO-4 :	Analysis different causes for image degradation	2	90	85
CLO-5 :	Interpret Image compression standards.	2	80	80
CLO-6 :	Interpret image segmentation and representation techniques.	3	85	80

Program Learning Outcomes (PLO)														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
M	-	-	M	-	-	-	-	-	-	-	L	L	-	L
M	L	M	M	-	-	-	-	-	L	-	L	M	-	M
M	-	M	M	-	-	-	-	-	-	-	L	L	-	L
M	-	-	M	L	-	-	-	-	-	-	L	M	-	M
M	L	-	M	-	-	M	-	-	-	-	L	M	-	L
M	L	L	M	-	-	-	-	M	-	-	L	L		M

Duration (hour)		9	9	9	9	9
S-1	SLO-1	Origins of digital image processing	Light used in Machine Vision	Image Enhancement Techniques:	Image Compression - Measuring image information	Types of task and production
	SLO-2	Origins of digital image processing	Basic Rules and Laws of Light Distribution	Spatial and Frequency domain	Spatial and temporal redundancy	Types of task and production
S-2	SLO-1	Fundamental steps in digital image processing	Light Filters	Spatial Domain	Image compression models - Huffman coding	System Categories - Common types of systems-sensors-vision sensors-
	SLO-2	Fundamental steps in digital image processing	Light Filters	Point operation &Maskoperation	Image compression models - Huffman coding	PC based system
S-3	SLO-1	Components of image processing system	Types of Light Filters	Histogram manipulation	Image compression models - Arithmetic coding	Mechanical Interfaces - Dimension and fixation-
	SLO-2	Components of image processing system	Types of Light Filters	Histogram equalization and procedure	Image compression models -Run length coding	Mechanical Interfaces - working distance-position tolerance
S-4	SLO-1	Elements of Visual Perception	Machine Vision versus Closed Circuit Television (CCTV)	Linear gray level transformation	Digital Image watermarking	Electrical interface- wiring and movement-
	SLO-2	Basics of Image Sensing and Acquisition	Machine Vision versus Closed Circuit Television (CCTV)	Linear gray level transformation	Digital Image watermarking	Power supply- Internal and External date connections.
S-5	SLO-1	Image Sampling	Imaging Sensors- CCD	Nonlinear gray level transformation	Image Segmentation- Point, line and edge Detection	Discrete Motion Production-
	SLO-2	Image Quantization	Imaging Sensors- CCD	Nonlinear gray level transformation	Image Segmentation- Point, line and edge	Production-Continuous Motion

					Detection	*Production-Line-Scan Processing*
S-6	SLO-1	*Basic Relationships between Pixels*	*Imaging Sensors- CMOS*	*Comparison between smoothing and sharpening spatial filters*	*Edge linking and Boundary Detection*	*Industrial Case Study- Glue Check under UV Light*
	SLO-2	*Basic Relationships between Pixels*	*Imaging Sensors-CMOS*	*Comparison between smoothing and sharpening spatial filters*	*Edge linking and Boundary Detection*	*Industrial Case Study- Glue Check under UV Light*
S-7	SLO-1	*Digital image file formats – GIF*	*Digital Cameras- B/W Sensor and Processing*	*Smoothing frequency domain filters (Ideal, Butterworth, Gaussian)*	*Thresholding, Basics of Global thresholding*	*Industrial Case StudyMultiple Position and Completeness Check*
	SLO-2	*Digital image file formats – JPEG*	*Digital Cameras- B/W Sensor and Processing*	*Smoothing frequency domain filters (Ideal, Butterworth, Gaussian)*	*Using edge to improve global thresholding*	*Industrial Case Study-Multiple Position and Completeness Check*
S-8	SLO-1	*Digital image file formats – PNG*	*Color Digital Cameras*	*Sharpening frequency domain filters (Ideal, Butterworth, Gaussian)*	*Multiple and variable thresholding*	*Industrial Case Study- Pin Type Verification*
	SLO-2	*Digital image file formats – TIFF, BMP*	*Camera Noise&Photon Noise.*	*Sharpening frequency domain filters (Ideal, Butterworth, Gaussian)*	*Multiple and variable thresholding*	*Industrial Case Study- Pin Type Verification*
S-9	SLO-1	*Applications of Digital Image Processing*	*Introduction to video analytics*	*Homomorphic filtering.*	*Region Based Segmentation*	*Industrial Case Study- Robot Guidance*
	SLO-2	*Applications of Digital Image Processing*	*Introduction to video analytics*	*Homomorphic filtering.*	*Pattern recognitions*	*Industrial Case Study-Robot Guidance*

Learning Resources	1. *Rafael C Gonzalez and Richard E Woods, Digital Image Processing, Pearson Education, 3rd Edition, 2009.* 2. *Jayarman.S, Esakkirajan.S and Veerakumar.T, Digital Image Processing, Tata McGraw Hill, 2010.* 3. *Alexander Hornberg , Handbook on Machine Vision , Wiley – VCH , 2008.* 4. *William K Pratt, Digital Image Processing, John Willey, 2007.*	5. *Myler, Harley R. Fundamentals of machine vision. SPIE Optical Engineering Press, 1999.* 6. *MillmanSonka, Vaclav Hlavac, Roger Boyle, and Broos Colic, Image Processing Analysis and Machine Vision, Thompson learning, 2014.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% Weightage)								Final Examination (50% Weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Understand										
Level 2	Apply	*40%*	-	*40%*	-	*40%*	-	*40%*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Create										
	Total	100%		100%		100%		100%		100%	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. P.Kartikeyan, Head – Operations Improvement, Nokia India,. kartikeyan.p@nokia.com	*1. Dr.K.Senthilkumaran, Assistant professor, IIITDM, Kancheepuram, skumaran@iiitdm.ac.in*	*1. Mr. G. Leela Prasad, SRMIST*
2. Dr. R. Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*2. Dr.B.Mohan, Professor, Anna University, mohan@mitindia.edu*	*2. Dr. Suresh Kannan I, SRMIST*
3. Dr. A. Velayutham, DRDO, Avadi, velayutham.a@cvrde.drdo.in		

Course Code	18MEE803J	Course Name	SENSORS FOR INTELLIGENT MANUFACTURING	Course Category	E	Professional Elective	L	T	P	C
							2	0	2	3

Pre-requisite Course	Nil	Co-requisite Course	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 :	Expose the basics and working principle of sensors and Transducers
CLR-2 :	Impart knowledge on motion sensors
CLR-3 :	Learn the Packaging techniques of sensors
CLR-4 :	Provide knowledge on sensors used in Robotics
CLR-5 :	Provide insights on advanced sensors
CLR-6 :	Impart knowledge onsensor based control

Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLO-1 :	Describe about sensors and transducers	1	90	85
CLO-2 :	Familiarize to use motion sensors for various applications	2	90	85
CLO-3 :	Develop packaging of various sensors	2	90	85
CLO-4 :	Understand the use of sensors in Robotic application	2	90	85
CLO-5 :	Gain knowledge on advanced sensors	2	90	85
CLO-6 :	Develop a control scheme based on sensor feedback.	2	90	85

Program Learning Outcomes (PLO)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	H	-	L	L	M	-	-	-	M	-	-	-	M	-	M
CLO-2 :	H	-	L	L	H	-	-	-	M	-	-	-	M	-	M
CLO-3 :	H	-	M	M	M	-	-	-	M	-	-	M	M	-	H
CLO-4 :	H	-	M	M	H	-	-	-	M	-	-	M	M	-	M
CLO-5 :	H	-	L	M	H	-	-	-	M	-	-	M	M	-	M
CLO-6 :	H	-	L	M	M	-	-	-	H	-	-	L	M	-	M

Duration (hour)		12	12	12	12	12
S-1	SLO-1	Role of sensors in manufacturing automation	Motion Sensors	Classification, characteristics	Semiconductor sensors	Types of controllers
	SLO-2	Active and passive sensors	Resistive strain gauge	Internal sensors – position	Hall elements	Electrical, pneumatic
S-2	SLO-1	Operating principles of different sensors electrical,	LVDT, RVDT	Velocity sensors	Silicon sensors for sensing radiation	Hydraulic prime movers and associated control hardware
	SLO-2	Operating principles of optical sensors	Capacitive, piezo	Acceleration sensors	Mechanical signals	Closed loop control of microcomputer based drives
S-3	SLO-1	Operating principles of acoustic sensors	Seismic pickups,	Force sensors	Magnetic signals	Relay control systems
	SLO-2	Operating principles of pneumatic sensors	Vibrometers and accelerometers	External sensors	Chemical and other signals	PLC systems and programming,
S-4	SLO-1	Lab 1:Study of the characteristics of a Piezo resistive Sensor for Pressure Measurement	Lab 4: Characteristics study of LVDT	Lab7: Study of the characteristics of a Photo reflective sensor for Speed Measurement	Lab 10: Study of PLC system and Programming	Lab 13: Study of Level sensors
	SLO-2					
S-5	SLO-1					
	SLO-2					
S-6	SLO-1	Operating principles of magnetic sensors	Sensors for CNC machine tools.	Proximity, touch Slip sensors.	Catalytic devices	Control including sequence control
	SLO-2	Operating principles of electro-optical sensors	Packaging techniques of mechanical sensors	Robotic vision.	Gas sensors	Sensor based control of various actuators.

S-7	SLO-1	*Vision sensors, Active transducers, passive transducers*	*Electrical interconnection*	*Process of imaging, architecture of robotic vision systems*	*Acoustic sensors*	*Mechatronic devices*
	SLO-2	*Classification of transducers, Sensors and Transducers for: flow, temperature, pressure and torque,*	*Packaging processes*	*Image acquisition, components of vision system*	*Applications of sensors in Robotics*	*Uses of mechatronic devices in for Intelligent Manufacturing*
S-8	SLO-1	*Lab2: Characteristics study of Resistance Temperature Detector (RTD)*	*Lab 5: Characteristics study of RVDT*	*Lab:8 Characteristics study of Reflective Beam Sensor*	*Lab 11: Study of Force and torque sensors*	*Lab 14: Study of Smart material sensors*
	SLO-2					
S-9	SLO-1					
	SLO-2					
S-10	SLO-1	*Current and torque and speed measurements using digital measurement techniques*	*Mechanical transduction techniques*	*Image representation, image processing in robotic vision systems*	*Tactile sensors*	*Autonomous mobile robots*
	SLO-2				*Future Inertial Micro machined Sensors*	*Applications of autonomous mobile robots*
S-11	SLO-1	*Lab 3: Experiment on the Calibration of a Thermocouple*	*Lab 6: Characteristics study of an Electromagnetic Flow meter*	*Lab:9 Experiment on image acquisition and processing*	*Lab 12: Study of Acceleration sensors*	*Lab 15: Study of Micro and Nano sensors*
	SLO-2					
S-12	SLO-1					
	SLO-2					

Learning Resources	1. *Stephen Beeby, Graham Ensell, Michael Kraft, Neil White, MEMS Mechanical Sensors, Artech House, Inc. London, 2004.* 2. *J. Vetelino and A. Reghu, Introduction to sensors, CRC Press, 2010.* 3. *J. Fraden, Handbook of Modern Sensors: Physics, Designs and Applications, 4th edition, Springer, 2010.* 4. *T. G. Beckwith, R. D. Marangoni and J. H. Lienhard V., Mechanical Measurements, Pearson Prentice Hall, 2009. Doebelin, Measurement systems: Applications and Design, 5th edition, McGraw Hill Book, 2004.*	5. *Doebelin, Measurement systems: Applications and Design, 5th edition, McGraw Hill Book, 2004.* 6. *I. R. Sinclair, Sensors and Transducers, Elsevier, 2001.* 7. *J. S. Wilson, Sensor Technology Handbook, Newnes, 2004.* 8. *B. K. Ghosh, T. J. Tarn and N. Xi, Control in Robotics and Automation: Sensor-Based Integration, Academic Press, 1999.* 9. *C.W. de Silava, Sensors and Actuators, 2nd edition, CRC Press, 2016.*

Learning Assessment											
	Bloom,s Level of Thinking	Continuous Learning Assessment (50% Weightage)								Final Examination (50% Weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*20%*	*20%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*
	Understand										
Level 2	Apply	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*
	Analyze										
Level 3	Evaluate	*10%*	*10%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*
	Create										
	Total	100%		100%		100%		100%		100%	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
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2. Dr. R. Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*2. Dr.B.Mohan, Professor, Anna University, mohan@mitindia.edu*	*2. Dr Suresh Kannan I, SRMIST*
3. Dr. A. Velayutham, DRDO, Avadi, velayutham.a@cvrde.drdo.in		

Course Code	18MEE804T	Course Name	INDUSTRY 4.0	Course Category	E	Professional Elective	L	T	P	C
							3	0	0	3

Pre-requisite Course	Nil	Co-requisite Course	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 :	Acquire knowledge on principles of industry 4.0 and building blocks of industry 4.0
CLR-2 :	Acquire knowledge on IoT enabled manufacturing systems
CLR-3 :	Understand cloud based cyber physical systems in manufacturing
CLR-4 :	Apply data analytics in manufacturing
CLR-5 :	Understand and apply additive manufacturing technologies
CLR-6 :	Acquire knowledge on technologies and application of industry 4.0

Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLO-1 :	Explain the evolution of industry 4.0	2	90	80
CLO-2 :	Explain the concept of IoT	1	85	80
CLO-3 :	Understand the application areas of IoT in manufacturing	2	85	80
CLO-4 :	Explain the concept of cloud manufacturing	2	90	85
CLO-5 :	Explain the advances in robotics in the era of industry 4.0	1	90	85
CLO-6 :	Identify advances in virtual factory research and application	1	85	80

Program Learning Outcomes (PLO)														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
H	-	M	-	-	-	-	-	-	-	-	M	H	---	H
H	-	M	L	H	-	-	-	-	-	-	H	H	---	H
H	L	M	L	L	-	-	-	-	-	-	M	M	---	M
H	-	H	L	L	-	-	-	-	-	-	M	M	---	M
H	-	H	L	L	-	-	-	M	L	-	L	M	---	M
H	-	H	M	L	-	-	-	L	-	L	M	M	---	M

Duration (Hour)		9	9	9	9	9
S-1	SLO – 1	Industry 4.0 – Definition	The concept of IoT	Concept of cloud manufacturing	Power consumption in manufacturing	Advances of robotics in the era of industry 4.0
	SLO – 2	Why industry 4.0 and why now?	Existing manufacturing paradigms and their limitations – agile manufacturing	Real time production information	Anomaly detection in air conditioner	Recent technological components of robots
S-2	SLO – 1	Phases of industrial developments	Networked manufacturing	Cloud service selection and composition	Anomaly detection in air conditioner	Artificial intelligence
	SLO – 2	Central features of the concept	Reconfigurable manufacturing system	Overall architecture of manufacturing resources configuration method	Smart remote machinery maintenance system	Internet of robot things, Cloud robotics
S-3	SLO – 1	Principles of industry 4.0	Product service system / industrial product service system	Cloud machine model	Smart remote machinery maintenance system	Cognitive approach of cyber physical robotics
	SLO – 2	Main characteristics of industry 4.0	Manufacturing grid Cloud manufacturing	Cloud machine model	Quality perdition in steel manufacturing	Industrial robotic application
S-4	SLO – 1	Building blocks of Industry 4.0	Limitations of agile manufacturing system	Cloud machine model	Quality perdition in steel manufacturing	Advances in virtual factory research and application
	SLO – 2	The value chain	Applications of IoT in Manufacturing system	Application of cyber physical system &IoT	Predicting drilling efficiency	Virtual factory software
S-5	SLO – 1	Creating the value chain	Key features and limitations of IoT in Manufacturing System	Cloud manufacturing framework	Techniques used for predictive analytics	Additive manufacturing technologies and application
	SLO – 2	Benefits of industry 4.0	Architecture of IoT – MS	Manufacturing capability and manufacturing resource	Techniques used for predictive analytics	Advantages and disadvantages of additive manufacturing

S-6	SLO – 1	*Challenges of industry 4.0*	*Integration framework of real time manufacturing information – sharing and integration*	*Cloud architecture*	*Forecast accuracy calculation*	*Application areas of additive manufacturing*
	SLO – 2	*Smart manufacturing*	*Real time manufacturing data processing, sharing and exchange service*	*Approaches to achieve product information sharing*	*Forecast accuracy calculation*	*Impact of additive manufacturing techniques on society*
S-7	SLO – 1	*Industrial internet of things*	*The work logic of IoT MS, Description of core technologies of IoT MS*	*Standardization for cloud manufacturing*	*Real world case study – definition*	*Impact on manufacturing and supply chain*
	SLO – 2	*Gateways*	*IoT enabled smart assembly station*	*Standardization for cloud manufacturing*	*Data gathering and cleaning*	*Digital traceability through production value chain*
S-8	SLO – 1	*Wireless Communication technologies*	*Overall architecture of IoT enabled smart assembly station*	*Overview of cyber security in industry 4.0 era*	*Automation based lean production*	*Digital traceability technologies*
	SLO – 2	*Industry 4.0 – the way forward*	*IoT enabled smart trolley*	*Overview of cyber security in industry 4.0 era*	*Automation based lean production*	*Architectural framework of the digital traceability system, Application of digital traceability*
S-9	SLO – 1	*Technology road map for industry 4.0*	*IoT enabled materials handling*	*Security threat and vulnerabilities of IoT*	*Model application*	*Project management in digital traceability, Examples for IoT in value creation in different industries*
	SLO – 2	*Technology road map for industry 4.0*	*Real time information enabled material handling strategy*	*Cases – cyber security*	*Model application*	*smart manufacturing – maturity model, Smart agriculture, Smart city Smart life and smart health*

Learning Resources	*1. ArshdeepBahga, Vijay Madisetti, Internet of Things – A hands on approach, ArshdeepBahga& Vijay Madisetti, 2014* *2. Yingfeng Zhang, Fei Tao, Optimization of manufacturing using internet of things, Academic Press Elsevier, 2017.* *3. Lihui Wang, Xi Vincent Wang, Cloud based cyber physical systems in manufacturing, Springer International Publishing, 2018.*	*4. Christoph Jan Bartodziej, The concept of industry 4.0 – An empirical analysis of technologies and applications in production logistics, Springer Gabler, 2017* *5. Alp Ustundag, EmriChevikcan, Industry 4.0 - Managing the digital transformation, Springer International Publishing, 2018.*

Learning Assessment											
	Bloom's Level of Thinking	Continuous Learning Assessment (50% Weightage)								Final Examination (50% Weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*40%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
Level 2	Apply Analyze	*40%*	-	*40%*	-	*40%*	-	*40%*	-	*40%*	-
Level 3	Evaluate Create	*20%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Total	100%		100%		100%		100%		100%	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from industry	Expert from higher technical institution	Internal Expert
1. Mr. P.Kartikeyan, Head – Operations Improvement, Nokia India, kartikeyan.p@nokia.com	*1. Dr.K.Senthilkumaran, Assistant professor, IIITDM, Kancheepuram, skumaran@iiitdm.ac.in*	*1. Mr. Dinakar. N, SRMIST*
2. Dr. R. Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*2. Dr.B.Mohan, Professor, Anna University, mohan@mitindia.edu*	*2. Dr. Suresh Kannan I, SRMIST*
3. Dr. A. Velayutham, DRDO, Avadi, velayutham.a@cvrde.drdo.in		

Course Code	18MEE805T	Course Name	MANUFACTURING EXECUTION SYSTEMS	Course Category	E	Professional Elective	L	T	P	C
							3	0	0	3

Pre-requisite Course	Nil	Co-requisite Course	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 :	Identify the fundamental concepts of MES.
CLR-2 :	Utilize the core functions of MES.
CLR-3 :	Apply technical aspects of MES.
CLR-4 :	Identify the requirementsof the factory of the future.
CLR-5 :	Evaluation of Cost Effectiveness in MES.
CLR-6 :	Implementation in Production and its significance.

Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	Learning			Program Learning Outcomes (PLO)													
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	Apply the fundamental concepts and core function of MES	3	90	80	H	H	H	H	-	-	-	-	M	M	M	H	H	-	H
CLO-2 :	Understand what and why MES in modern production systems	3	90	80	H	H	H	M	-	-	-	-	H	L	M	H	H	-	H
CLO-3 :	Setup, analysis, and giving possible application of MES	3	90	80	H	H	H	H	-	-	-	-	H	H	M	H	H	-	H
CLO-4 :	Know the connection of function within production systems to MES	3	90	80	H	M	M	M	-	-	-	-	H	M	H	H	H	-	H
CLO-5 :	Identify the requirements of the factory of the future	3	90	80	H	H	M	H	-	-	-	-	M	H	M	H	H	-	H
CLO-6 :	Evaluate the Cost Effectiveness in MES	3	90	80	H	H	L	M	-	-	-	-	L	H	M	H	H	-	H

Duration (hour)		9	9	9	9	9
S-1	SLO-1	Historical Development of MES, Standards of MES	Core Function—Production Flow-OrientedDesign	Integration within the Overall Process	Software Architecture, Fundamental Variants	Implementing IT Systems in General
	SLO-2	Development of Business Data Processing	Cross-System Cohesiveness, Classification in the Overall System	Order Data Management	Overview of Central Components	Problems duringImplementation
S-2	SLO-1	Definitions of Terms - Classification of Terms	General and Complete Data Model, Origins of Master Data	Supply Management within the MES, Demand Planning	Platform Independence, Scalability	Preparation of the Implementation Project
	SLO-2	Company Management Level	Data Model for Product Definition, Relevant Concepts	Interaction between the ERP Systemand the MES, Material Warehousing Costs	Flexible Adjustment versus Suitability for Updates	Analysis of the Actual Situation
S-3	SLO-1	Production Management Level	The Operation, Work Plan, Parts List	The Planning Process and Planning Objectives	MES and Service-Oriented Architecture	Suitable Key Figures for SuccessMonitoring
	SLO-2	Control/Automation Level	Change Management and Product History	Forward Planning/Reverse Planning/Bottleneck Planning	Database, Resource Monitoring	Creation of a Project Plan
S-4	SLO-1	Shortfalls of ExistingArchitectures andSolutions	Data Model for Resource Management.	Collision-Free Planning of a Time Container	Scaling the Database System	Selection of a Suitable System
	SLO-2	Patchwork, No Common Database, Excessive Response Times	Description of ProductionEnvironment	The Importance of the Control Station	Data Management and Archiving, Running Maintenance	Implementation Process, Project Management
S-5	SLO-1	High Operating and ManagementOutlay	Description of ProductionEnvironment	Personnel Planning and Release of Orders	Interfaces with Other IT Systems	Training Management, Operating Concept

	SLO-2	*Demands of Future Production ManagementSystems*	*Description of ProductionEnvironment*	*General Information on Order Processing and Classification*	*Usage and Visualization, Reporting, Automated Information Distribution*	*Sensient Technologies: Emulsions*
S-6	SLO-1	*Target Management, Integration of Applications and Data*	*Production Personnel*	*Order Preparation and Setup*	*Value-Benefit Analysis,General Information on CostEffectiveness*	*Basic Quantity Units and Production Units*
	SLO-2	*Real-Time Data Management*	*Operating Resources*	*Order Control,Managing the Production Bin, Material Flow Control*	*Performance Measurement*	*Realization and Implementation*
S-7	SLO-1	*Lean Sigma and MES*	*Materials and Preliminary Products*	*Order Processing and Operating DataRecording*	*General Information on Evaluation*	*Basic Quantity Units and ProductionUnits*
	SLO-2	*Commonalities between Existing Approachesand MES*	*Information and Documents*	*Process and Quality Assurance*	*The Benefits of an MES*	*Tasks of the MES, Challenges,*
S-8	SLO-1	*Norms and Guidelines, Recommendations*	*System and Auxiliary Data*	*Performance Data*	*Integrated Data Transparency, Reducing Time Usage*	*Realization and Implementation*
	SLO-2	*Adjacent Areas, Product Lifecycle Management*	*Order Fulfillment Data and Orders*	*Maintenance Management*	*Reducing Administration Expenses,Improved Customer Service*	*The MES as a Medium of Product-Development Management*
S-9	SLO -1	*Implementation Strategies*	*Production Data, Operating Data, andMachine Data*	*Preventive Maintenance and Repair*	*Early Warning System, Real-Time CostControl*	*Standardization of Function Modules*
	SLO -2	*Points of Contact with MES*	*Derived Performance Data and Figures*	*Alarm Management*	*The Costs of an MES*	*Merging Consultancy Activities andIT Systems*

Learning Resources	1. *Heiko Meyer, Franz Fuchs, Klaus Thiel, Manufacturing Execution Systems, McGraw-Hill, 2009.* 2. *Jürgen Kletti, Manufacturing Execution System – Springer, 2010.* 3. *Bianca Scholten, MES Guide for Executives – International society of Automation, 2009.*	4. *Michael McClellan, Applying Manufacturing Execution Systems, CRC Press, 2007.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% Weightage)								Final Examination (50% Weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*40%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
Level 2	Apply Analyze	*40%*	-	*40%*	-	*40%*	-	*40%*	-	*40%*	-
Level 3	Evaluate Create	*20%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Total	100%		100%		100%		100%		100%	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

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Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. P.Kartikeyan, Head – Operations Improvement, Nokia India, kartikeyan.p@nokia.com	*1. Dr.K.Senthilkumaran, Assistant professor, IIITDM, Kancheepuram, skumaran@iiitdm.ac.in*	*1. Mr.S.Thamilarasu, SRM IST*
2. Dr. R. Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*2. Dr.B.Mohan, Professor, Anna University, mohan@mitindia.edu*	*2. Dr. Suresh Kannan I, SRMIST*
3. Dr. A. Velayutham, DRDO, Avadi, velayutham.a@cvrde.drdo.in		

Course Code	18MEE806T	Course Name	ADDITIVE MANUFACTURING TECHNOLOGY	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

Pre-requisite Course	*Nil*	Co-requisite Course	*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 :	*Learn about Sustainable and Green Manufacturing Techniques*
CLR-2 :	*Aspects of Green supply chain and clean energy in manufacturing*
CLR-3 :	*Understanding the principle of green manufacturing*
CLR-4 :	*Learn about green in Manufacturing Processes*
CLR-5 :	*Introduce the concept of life cycle analysis (LCA)*
CLR-6 :	*Sustainability aspects in modern manufacturing enterprises*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Understand the need for green and sustainable manufacturing*	*1*	*80*	*70*	*M*	-	*M*	-	-	-	-	-	-	-	-	-	-	-	-
CLO-2 :	*Identification of clean energy and green supply chain in manufacturing*	*2*	*85*	*75*	*H*	-	-	-	*M*	-	-	-	-	-	-	-	*H*		-
CLO-3 :	*Apply the concepts green principles and industrial ecology tools*	*2*	*75*	*70*	*H*	*M*	*H*	*H*	-	-	-	-	-	-	-	*M*	*H*	-	-
CLO-4 :	*Identification the strategies for green manufacturing*	*2*	*80*	*75*	*H*	-	*M*	-	*M*	-	-	-	-	-	-	-	*H*	-	*M*
CLO-5 :	*Analyze the technologies enabling green manufacturing*	*1*	*75*	*70*	*H*	-	-	*M*	-	-	-	-	-	-	-	*M*	*M*	-	*H*
CLO-6 :	*Apply the concepts of sustainability in modern manufacturing enterprises*	*2*	*80*	*70*	*M*	-	-	*M*	*M*	-	*L*	-	-	-	-	*M*	-	-	*H*

Duration (hour)		9	9	9	9	9
S-1	SLO-1	*History and Need of AM*	*Preparation of CAD Model:*	*Stereo lithography (SLA) : Introduction to SLA*	*Selective Laser Sintering (SLS): Introduction to SLS*	*Materials for AM: Metals, Biomaterials for AM*
	SLO-2	*Evolution of AM*	*Interfacing of CAD and AM , File formats used in AM*	*Basic concepts and Working Principle of SLA*	*Basic concepts and Working Principle of SLS*	*Polymers for AM*
S-2	SLO-1	*Basic concepts and working principle of AM*	*Introduction to STL File format*	*Constructional details for SLA*	*Constructional details for SLS*	*Ceramics for AM*
	SLO-2	*Additive Manufacturing vs Subtractive manufacturing*	*Problems (Errors) with STL file*	*Advantages of SLA*	*Advantages of SLS*	*Composites for AM*
S-3	SLO-1	*AM Process chain*	*Reverse engineering: Need for Reverse engineering, Introduction to Co-ordinate Measuring machine (CMM)..*	*Limitations of SLA*	*Limitations of SLS*	*Applications of AM in Manufacturing and tooling*
	SLO-2	*AM Process chain*	*Reverse engineering: CMM measurement process – Data collection, Digitization from surface, Preprocessing, Surface fitting.*	*Applications of SLA*	*Applications of SLS*	*Applications of AM in Space*
S-4	SLO-1	*Rapid prototyping on product development*	*Rapid tooling*	*Fused deposition modelling (FDM) : Introduction to FDM*	*Laser Engineered Net Shaping (LENS): Introduction to LENS*	*Applications of AM in Automotive industry*
	SLO-2	*Rapid prototyping on product development*	*Rapid tooling*	*Basic concepts and Working Principle of FDM*	*Basic concepts and Working Principle of LENS*	*Applications of AM in Aerospace industry*
S-5	SLO-1	*Classification of AM processes*	*Design for AM: Part orientation*	*Constructional details for FDM*	*Constructional details for LENS*	*Applications of AM in Biomedical industry*
	SLO-2	*Classification of AM processes*	*Removal of supports*	*Advantages of FDM*	*Advantages of LENS*	*Applications of AM in Biomedical industry*

S-6	SLO-1	*Other Related technologies: Overview about other technologies related to AM*	*Hollowing out parts*	*Limitations of FDM*	*Limitations of LENS*	*Applications of AM in Jewellery industry*
	SLO-2	*Computer Aided Engineering (CAE)*	*Inclusion of Undercuts and other manufacturing constraints*	*Applications of FDM*	*Applications of LENS*	*Applications of AM in Various other fields.*
S-7	SLO-1	*Haptic based CAD*	*Interlocking features, Reduction of part count in assembly*	*Laminated Object Manufacturing (LOM) : Introduction to LOM*	*Electron Beam Melting (EBM): Introduction to EBM*	*Introduction to Direct digital manufacturing (DDM)*
	SLO-2	*Haptic based CAD*	*Identification markings / numbers*	*Basic concepts and Working Principle of LOM*	*Basic concepts and Working Principle of EBM*	*Rapid prototyping vs DDM*
S-8	SLO-1	*AM unique capabilities: Shape complexity, Hierarchical complexity*	*Engineering design rules for AM: Tolerances – Digital to Object*	*Constructional details for LOM*	*Constructional details for EBM*	*Future directions of AM*
	SLO-2	*AM unique capabilities: Functional complexity, Material complexity*	*Design freedom, Relative fit*	*Advantages of LOM*	*Advantages of EBM*	*Future directions of AM*
S-9	SLO-1	*Benefits of AM.*	*Flexures, Hinges, Snap fits*	*Limitations of LOM*	*Limitations of EBM*	*Digiproneurship*
	SLO-2	*Limitations of AM.*	*Orientation and Clamping*	*Applications of LOM*	*Applications of EBM*	*Digiproneurship*

Learning Resources	1. *Li Yang, Keng Hsu, Brian Baughman, Donald Godfrey, Francisco Medina, MamballykalathilMenon, Soeren Wiener, Additive Manufacturing of Metals* 2. *The Technology, Materials, Design and Production", Springer 2017.* 3. *Ian Gibson, David Rosen, Brent Stucker, Additive Manufacturing Technologies_ 3D Printing, Rapid Prototyping, and Direct Digital Manufacturing", Springer 2015.*	4. *Andreas Gebhardt, Understanding Additive Manufacturing. Rapid Prototyping - Rapid Tooling - Rapid manufacturing, Hanser publications 2011.* 5. *T. S. Srivatsan and T. S. Sudarshan,"Additive Manufacturing Innovations, Advances, and Applications, Taylor & Francis group 2016.* 6. *Ali K Kamrani, EmadAbouel Nasr, Rapid prototyping - Theory and Practice", Springer 2005.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% Weightage)								Final Examination (50% Weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*40%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Understand										
Level 2	Apply	*40%*	-	*40%*	-	*40%*	-	*40%*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*20%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Create										
	Total	100%		100%		100%		100%		100%	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
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2. Dr. R. Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*2. Dr.B.Mohan, Professor, Anna University, mohan@mitindia.edu*	*2. Dr. Suresh Kannan I, SRMIST*
3. Dr. A. Velayutham, DRDO, Avadi, velayutham.a@cvrde.drdo.in		

Course Code	18MEE807T	Course Name	INDUSTRIAL ROBOTICS AND MATERIAL HANDLING SYSTEMS	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

Pre-requisite Course	*Nil*	Co-requisite Course	*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 :	*Introduce the basic concepts, parts of robots and types of robots*
CLR-2 :	*Familiar with the various drive systems for robot, sensors and theirapplications in robots and programming of robots*
CLR-3 :	*Select the robots according to its usage*
CLR-4 :	*Know about the various applications of robots, justification and implementation of robot*
CLR-5 :	*Know about material handling in a system*
CLR-6 :	*Acquire knowledge on various material handling equipment used both in automated andnon-automated systems*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Understand the fundamentals of robot technology, sensors, drives and systems*	2	90	85	*H*	-	*H*	*L*	*M*	-	-	-	-	-	*H*	-	*H*	-	*H*
CLO-2 :	*Recognize the ideas about robot cell design, work cell control*	2	90	85	*H*	-	*H*	*L*	*M*	-	-	-	-	-	*H*	-	*H*	-	*H*
CLO-3 :	*Have knowledge about various applications of robots in material handling*	1	90	85	*M*	-	*M*	*L*	*M*	-	-	-	-	-	*L*	-	*H*	-	*H*
CLO-4 :	*Understand the concepts of automated material handling and its types*	2	90	85	*L*	-	*L*	*L*	*M*	-	-	-	-	-	*M*	-	*H*	-	*H*
CLO-5 :	*Identify the application of automated guided vehicles in material handling*	1	90	85	*M*	-	*H*	*L*	*M*	-	-	-	-	-	*M*	-	*H*	-	*H*
CLO-6 :	*Recognize about vehicle guidance and routing in material handling*	2	90	85	*H*	-	*H*	*L*	*M*	-	-	-	-	-	*M*	-	*H*	-	*H*

Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Automation and Robotics*	*Robot cell layouts- Robot centered cell*	*General consideration in Robot Material Handling*	*Automated material handling*	*Automated Guided Vehicle Systems - Introduction*
	SLO-2	*History of Robots*	*In line Robot cell*	*Material Transfer Application*	*Hand trucks, Powered trucks*	*Introduction to Drones*
S-2	SLO-1	*Robot Anatomy*	*Mobile robot cell*	*Pick and place operations*	*Cranes monorails and Hoists*	*Driverless Trains*
	SLO-2	*Robot configurations*	*Multiple robots and machine Interface*	*Palletizing and related operations*	*Conveyors systems*	*AGVs Pallet Trucks*
S-3	SLO-1	*Robot motions, Joint Notation Scheme*	*MR- MI Example*	*Machine loading and unloading*	*Selection of material handling equipment*	*AGVs Unit load carriers*
	SLO-2	*Work volume*	*Other considerations in work cell design*	*Die casting, plastic molding*	*Principles of material handling*	*Driverless train operation*
S-4	SLO-1	*Polar, Cylindrical, Cartesian*	*Work cell control*	*Forging, Machining operations*	*Roller, stake wheel conveyor*	*Storage/ Distribution system*
	SLO-2	*Robot drive systems*	*Sequence control*	*Stamping press operations*	*Belt, chain conveyors*	*Assembly line operation*
S-5	SLO-1	*Speed of motion*	*operation interface*	*Robots in spot welding*	*Overhead trolley conveyor*	*Miscellaneous operation*
	SLO-2	*Load carrying capacity*	*Safety monitoring*	*Robots in arc welding*	*slat conveyors*	*Functions of AGV*
S-6	SLO-1	*4 types of robot control system*	*Interlocks*	*Problems for Robots in arc welding*	*In floor towline conveyor*	*Vehicle guidance and routing*
	SLO-2	*Precision of movement*	*Error detection and recovery*	*Features of the welding robot*	*Cart on track conveyor*	*Operation of on board sensor system*
S-7	SLO-1	*End effectors- types of grippers*	*Work cell controller*	*Sensors in arc welding robot*	*Other handling equipment, Dial Indexing tables*	*Frequency select, path switch select method*
	SLO-2	*Gripper selection and design*	*Robot controller*	*Vision based systems, Benefits*	*Elevators, Pipelines*	*Traffic control and safety*
S-8	SLO-1	*Transducers and sensors*	*Electro mechanical Relays, Programmable controllers*	*Robots in Spray coating*	*Containers, Highway Tractor trailers*	*On board vehicle sensing, zone blocking*

	SLO-2	*Tactile sensors*	*A computer as the work cell controller*	*Immersion and flow coating, Spray coating methods*	*Railway trains, Cargo aircraft, Ship, barges.*	*System management, On board control panel*
S-9	SLO-1	*Proximity and Range sensors*	*Robot cycle time analysis*	*Benefits of robot spray coating*	*Types of AS / RS*	*Remote call stations, Central computer control*
	SLO-2	*Uses of sensors in robotics*	*Elements in RTM*	*Other Processing operations using robots*	*Advanced ware housing robots, Applications.*	*Automotive Intelligent vehicles*

Learning Resources	1. *Mikell P Groover, Mitchell Weiss, Rogen N Nagel, Nicholas G Odrey, Ashish Dutta, Industrial Robotics Technology,Programmming, and Applications, Tata McGraw Hill Special Indian Edition, 2012.* 2. *K.Lalit Narayan, K.Mallikarjuna Rao, Computer Aided Design and Manufacturing, Prentice Hall of India, 2008.* 3. *Mikell P Groover, Mitchell Weiss, Roger N Nagel, Industrial Robotics Technology, Programming, and Applications, Tata McGraw Hill Publishers, 2008.*	4. *S.R.Deb, S.Deb, Robotics Technology & Flexible Automation, Tata McGraw-Hill Education, 2012.* 5. *James A Rehg, Introduction to Robotics in CIM system, Prentice Hall, 2002.* 6. *S.K.Saha, Introduction to Robotics, Tata McGraw Hill Publishing Company Limited, 2014.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% Weightage)								Final Examination (50% Weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*40%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
Level 2	Apply Analyze	*40%*	-	*40%*	-	*40%*	-	*40%*	-	*40%*	-
Level 3	Evaluate Create	*20%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Total	100%		100%		100%		100%		100%	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
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2. Dr. R. Kalimuthu, ISRO, Mahendragiri, r_kalimuthu@vssc.gov.in	*2. Dr.B.Mohan, Professor, Anna University, mohan@mitindia.edu*	*2. Dr. Suresh Kannan I, SRMIST*
3. Dr. A. Velayutham, DRDO, Avadi, velayutham.a@cvrde.drdo.in		

Course Code	18MEE808T	Course Name	SUSTAINABLE GREEN MANUFACTURING	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

Pre-requisite Course	*Nil*	Co-requisite Course	*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 :	*Learn about Sustainable and Green Manufacturing Techniques*
CLR-2 :	*Aspects of Green supply chain and clean energy in manufacturing*
CLR-3 :	*Understanding the principle of green manufacturing*
CLR-4 :	*Learn about green in Manufacturing Processes*
CLR-5 :	*Introduce the concept of life cycle analysis (LCA)*
CLR-6 :	*Sustainability aspects in modern manufacturing enterprises*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)													
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Understand the need for green and sustainable manufacturing*	2	90	90	*H*	*H*	-	-	-	*H*	*H*	-	-	-	-	*H*	-	-	*H*
CLO-2 :	*Identification of clean energy and green supply chain in manufacturing*	2	85	80	*H*	-	*H*	*H*	-	*H*	*H*	-	-	-	-	*H*	-	-	*H*
CLO-3 :	*Apply the concepts green principles and industrial ecology tools*	2	85	80	*H*	-	*M*	*L*	-	*H*	*H*	-	-	-	-	-	-	-	*H*
CLO-4 :	*Identification the strategies for green manufacturing*	2	85	85	*M*	*L*	-	-	-	*H*	*H*	-	-	-		*H*	-	-	*M*
CLO-5 :	*Analyze the technologies enabling green manufacturing*	2	90	85	*M*	*L*	*H*	*H*	*M*	*H*	*H*	-	*H*	-	-	*H*	-	-	*M*
CLO-6 :	*Apply the concepts of sustainability in modern manufacturing enterprises*	2	85	70	*H*	*H*	*H*	*H*	*M*	*H*	*H*	-	*H*	-	-	*H*	-	-	*M*

Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Concept of Sustainability*	*Introduction to thermodynamics analysis in manufacturing processes*	*Principle of Green Manufacturing*	*Functions and types of cutting fluids*	*Introduction to Green supply chain*
	SLO-2	*Introduction to green Manufacturing*	*Thermodynamic framework of manufacturing processes*	*Cleaner Production , Dematerialization*	*Problems related to cutting fluids*	*Green Supply Chain*
S-2	SLO-1	*Motivations for sustainable development*	*Estimation of minimum work for materials transformations*	*Closed Loop Production systems Economic and Ecological Benefits of Closed-Loop Systems*	*Dry machining*	*Issues in Green supply Chain Techniques*
	SLO-2	*Motivations for sustainable Manufacturing*	*Estimation of minimum work for materials transformations*	*Design for Disassembly, Industrial Metabolism*	*Advantages and Limitations*	*Green packaging*
S-3	SLO-1	*Productivity and sustainability*	*Estimation of minimum work for materials transformations*	*Adoption of low carbon technologies*	*Near dry machining*	*The Packaging supply chain*
	SLO-2	*Metrics for green manufacturing*	*Temperature and Pressure Changes for Open Materials-Processing Systems*	*Need to reduce the carbon footprint of manufacturing operations*	*Advantages, Disadvantages*	*Future of Green Supply Chain*
S-4	SLO-1	*Societal metrics*	*Energy use for elastic – plastic deformation*	*Life Cycle assessment*	*Minimum Quantity Lubrication systems*	*Lean Production*
	SLO-2	*Economic Metrics*	*Electric energy used in manufacturing processes*	*Life cycle assessment elements*	*Economics of Environmentally Friendly Machining*	*Types of wastes*
S-5	SLO-1	*Environmental metrics*	*Resource accounting*	*Life cycle assessment procedure*	*Development of Environmentally Friendly*	*Lean Manufacturing Techniques*

					cutting fluids, cutting tools and machine tools	
	SLO-2	*Barriers to Green Manufacturing*	*Introduction to Clean Energy Technologies*	*Life Cycle Assessment (LCA) of Machine tools*	*Enabling Technologies for Green Manufacturing*	*Agile Manufacturing*
S-6	SLO-1	*Advantages and Limitations of Green manufacturing*	*Solar Photovoltaic*	*Design for Environment*	*Sustainable solutions*	*Components of the agile manufacturing system/enterprise*
	SLO-2	*Environmental Impact of Manufacturing*	*Wind Energy*	*Product life extension and the service economy*	*Adoptrontics in Machine tools*	*Comparison between agile and traditional manufacturing enterprises*
S-7	SLO-1	*Standards for green manufacturing*	*Fuel cells*	*Eco Labelling, Industrial Ecology tools*	*Reconfigurable Machine tools*	*Analysis of Manufacturing Firms for Agility*
	SLO-2	*ISO 14000*	*Comparison of lean Energy Technologies*	*Case studies in Industrial Ecology*	*Process Monitoring System*	*Remanufacturing*
S-8	SLO-1	*OHSAS 18000*	*Application Potentials of clean energy supply in green manufacturing*	*Case studies in Industrial Ecology*	*Smart building blocks*	*Recycling*
	SLO-2	*Sustainability rating schemes*	*Cost benefit of environmental emission mitigation through clean energy supply*	*How is Industrial Ecology Viewed by Industry*	*Add-ons for machine tool upgrade*	*Materials for sustainability and recycling*
S-9	SLO-1	*Strategies for Green Manufacturing*	*Technological Performance of clean Energy Supply.*	*Awareness of Industrial Ecology and its components*	*Applying Sensor Flows in Decision Making (Automated Manufacturing) Manufacturing Complexity*	*Sustainability Assessments of Competitive Manufacturing Strategies*
	SLO-2	*Strategies for Green Manufacturing*	*Energy efficient manufacturing processes*	*Case studies of product improvement and redesign*	*Environmental implications of nano manufacturing and Semiconductor manufacturing*	*Sustainability Assessment for Industrial Estates*

Learning Resources	1. *Dornfeld, David A., ed. Green manufacturing: fundamentals and applications. Springer Science & Business Media, 2012.* 2. *Gouge, Michael, and Pan Michaleris, eds. Thermo-mechanical modeling of additive manufacturing. Butterworth-Heinemann, 2017.* 3. *Davim, J. Paulo, ed. Sustainable Manufacturing. John Wiley & Sons, 2013.* 4. *Dixit, Uday S., D. K. Sarma, and J. Paulo Davim. Environmentally friendly machining. Springer Science & Business Media, 2012.* 5. *Stark, Rainer, GüntherSeliger, and JérémyBonvoisin. Sustainable Manufacturing. Springer, 2017.*	6. *Garbie, Ibrahim. Sustainability in manufacturing enterprises: Concepts, analyses and assessments for industry 4.0. Springer, 2016.* 7. *Madu, Christian N., ed. Handbook of environmentally conscious manufacturing. Springer Science & Business Media, 2012.* 8. *Fiksel, Joseph. Design for environment: a guide to sustainable product development: eco-efficient product development. McGraw Hill Professional, Boston, 2009.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% Weightage)								Final Examination (50% Weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*40%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
Level 2	Apply Analyze	*40%*	-	*40%*	-	*40%*	-	*40%*	-	*40%*	-
Level 3	Evaluate Create	*20%*	-	*30%*	-	*30%*	-	*30%*	-	*30%*	-
	Total	100%		100%		100%		100%		100%	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

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Course Code	18MEE809J	Course Name	DATABASE MANAGEMENT SYSTEM	Course Category	E	Professional Elective	L	T	P	C
							2	0	2	3

Pre-requisite Course	Nil	Co-requisite Course	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 :	To impart an introduction to the theory and practice of database systems
CLR-2 :	To learn various database models and query language.
CLR-3 :	To understand effective manipulation of memory space for database files.
CLR-4 :	To understand the normalization in building effective database table
CLR-5 :	To protect the data and database from foreign access

Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	Develop the terminology and features in database	2	90	85	H	M	-	M	-	-	-	-	M	H	-	M	-	-	-
CLO-2 :	Analyze the information of storage details	2	90	85	H	L	-	-	-	-	-	-	-	H	-	L	-	-	-
CLO-3 :	Transform an information into relational database	2	90	85	H	M	M	M	-	-	-	-	M	H	-	H	-	-	-
CLO-4 :	Ability to work in data manipulation	2	90	85	H	L	-	-	-	-	-	-	M	L	-	L	-	-	-
CLO-5 :	Analyze the Client/Server and Internet Database Environment	2	90	85	H	M	-	L	-	-	-	-	-	H	-	M	-	-	-
CLO-6 :	Write queries for design and manipulation of database table using MySQL or Oracle	2	90	85	H	H	M	M	M	-	-	-	M	H	-	H	-	-	-

Duration (hour)		12	12	12	12	12
S-1	SLO-1	Introduction to database Systems	Entity types	Relational Model	Structured Query Language (SQL)	Introduction to parallel database
	SLO-2	History of DBMS applications	Entity sets	Structural of database	SQL Data definition	I/O Parallelism
S-2	SLO-1	File System versus a DBMS	Attributes and Keys	Structure of relational Databases	Queries on Single Relation	Lab 13: Simple PL/SQL Programs, Use of Exceptions, Cursor, Procedure, Function, Trigger, Sequence
	SLO-2	Database Language	Basic building blocks	Keys, Schema Diagram	Queries on multiple Relations	
S-3	SLO-1	Lab 1: Creating database table	Levels of data abstraction	Relational Algebra	Overview of SQL	Security :Database security – Granting,Removing
	SLO-2		Physical Schemas and Conceptual Schemas	Relational Algebra - Set Operation, Renaming,	Basic structure of SQL Queries	Type of Security
S-4	SLO-1	Lab 2: DDL Commands	Overview ofEntity-Relationship (E-R) Model	Relational Algebra - Joins	Lab 9:Simple queries	Control measures
	SLO-2		Relationship set, Entity set	Relational Algebra - Division		Database Recovery
S-5	SLO-1	Database Interface	Database design and Entity-Relationship(ER) Model, Design alternatives	Lab 7: Joining tables	Lab 10: Nested queries	Storage, Data access
	SLO-2	Form based Interface, Graphical based Interface	Constraints, Entity-Relationship (ER)-Diagrams, Roles and Structural Constraints			Buffer Management
S-6	SLO-1	Database Environment	Lab 4: Basic SELECT statements	Relational Algebra - Division	Data definition commands, DML Commands, Set operations	Database – Backup
	SLO-2	Database Component Modules		Extended Relational Algebra Operations	Aggregate functions	Recovery Algorithm

S-7	SLO-1	*Database System utilities*	*Lab 5: Advanced SELECT statements*	*Views*	*Lab 11:Creation, Insertion, Updating, Deletion ofViews operation*	*Lab 14: DBMS for CAD software design*
	SLO-2	*Database System Architecture*		*Functional Dependency*		
S-8	SLO-1	*Lab 3: Data Manipulation Commands*	*Entity-Relationship(ER) Design Issues*	*Various process in designing a Database*	*Aggregate functions - Basic aggregation*	*Emerging Database technology - Mobile database*
	SLO-2		*E-R Model and Enhanced entity-relationship (EER) Model*	*Lab 8: Basic SQL functions*	*Aggregate functions- Aggregation with Grouping*	*Emerging Database technology - Multimedia database*
S-9	SLO-1	*Data Independence*	*Enhanced entity-relationship (EER) Model*		*Lab 12: Basics of PL/SQL*	*Access controls*
	SLO-2	*Data Mappings*	*Enhanced entity-relationship(EER)-Specialization*	*Normalization using functional dependencies*		*Security for internet applications*
S-10	SLO-1	*Structure of DBMS*	*Enhanced entity-relationship(EER)-Generalization*	*Decomposition*	*Null values, Joins, Nested queries*	*Web Technology in Smart Manufacturing*
	SLO-2	*Security and Authorization,*	*Enhanced entity-relationship(EER)-Attribute Inheritance*	*Boyce-Codd Normal Form*	*Client/Server Database Environment*	*Web Technology in Smart Manufacturing*
S-11	SLO-1	*Database Turning*	*Constrain on Generalization*	*DBMS application in Computer Integrated manufacturing*	*Basics of Ontology Language and its applications.*	*DBMS for computer integrated manufacturing*
	SLO-2	*Data Models*	*Aggregation*	*3NF, Correctness of the 3NF Algorithm*	*Design Challenges in SPARQL,*	*Material Handling System Design*
S12	SLO-1	*Types of DBMS*	*Lab 6: Constraints in Tables*	*Comparison of BCNF and 3NF*	*SPARQL Query Forms,*	*Lab 15:Report Generation for Material Handling System Design*
	SLO-2	*Objective data model and Hierarchical data model*		*Normalization using multivalued dependencies*	*SPARQL Graph Patterns*	

Learning Resources	1. *RamezElmasri, Shanmkant B., Fundamentals of Database System, 5th Edition, Pearson, 2011.* 2. *Silberschatz, Abraham, Henry F. Korth, and ShashankSudarshan. Database system concepts. Vol. 4. New York: McGraw-Hill, 1997.* 3. *Ramakrishnan, Raghu, and Johannes Gehrke. Database management systems. McGraw Hill, 2000.*	4. *Hansen, Gary W., and James V. Hansen. Database management and design. 1996.* 5. *Peter rob, Carlos Coronel, Database Systems – Design, Implementation, and Management , 9th Edition, 2009, Thomson Learning System Software Needed: Oracle 8, MySQL*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% Weightage)								Final Examination (50% Weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*20%*	*20%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*
Level 2	Apply Analyze	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*	*20%*
Level 3	Evaluate Create	*10%*	*10%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*	*15%*
	Total	100%		100%		100%		100%		100%	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

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