ACADEMIC CURRICULA

POST GRADUATE DEGREE PROGRAMMES

Master of Technology

(Choice Based Flexible Credit System)

Regulations 2021

Volume – 25
Syllabi for School of Mechanical Engineering Programmes

Professional Core and Elective Courses

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

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

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

ACADEMIC CURRICULA

School of Mechanical Engineering

Professional Core Course

Regulations 2021

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

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

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

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

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

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

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

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

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

Learning Assessment

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

Course Designers

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

ACADEMIC CURRICULA

Automotive Hybrid Systems Engineering
Automotive Technology
Electric Vehicle Technology

Professional Core Courses

Regulations 2021

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

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

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

Course Code	21AUC501T	Course Name	AUTOMOTIVE ENGINE AND TRANSMISSION SYSTEMS	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	1	0	4

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*offer wide range of career opportunities in the automotive industry, including roles in design, testing, manufacturing, and service.*
CLR-2:	*equip with the technical expertise and practical experience sought by employers in the industry.*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*analyze engine performance metrics such as power output, torque, efficiency, and emissions.*	*2*	*1*	*3*
CO-2:	*describe the components and operation of air intake and fuel supply systems in internal combustion engines.*	*2*		*3*
CO-3:	*describe the purpose and components of engine lubrication and cooling system.*		*2*	*3*
CO-4:	*differentiate between manual and automatic systems and analyze factors affecting transmission efficiency and performance.*	*2*		*3*
CO-5:	*describe the different types of transmissions used in hybrid and electric vehicles and evaluate vehicle performance.*		*1*	*3*

Module 1- Internal Combustion Engines	***12 Hour***
Classification – Working Principles – Design and Operating Variables – Performance Characteristics – Advancements in Engine Technology for Performance improvement and emission reduction Recent emission norms.	
Module 2 - Air Intake and Fuel Supply Systems	***12 Hour***
Intake system components - Discharge coefficient, Pressure drop - Air filter, intake manifold, Plenum, Ram pressure charging, Connecting Pipe SI Engine: Properties of air-fuel mixtures-Mixture requirements for steady state and transient operation, Mixture formation studies of volatile fuels, Effects of altitude on carburetion - Petrol injection - Single point, multi point and direct injection systems - Principles and Features, Electronic fuel injection systems. CI Engine: Evolution of Fuel injection system –Pumps – Injectors and Nozzles – Spray formation characteristics	
Module 3- Lubrication and Cooling Systems	***12 Hour***
Need for cooling system–components-Thermo-syphon and Forced circulation-pressure cooling system - properties of coolant, additives for coolants Need for lubrication system-Mist lubrication system, wet and dry sump lubrication – Properties of lubricants, Grading of Lubrication oil-consumption of oil SAE grades.	
Module 4- Conventional and Automatic Transmission	***12 Hour***
Different types of clutches and requirement of transmission system–Principle, construction, torque capacity and design aspects of friction clutches–Objective of the gear box-Different types of gear boxes-Determination of gear ratios – Typical problems. Conventional automatic (hydraulic), Continuously Variable Transmission - Dual-Clutch Transmission – Hydrodynamic and Hydrostatic Drives Principle Operation and Performance.	
Module 5- Hybrid and Electric Transmission	***12 Hour***
Transmission systems in hybrid vehicles – Electric Vehicle Transmission - Permanent Magnet Motor drives (Configuration, Principle and Operation) Single speed, Multi-ratio transmission. Electric vehicle reduction gears - Smart transmissions (adaptive shifting)	

Learning Resources	*1.GanesanV, Internal Combustion Engines,4th edition, Tata McGraw Hill Book Cop.,2015* *2. Richard Stone Introduction to Internal Combustion Engines,4th edition 2012* *3 John.B. Heywood McGraw Hill Education; 1st edition (1 July 2017), 978-1259002076* *4. Duffy Smith, Auto Fuel Systems, The Good Heart Wilcox Company Inc., Publishers,1987*	*5. Edward F, Obert, Internal Combustion Engines and Air Pollution, In text Education Publishers, 1980.* *6. Yi Zhang, Automotive Power Transmission Systems, John Wiley & Sons, 2018* *7. Robert Fischer The Automotive Transmission Book, Springer 2015* *8. Newton Steeds and Gaurette The Motor Vehicle, 13th edition, 2001*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr. Thanigai Arasu G, Deputy Manager, RNTBCI, Thanigai.arasu@rntbci.com*	1. *Prof. S. Sunil, MIT Campus, Anna University, ssunil@mitindia.edu*	1. *Mr. Yokeshwaran S, SRMIST*
2. *Mr. E. Joshua Paul, Senior Engineer, L & T Technology services, Joshua.paul@ltts.com*	2. *Dr. Ilango M. Assistant Professor, NIT Calicut, ilango@nitc.ac.in*	2. *Mr. Jerome Stanley M, SRMIST*

Course Code	21AUC502T	Course Name	HYBRID ELECTRIC VEHICLE SYSTEM DESIGN ARCHITECTURE	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							2	1	0	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*provide the foundational knowledge necessary to innovate and improve hybrid vehicle technology.*
CLR-2:	*explore industry requirement as manufacturers develop more sophisticated hybrid systems to meet regulatory and consumer demands.*
CLR-3:	*understand power flow and energy distribution in hybrid vehicles*
CLR-4:	*study the various configuration of torque coupling suitable for parallel hybrid vehicles.*
CLR-5:	*understand various driving cycle suitable to test and verify the performance of the vehicles.*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*analyze the factors influencing the performance and efficiency of HEV.*	*3*	*1*	*3*
CO-2:	*explore various transmission systems, their design characteristics, performance and efficiency.*	*3*		*3*
CO-3:	*analyze power flow in hybrid electric vehicle systems including the distribution of power between the engine, motor, and battery.*	*2*		*3*
CO-4:	*integrating torque coupling mechanisms in parallel hybrid vehicles.*		*1*	*3*
CO-5:	*analyze and interpret drive cycle data to evaluate vehicle performance under various operating conditions.*		*1*	*3*

Module 1- Dynamics of Hybrid Electric Vehicles	***9 Hour***
Motion and dynamics equation for vehicles- Derivation of road load equation, Estimation of Total driving resistance, Basics of tire dynamics- Adhesion, Dynamic wheel radius, tire slip and estimation of tire load.	
Module 2- Vehicle Power Plant and Transmission Characteristics	***9 Hour***
Drivetrain configuration- powerplant, clutch/torque converters, gear box, final drive, differential shaft, driven wheel. IC engine- Types, characteristics curves (power and torque vs speed), Electric motors- types/classification, characteristic curves. Need for gear box- tractive force vs speed map with and without gear box, Vehicle performance assessment.	
Module 3- Power Flow in HEV	***9 Hour***
Power flow control- Optimum ICE operational limits, optimum electric motor operational limits, safe battery voltage. Power flow control in series hybrid- Start-up, Acceleration, braking & deceleration, full load, and vehicle at stop, Power flow control in parallel hybrid- Start-up, Acceleration, braking & deceleration, full load, and vehicle at stop, Power flow control in series-parallel hybrid- Start-up, Acceleration, braking & deceleration, full load, and vehicle at stop, battery charging during drive, battery charging at stops. Power flow control in complex hybrid control (e-axles)- Front hybrid; rear electric and Front electric; rear hybrid.	
Module 4- Torque Coupling and Analysis of parallel drive train	***9 Hour***
Torque coupling, Speed coupling, Torque couplers- Configuration of torque coupler, pulley / chain assembly torque coupler, mechanical speed couple, Planetary gear drive- configuration, operational scenarios, post transmission, Parallel Hybrid Drive Train with Torque Coupling (Pre-transmission), Parallel Hybrid Drive Train with Speed Coupling- Hybrid traction, engine alone traction, motor alone traction, regenerative braking, battery charging from ICE.	
Module 5- Drive Cycle and Detailed Analysis	***9 Hour***

Drive cycles- Initial acceleration, cruising at rated vehicle speed, cruising at maximum vehicle speed. New European Driving Cycle (NEDC), Federal Test Procedure FTP-75. Case study on Integrated motor assist and Hybrid Trans Axle.

Learning Resources	1. *I. Husain, Electric and Hybrid Electric Vehicles, CRC Press, 2018* 2. *M. Ehsani, Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design, CRC Press, 2005* 3. *G. Lechner and H. Naunheimer, Automotive Transmissions: Fundamentals, Selection, Design and Application, Springer, 1999*	4. *A. E. Fuhs, Hybrid Vehicles and the Future of Personal Transportation, CRC Press, 2009.* 5. *L. Guzella, A. Sciarretta, Vehicle Propulsion Systems, Springer, 2007*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr. Thanigai Arasu G, Deputy Manager, RNTBCI, Thanigai.arasu@rntbci.com*	1. *Prof. S. Sunil, MIT Campus, Anna University, ssunil@mitindia.edu*	1. *Mr. Yokeshwaran S, SRMIST*
2. *Mr. E. Joshua Paul, Senior Engineer, L & T Technology services, Joshua.paul@ltts.com*	2. *Dr. Ilango M. Assistant Professor, NIT Calicut, ilango@nitc.ac.in*	2. *Mr. Jerome Stanley M, SRMIST*

Course Code	21AUC511T	Course Name	AUTOMOTIVE ENGINEERING	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	0	.3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*provide an insight about vehicle classification and chassis layouts.*
CLR-2:	*impart knowledge about engines and its subsystems.*
CLR-3:	*understand various types of clutches, transmission system and brakes.*
CLR-4:	*explore various components and functions of steering, front axle and suspension systems.*
CLR-5:	*acquaint knowledge about drive line, rear axle, wheels and tyres.*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*classify various types of vehicles and its chassis layouts*		*3*	
CO-2:	*understand various types of engines and its subsystems*	*1*		*3*
CO-3:	*identify various types of clutches, transmission system and brakes.*		*2*	*3*
CO-4:	*understand the functions of steering, front axle and suspension systems.*			*3*
CO-5:	*identify various types of driveline, rear axle, wheels and tyres.*	*1*		*3*

Module-1 - Vehicle Classification and Chassis Layouts	**9 Hour**
Various vehicle chassis layouts - Classification based on controls positioning. Types of Chassis – Design considerations for conventional and Electric vehicles, construction of Body frame structure, Skateboard chassis model - EV platform and its Case studies.	
Module-2 - Engine and Subsystems	**9 Hour**
Engine components and their functions, Intake and Exhaust system components and their functions - Classification based on fuel - Gasoline, Diesel, Hybrid Vehicles, Types of cooling system and Lubrication system - Properties of coolants and lubricants.	
Module-3 - Clutch, Transmission and Brakes	**9 Hour**
Functions and type of various clutches, tractive force, gradeabilty, power required and engine characteristics, gear ratio requirement. Various types of gear boxes and calculation of gear ratios, Automatic transmission. EV Power train – Component Overview. Various types of Brakes and its functions, Regenerative braking – system configuration, braking control.	
Module-4 -Steering, Front Axle and Suspension	**9 Hour**
Steering requirements, steering gears box types, steering system and linkages, steering geometry, power steering. Purpose of front and rear suspension, types of suspension system, Active and Passive types of suspension. Case studies - EV s Drive systems.	
Module-5 -Drive Line, Rear Axle, Wheels and Tyres	**9 Hour**

Propeller shaft, final drive - types, Drive axles and differential, Full ,semi-floating and three-quarter floating, Multi axle vehicles, Types of wheels, rims, tread patterns of tyre, tube and tubeless tyres for EVs and its specifications. Mechanical failures, and sudden collisions - Case studies.

Learning Resources	*1. Newton Steeds and Gaurette The Motor Vehicle, 13th edition, 2001.* *2. Rajput.R.K"A Text Book of Automobile Engineering", Laxmi Publications (P)Ltd, 2007.*	*3. Kamaraju Ramakrishna, "Automobile Engineering", Printice Hall of India,2012.* *4. Donald L Anglin, William H Crouse, "Automotive Mechanics 10 Edition", TATA McGraw Hill Education, 2006.*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. Devanathan, Software Function Developer, RNTBCI Devanathan.kannan@rntbci.com	1. Dr. Jenoris Muthiya, Assistant Professor, Dayananda Sagar College of Engineering, jenorismuthiya-au@dayanandasagar.edu	1. Mr. S. Kiran, SRMIST
2. Mr. Mothilal Nehru Harichandran, Senior Engineer, RNTBCI, mothilal-nehru.harichandran@rntbci.com	2. Dr.Prabu K, Associate Professor Senior, VIT , prabu.k@vit.ac.in	2. Dr. K. Kamalakkannan, SRMIST

Course Code	21AUC512T	Course Name	ELECTRIC VEHICLE SYSTEM ARCHITECTURE	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	1	0	4

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*provide an insight about EV Systems Integration*
CLR-2:	*impart knowledge about Propulsion System in EVs*
CLR-3:	*understand various Drive Systems in EVs.*
CLR-4:	*explore various Energy Systems for EVs*
CLR-5:	*acquaint knowledge about charging Systems for EVs*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*classify various methods of EV Systems Integration*	*2*	*3*	
CO-2:	*understand various types of Propulsion System in EVs*	*1*	*3*	
CO-3:	*identify various types of Drive Systems in EVs.*	*3*		*3*
CO-4:	*understand the functions of Energy Systems for EVs*	*1*	*3*	
CO-5:	*identify various types of Charging Systems for EVs*	*2*	*3*	

Module-1 -EV Systems Integration	***12 Hour***
Challenges of Automotive Systems Engineering, General Layout of EV system, EV types and sub-systems components, electric vehicle components, Functional requirements design and development, Sizing and Design layout, Architectures Overview, Types of EV Vehicles, Dynamics of EVs- Electric Power Train Configuration, Power flow control in Electric drives, Comparison Electric Vehicle Vs IC engine acceleration, Case Study: EV for Future	
Module-2 -Propulsion Systems	***12 Hour***
Electric Traction: Fundamentals & General Configuration AC Vs. DC Electric drive-train topology, Brushed DC electric motor-operation-Torque -speed characteristics Modelling of EV: Structural Modelling of EV: Electrical (Power Train), Modelling: Comprehensive EV system, sizing and mass calculation Testing EV power train, Validating EV power train, Real-time data generation under various drive condition from Indian context at various cities.	
Module-3-Drive Systems	***12 Hour***
Drive losses-DC regulation and voltage regulation-switching devices, Buck-Boost regulators-single phase/three phase inverters, Characteristics of PWM control modules, Motor Controls, Electric Motor Energy Management, Motor efficiency,	

Module-4 -Energy Systems	***12 Hour***
Energy Storage Requirements in Electric Vehicles, Battery equivalent circuit, Battery capacity ,charge equalization, Battery modelling and its analysis ,Battery selection criteria: Various Battery parameters, battery modelling-battery based energy storage and its analysis , Peukert co-efficient, Battery selection and sizing -Numerical Examples Hybridization of different energy storage devices ,Energy Management Strategies -Overview, Classification Case Study on different energy management strategies	
Module-5 -Charging Systems	***12 Hour***
EV parameters (viz., energy, power, energy density, power density, efficiency, torque, thermal management) Power Train components (motors, drives etc) Vehicle system integration (eg. Performance, drivability) and interface (electrical and non- electrical) HV/LV electrical systems, DC/DC voltage conversion, DC/AC voltage conversion, Charging station and infrastructure efficiency, Selection of appropriate cables, Connectors, fuses, Charging infrastructure, Various charging ports, Charging interfaces, SAEJ1772USABC/FREEDOMCAR - and life cycle testing ,Short Circuit and Overcharge ,Safe and Reliable Electrical System	

Learning Resources	1. *Advances in Battery Technologies for Electric Vehicles, 1st Edition, Bruno Scrosati Jurgen Garche Werner Tillmetz, Hardcover ISBN: 9781782423775, e-Book ISBN: 9781782423980, Imprint: Woodhead Publishing, Published Date: 21st May 2015.* 2. *Linden's Handbook of Batteries, Fifth Edition 5th Edition, by Kirby W. Beard, ISBN-13: 978-1260115925, ISBN-10: 1260115925.* 3. *Hydrogen and Fuel Cells Emerging Technologies and Applications, 2nd Edition 2012* 4. *Iqbal Husain, ―Electric and Hybrid Vehicles Design Fundamentals‖ Published by: CRC Press, Boca Raton, Florida, USA, 2003.*	5. *Thomas B. Johansson, Renewable Energy: Sources for Fuels and Electricity, Islan Press 2009.rs: Bent Sorensen, Hardcover ISBN: 9780123877093,* 6. *James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2012.* 7. *Mehrdad Ehsani, Yimin Gao, Sebastian E.Gsay, Ali Emadi, ―Modern Electric, Hybrid Electric and Fuel Cell Vehicles-Fundamentals-Theory and Design‖, CRC Press* 8. *Bosch Automotive Handbook‖, 8th Edition*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr. T. Kasiraja, Global Senior Manager, Visteon, tkasiraj@visteon.com*	1. *Dr. Jenoris Muthiya, Assistant Professor, Dayananda Sagar College of Engineering, jenorismuthiya-au@dayanandasagar.edu*	1. *Dr. K. Kamalakkannan, SRMIST*
2. *Mr. Mothilal Nehru Harichandran, Senior Engineer, RNTBCI, mothilal-nehru.harichandran@rntbci.com*	2. *Dr.Prabu K, Associate Professor Senior, VIT , prabu.k@vit.ac.in*	2. *Dr. C. Carunaiselvae, SRMIST*

Course Code	21AUC513J	Course Name	ENERGY STORAGE SYSTEM FOR ELECTRIC VEHICLE APPLICATIONS	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	2	4

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*familiarize with the various battery charging techniques*
CLR-2:	*gain knowledge about battery charging and its techniques*
CLR-3:	*provide the knowledge about alternate energy and conversion systems*
CLR-4:	*provide the knowledge about fuel cell technology*
CLR-5:	*provide the knowledge energy storage system for electric vehicle applications*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Programme Outcomes (PO)		
		1	**2**	**3**
CO-1:	*understand the various types of battery and its technology*	*2*	*1*	
CO-2:	*understand the EV battery charging technology*	*2*	*1*	
CO-3:	*understand the various types of alternate energy conversion system*	*2*	*1*	
CO-4:	*understand the various types of Hydrogen fuel cell technology and its usage*	*2*	*1*	
CO-5:	*understand the energy storage system for EV vehicle applications*	*2*	*1*	

Module-1 -Batteries and Characteristics	***15 Hour***
Batteries-types-principle-construction-working - characteristics, Measurement of OCV, Energy requirement based on GVW, Charging/discharging regimes, Rate capacitance test, Losses in Battery, Durability, Efficiency, Thermal Runaway, Technique's to enhance Battery Life. *Practice: 1: Study on functional dissection of Battery, 2: Li-polymer batteries Charging techniques, 3: To perform the specific charge/discharge characteristics of a Lead Acid battery through experimental testing*	
Module-2 -EV Batteries and Charging Techniques	***15 Hour***
Investigation on Pros and Cons of batteries for E-mobility, modelling of specific charge/discharge characteristics, Battery testing: urban and highway driving cycles, Batteries for high current applications, Durability analysis, Advancement in EV Batteries, Design considerations, BMS and Charging Techniques, Safety considerations and Environmental impact. *Practice: 4: To perform the specific charge/discharge characteristics of a Li-Ion Acid battery through experimental testing, 5: Super capacitors components and design, Super capacitor-Electrical Characteristics. Power Density Vs. Energy Density*	
Module-3 - Alternate Energy Conversion Systems	***15 Hour***
Solar Photovoltaic, Super capacitors Ultra-capacitors, Fuel cells, and Flywheels. Hybridization techniques, PEM Fuel Cell and its characteristics, PEM Fuel Cell Balance of Plant (BoP), Thermal and Water Management. Solid Oxide Fuel cell. *Practice: 6: Various Power system hybridization Battery – Fuel Cell hybridization for transportation applications Battery, 7: PEM fuel cell polarization characteristics with 25 cm2 cell*	

Module-4 -Hydrogen Fuel	***15 Hour***
Hydrogen as a fuel, Energy carrier for hydrogen, Reforming techniques, Electrolysis techniques, ON-board hydrogen generation systems, Hydrogen Storage principles, Types of Storage System, , Significance of Cryogenic storage, Hydrogen refueling infrastructure, Hydrogen Storage limitations *Practice: 8: Experiment on Hydrogen generation Measurement (PEM-Water Electrolyser) 0.5 Nm3/h, 9: Wind Power-Electrolyser Hybridization*	
Module-5 -Trends in Energy Storage for EV	***15 Hour***
Plug-in Hybrid Electric Vehicles, Fundamentals and controls Battery Management System (BMS), Case Study on BMS Fuel Technologies in a Carbon- Constrained World, Global Energy Systems Modelling, US DOE, Case Study on EMS Modelling on Energy Demand for Battery Charging Infrastructure, Integration of Renewable Energy Systems, Water Generation and Thermal Management in Fuel cells, Impact of EV's on power grid, Optimal Location of Charging Station Vehicle to Grid (V2G). *Practice: 10: Electro chemical Modelling of Battery Fuel Cells, 11: Modellingof Thermal Management in Fuel Cells*	

Learning Resources	*1.Advances in Battery Technologies for Electric Vehicles, 1st Edition, Editors: Bruno ScrosatiJurgenGarche Werner Tillmetz, Hardcover ISBN: 9781782423775, Imprint: Woodhead Publishing, 2015.* *2.Linden's Handbook of Batteries, Fifth Edition 5th Edition, by Kirby W. Beard (Author), ISBN-13: 978-1260115925, ISBN-10: 1260115925.* *3.Hydrogen and Fuel Cells Emerging Technologies and Applications, Book • 2nd Edition • 2012 Authors: Bent Sørensen, Hardcover ISBN: 9780123877093, eBook ISBN: 9780123965035.*	*4.Iqbal Husain, "Electric and Hybrid Vehicles Design Fundamentals" Published by: CRC Press, Boca Raton, Florida, USA, 2003.* *5.Thomas B. Johansson," Renewable Energy: Sources for Fuels and Electricity" Islan Press 2009.* *6. Reasbeck Smith "Batteries of Automotive Use", 2012*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Dr.Sundar Pethiah, Singapore Power group, sundar.energy@gmail.com*	1. *Dr. S.Nataraj, SVCE, natraj@svce.ac.in*	1. *Dr. C.Prabhu, SRMIST*
2. *Mr. E. Joshua Paul, Senior Engineer, L & T Technology services, Joshua.paul@ltts.com*	2. *Mr. Arockiya Vijay, SRMIST, arockiaj1@srmist.edu.in*	2. *Dr.T.Prakash, SRMIST*

Course Code	21AUC514J	Course Name	POWER ELECTRONICS IN ELECTRIC VEHICLES	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	2	4

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*define and understand the power semiconductor components and its characteristics*
CLR-2:	*distinguish and demonstrate the different DC-DC and AC-AC converters topology*
CLR-3:	*interpret and relate the operation, characteristics and performance parameters of rectifiers*
CLR-4:	*compare and contrast the operation, switching techniques for various types of DC-AC inverters*
CLR-5:	*design and develop the motor drives for automotive motor control applications*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	**Programme Outcomes (PO)**		
		1	***2***	***3***
CO-1:	*list and recognize the various power semiconductor devices suitable for motor drive applications*	*3*		
CO-2:	*identify and solve the DC-DC and AC-AC converters suitable for the desired requirements*		*3*	
CO-3:	*experiment and sketch the various AC-DC Rectifier configurations and their input and output Waveforms*		*3*	
CO-4:	*relate and use the DC - AC Inverters with various sources and control techniques*		*3*	
CO-5:	*investigate and select the various motor drives suitable for the desired applications*			*3*

Module-1 -Automotive Semiconductor Devices	***15 Hour***
Power semiconductor devices, Diodes: Construction, characteristics and applications, Transistors: BJT, Power MOSFETs, and IGBTs: Construction, characteristics, and applications. Component Selection: R, L and C. PCB Layout and Design, Protection and Fault Handling. Operation parametrization: Turn ON and Turn OFF techniques, Series and Parallel operation, Protection circuit, Power Losses and Thermal analysis in semiconductors, Interpretation of data sheets Wide Band gap Semiconductors, Thermal Interface Material Case Study 1: Tesla Model S (Silicon carbide (SiC) power semiconductors) gallium nitride (GaN) high electron mobility transistors (HEMTs)Case Study 2: Porsche Taycan (800V system instead of the more common 400V)	
Module-2 -Power Distribution	***15 Hour***
Chopper circuit – Construction, Operation and Types, DC chopper: Buck, Boost, and Buck-Boost Converter: Construction, Principle of Operation and Characteristics – Duty cycle, Control strategies: Variable and constant frequency- Bi-directional operation, Isolated Converter Topologies: Push-Pull Converter: Topologies and Design Considerations, Multi-Output Converters: Output Voltage Regulation and Load Balancing. AC choppers: Construction, Working and types.	
Module-3 -Power Conversion	***15 Hour***
Rectifiers: 2 pulse and 6 pulse: Construction, Principle of Operation and Characteristics - Fire Angle Control Scheme, Ripple Inverters: Types of Inverters overview, Voltage Source Inverters: 120 and 180 degree mode of operation,-Filter circuits, Multilevel inverters. Power conversion efficiency of Traction Inverter Selection and Rating of switches	
Module-4 -Motor Drives Control	***15 Hour***

Drive module architecture, DC motor drives: DC motor- Construction, Working Principle and types, Speed control techniques, converter fed operation, Introduction to brushless motor drive. Induction Motor Drives: Induction motor- Construction, Working Principle and types, Speed control techniques, inverter fed operation, Introduction to permanent magnet motor drive, Configurations Drive module for Electric vehicles.
Module-5 -Power Electronics Interface for Electric Vehicles ***15 Hour***
Schematic diagram of the battery electric vehicles, Power distribution, Power Management Control Strategy, Back to Back power converters, Calculation of DC-Link Power, Design of heat sink, G2V and V2G operation in EV, Power Quality Improvement, Case Study: Automotive standards. EMI Standards and Compliance, Wireless EV Charging with WiTricity (Not for Examination)

Learning Resources	1. *.Ali_Emadi" Handbook of automotive power electronics and motor drives",3rd Edition, 2014* 2. *Ned Mohan, T.M.Undeland, W.P.Robbins," Power Electronics: Converters, applications and design", John wiley and Sons, 3rd Edition, 2006.*	3. *Rashid M.H., "Power Electronics Circuits, Devices and Applications", Prentice Hall India, 4th Edition, New Delhi, 2013*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr. Muzakkir Sharieff, CTO, Marlin Moto Corp Pvt, Ltd., muzakkirsharieff@gmail.com*	1. *Prof. S.Jeevananthan, PTU Puducherry, drsj_eee@pec.edu*	1. *Dr. C. Carunai Selvane, SRMIST*
2. *Mr. Dhinesh Natarajan, CTO, Welkinrim Technologies Pvt. Ltd., dineshnatarajan@welkinrim.com*	2. *Prof. Dr. S. Chitra Selvi, Anna University Dindugal, r.s.chitraselvi@auucedgl.ac.in*	2. *Dr. T. Praveenkumar, SRMIST*

Course Code	21AUC521J	Course Name	AUTOMOTIVE MECHANICAL SYSTEMS	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							2	0	2	3

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

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1:	*provide knowledge for understanding basic automotive engines.*
CLR-2:	*provide knowledge for understanding automobile body and chassis*
CLR-3:	*provide knowledge for understanding vehicle driveline and transmission systems.*
CLR-4:	*provide knowledge for understanding vehicle axles and steering systems.*
CLR-5:	*provide knowledge for understanding vehicle suspension and brake systems.*

Course Outcomes (CO):	*At the end of this course, learners will be able to:*	*Programme Outcomes (PO)*		
		1	*2*	*3*
CO-1:	*identify the need, requirement and function of basic automotive engines*	2	1	
CO-2:	*identify the need and requirement of automotive body and chassis.*	2	1	
CO-3:	*describe the different transmission and driveline systems of automotive vehicle*	2	3	
CO-4:	*explain the various axles and steering systems of automotive vehicle.*	3	1	
CO-5:	*describe various types and requirement of suspension and braking systems of automotive vehicle.*	2	3	

Module-1 - SI and CI Engines	***12 Hour***
Thermodynamic cycles; Four stroke SI and CI engines, Valve timing diagram, Firing order and its significance, Relative merits and demerits of SI and CI engines, Two stroke engines. Comparison of 4-stroke and 2-stroke engine operation. Engine Performance, Measurement and calculation techniques of performance parameters, SI engines, petrol injection, Open loop and closed loop systems, Mono point, multi-point and direct injection systems, Principles and Features, Bosch injection systems, CI Engines: Requirements, Air and solid injection, function of components, pressure waves, injection lag, Fuel injector. Types of injection nozzle, Nozzle tests. Spray characteristics, Injection timing, Factors influencing fuel spray atomization. Penetration and dispersion of diesel Fuel air mixing, Stages of combustion. *Practice:* *1: Study of gasoline and diesel fuel supply system.* *2: Dismantling and assembly of four stroke SI engine.* *3: Dismantling and assembly of four stroke CI engine.*	
Module-2 - Chassis and Body	***12 Hour***
Classification of vehicle, Steering location and drive. Chassis, types of chassis, Types of frames, loads acting on frame. Automobile body and various style, Pillar, Integrated body construction, Monocoque (BIW). Chassis and body materials, Vehicle interior system. Aerodynamics: drag and lift. Vehicle ergonomics. Driver visibility, Vehicle crashworthiness. *Practice:* *4. Study and measurement of various types of vehicle frame, body and driver seat.*	

5. Performing dynamic wheel balancing, tyre removal and fitment on the given HMV tyre. *6. Determination of caster, camber, toe-in and toe-out of the given HMV using computerized wheel alignment system.*
Module-3 - Transmission and Driveline ***12 Hour***
Clutches, Fluid coupling, Torque convertors, Manual gear boxes, Automated Manual Transmissions (AMT), Dual Clutch Transmissions (DCT), Automatic Transmissions (AT), Continuously Variable Transmissions (CVT), Transfer gear box, Over-drive, Universal joints, CV joints, Propeller shaft, Differential, Final Drive, Wheels and Tyres: nomenclature, Radial and Bias tyres, Tube and Tubeless tyres, Effect of tyre pressure. *Practice:* *7. Dismantling, study and assembling of automobile clutches,* *8. Calculating the maximum torque carrying capacity of the given clutch using clutch dynamometer,* *9. Study and analysis of the construction of various wheels and tyres.*
Module-4 - Axle and Steering ***12 Hour***
Front axle, rear axles: full, three-quarter and semi-floating arrangements, Steering system layout and linkages, Front wheel geometry: castor, camber, Front wheel geometry: king pin inclination, toe-in and out. Ackermann and Davis steering, Conditions for true rolling motion of wheels during steering, Steering gear box and types, Steering ratio, Turning radius, Power assisted steering systems, Steer by wire, Over-steer and Understeer, Wheel Wobble and Shimmy. *Practice:* *10: Study of various types of front and rear axles and final drives. Calculation of final drive ratio.* *11: Dismantling, study and assembling of different automobile steering systems.* *12: Determination of slide slip, suspension efficiency and brake efficiency using car test lane.*
Module-5 - Suspension and Brake ***12 Hour***
Need of suspension, Coil Spring, Leaf Spring. Shock Absorbers. MR dampers, Torsion bar springs, Conventional and independent suspension systems. Conventional and independent suspension systems, Air suspension system. Active suspension systems, Function of brake system, disc brake, drum brake, Brake Actuating Systems, power assisted brakes. Air brake system, parking brake. TCS, ESP, AEB, EPB, Regenerative braking. *Practice:* *13. Dismantling, study and assembling of automobile suspension system.* *14. Dismantling, assembling and SLO-2 bleeding of a braking system.* *15.: Performing dynamic wheel balancing, tyre removal and fitment on the given LMV tyre.*

Learning Resources	1. *Internal Combustion Engines, Ganesan, Tata McGraw-Hill Education, 2017* 2. *Motor Vehicles, Newton, Steed and Garrot, 13th Edition, Butterworth London* 3. *Vehicle and Engine Technology, Heisler, Second Edition SAE International Publication.* 4. *Advanced Vehicle Technology, Heisler, Second Edition SAE International Publication.*	5. *The Automotive Chassis, J. Reimpell H. Stoll, J.W. Betzler, SAE International Publication* 6. *R. K. Rajput, "A Textbook of Automobile Engineering", Laxmi Publication, New Delhi, 2013.* 7. *P.M.Heldt, "Automotive Chassis", Chilton Co., New York, 1982.* 8. *G.J.Giles, "Steering Suspension and Tyres", Illiffe Books Ltd., London, 1975.*

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

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr. Nava kumar.M, TVS Sundram Fasteners, navakumarmech@gmail.com*	1. *Prof. S. Sunil, MIT Campus, Anna University, ssunil@mitindia.edu*	1. *Dr. D. Boopathi, SRMIST*
2. *Dr. M. Parthasarthy, Sankar Advanced Mobility Solutions, msarathymech@gmail.com*	2. *Prof. R. Silambarasan, Annapoorana Engineering College, simbu2explore@gmail.com*	2. *Dr. K. Kamalakkannan, SRMIST*

Course Code	21AUC522J	Course Name	AUTOMOTIVE ELECTRICAL AND POWER ELECTRONICS	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	2	4

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*make aware of fundamental concepts of electrical engineering relevant to automobile*
CLR-2:	*provide knowledge on basic electronics components*
CLR-3:	*provide knowledge for understanding starting system components and their interaction*
CLR-4:	*provide knowledge for understanding of automotive charging unit.*
CLR-5:	*provide knowledge for understanding power electronics and its applications in automobiles.*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*identify the need, requirement and function of basic electrical components for automotive.*	3		3
CO-2:	*identify the need and requirement of electronics semiconductors for automotive.*	3		3
CO-3:	*describe the different starting systems for vehicle and component interactions.*	2	3	
CO-4:	*explain the various charging units deployed for automotive vehicle.*	2	1	
CO-5:	*identify the need, requirement and fundamentals of power electronics.*	3		3

Module 1 - Fundamentals of Electric Circuits	***15 Hour***
Electric circuit elements-KVL, KCL-Series-Parallel connections--Network theorems--Equivalent circuit-Steady state in ac and dc--Transients in AC-Power in AC Circuits -Power in DC Circuits-Power factor improvement-Poly phase ac circuit-Concept of phasors-Phasor diagram-Magnetic circuits-Transformers *Practice* *1: Study of Automotive electrical system* *2: & Study of Automotive motoring and generating system* *3: Direction control of automotive motors*	
Module-2 - Fundamentals of Electronic Systems	***15 Hour***
Characteristics and applications of Diodes-Thyristors-Bipolar Junction Transistors-Metal–Oxide–Semiconductor Field Effect Transistors-Insulated Gate Bipolar Transistors-Boolean logic-Basic gates and Truth tables-DAC and ADC-Introductory. Switching functions-Bipolar Logic Families-MOS logic families, and their electrical behaviour.-Memory Elements-Timing circuits-Adders-Comparators-Shift registers-Counters *Practice* *4. Analyse the characteristics of Power BJT/MOSFET/IGBT & V/f control of three-phase induction motor* *5. Study of logic gates and applications.* *6. Study and applications of digital electronics*	

Module-3 - Electric Propulsion Unit	***15 Hour***
Introduction to electric components used in electric vehicles-Configuration of induction motor drives-Control of Induction Motor drives-Configuration of DC motor drives-Configuration of Permanent Magnet Motor Drives.-Configuration of Switch Reluctance Motor Drives.-Control of Switch Reluctance Motor Drives..-Torque–Speed Characteristics..-Drive system efficiency-Propulsion mode-Generation mode *Practice* *7. V/f control of induction motor drives* *8. Speed/direction control and regeneration of SRM motor in three wheeler.* *9. Speed/direction control and regeneration of BLDC motor in two wheeler.*	
Module-4 - Power Electronics and Applications	***15 Hour***
Step-Down (Buck) Converter-Step-Up (Boost) Converter-Buck–Boost Converter-DC–DC Converters Applied in EV Systems-Isolated Buck DC–DC Converter-Four-Quadrant DC–DC Converter-Filters and High-frequency Diode Rectifier Circuits-Vehicle Auxiliary power module-Basic Principle of Voltage Source Inverters-Current Source Inverter-Closed-loop Operation of Inverters-Regeneration in Inverters-Multilevel Inverters-Integrated starter generator ISG applications *Practice* *10. Design of buck convertor of (48V/12V) and boost convertor of (12V to 60V)* *11.Design of bi-directional convertor (12V to 48V)* *12.Design of invertor and measure THD for different configurations*	
Module-5 - Charging System	***15 Hour***
Connectors-Fuses.-Charging infrastructure-Various charging ports and Charging interfaces-SAEJ1772USABC and life cycle testing.-Impact of charging strategies-Economic and environmental considerations-Impact of EV fuelling on power grid-Effect of EV charging on generation- *Effect of EV charging on load profile-Plug-in Charging-On-board charging-Wireless charging* *Practice* *13.Three phase IGBT based PWM inverter control of induction motor and Study of driver circuits and generation of PWM signals for three phase inverters* *14.Study of Automotive wiring, fuse selection* *15. Study of Automotive charging system.*	

Learning Resources	*1. J. Nagrath, and DP Kothari "Basic Electrical Engineering", Tata McGraw Hill, 4th edition, April 2019.* *2.Tom Denton, 'Automotive Electrical and Electronic Systems', Routledge, Taylor and Francis Group, 5th Edition, 2017.* *3. Young A.P. and Griffiths. L. 'Automotive Electrical Equipment', ELBS & New Press1999* *4. William B.Ribbens, 'Understanding Automotive Electronics', 5th edition - Butter worth Heinemann Woburn, 1998.* *5. Crouse, W.H. 'Automobile Electrical Equipment', McGraw-Hill Book Co., Inc., New York, 3rd edition, 1986* *6. Kholi.P.L, 'Automotive Electrical Equipment', Tata McGraw-Hill Co., Ltd., New Delhi, 1975.* *7. Robert Bosch, 'Automotive Hand Book', SAE , 5th Edition, 2000* .	*8. Rashid M.H., "Power Electronics Circuits, Devices and Applications", Prentice Hall India,Third Edition, New Delhi, 2011.* *9.Ali Emadi, "Handbook of Automotive Power Electronics and Drives", Taylor & Francis Group, First Edition, USA, 2005.* *10. Bimal K Bose, "Modern Power Electronics and AC Drives", Pearson Education, second Edition, 2003.* *11. Dubey. G.K., "Thyristorised power controllers", new age International, New Delhi, 2002.* *12. Bhimbhra P.S., "Power Electronics", Khanna Publishers, New Delhi, 2005.* *13. P.C. Sen, "Modern Power Electronics", Wheeler Publishing Co, Third edition, New Delhi,2008.* *14. Thomas B. Johansson," Renewable Energy: Sources for Fuels and Electricity" Islan Press 2009*

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

Course Designers		
Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Mr. Muzakkir Sharieff, CTO, Marlin Moto Corp Pvt, Ltd., muzakkirsharieff@gmail.com*	1. *Prof. S.Jeevananthan,* PTU Puducherry**,** *drsj_eee@pec.edu*	1. *Dr. C. Carunai Selvane, SRMIST*
2. *Mr. Dhinesh Natarajan, CTO, Welkinrim Technologies Pvt. Ltd., dineshnatarajan@welkinrim.com*	2. *Prof. Dr. S. Chitra Selvi, Anna University Dindugal, r.s.chitraselvi@auucedgl*	2. *Dr. T. Praveenkumar, SRMIST*

Course Code	21AUC523J	Course Name	ENERGY STORAGE AND MANAGEMENT	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	2	4

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

Course Learning Rationale (CLR):	The purpose of learning this course is to:
CLR-1:	*provide the knowledge about energy production system*
CLR-2:	*provide the knowledge for about energy storage characteristics and parameters.*
CLR-3:	*provide the knowledge about hybrid energy storage system*
CLR-4:	*provide the knowledge about renewable energy systems.*
CLR-5:	*provide the knowledge about energy management systems.*

Course Outcomes (CO):	At the end of this course, learners will be able to:	Programme Outcomes (PO)		
		1	*2*	*3*
CO-1:	*understand the various energy production system its applications*	*2*		*1*
CO-2:	*identify the energy storage system and its parameters.*	*2*	*3*	
CO-3:	*understand the hybrid energy storage system and its applications*	*2*		*1*
CO-4:	*understand the renewable energy production systems*	*2*		*1*
CO-5:	*understand the energy storage managements system for electric vehicle applications*	*2*		*1*

Module-1 - Introduction to Energy Storage System	**15 Hour**
Introduction to energy storage for power systems: Role of energy storage systems, applications. Overview of energy storage technologies, Thermal, Mechanical, Chemical, Electrochemical, Electrical. Efficiency of energy storage systems *Practice* *1: Study on functional dissection of Battery* *2: Li-polymer batteries Charging techniques,* *3: To perform the specific charge/discharge characteristics of a Lead Acid battery through experimental testing*	
Module-2 - Electrical Energy Storage	**15 Hour**
Electrical energy storage: Batteries, Super capacitors, Superconducting Magnetic Energy Storage (SMES), charging methodologies, SoC, SoH estimation techniques. Hydrogen production and storage, fuel cells. Mobile storage system; electric vehicle, G2V, V2G. *Practice* *4: To perform the specific charge/discharge characteristics of a Li-Ion Acid battery through experimental testing* *5: Super capacitors components and design, Super capacitor-Electrical Characteristics. Power Density Vs. Energy Density*	
Module-3 - Hybrid Energy Storage	**15 Hour**
Hybrid Energy storage systems: configurations and applications. Importance of Hybrid systems, advantages and disadvantages.	

Practice *6: Various Power system hybridization Battery – Fuel Cell hybridization for transportation applications Battery* *7: PEM fuel cell polarization characteristics with 25 cm2 cell*	
Module-4 - Renewable Energy System	**15 Hour**
Storage for renewable energy systems: Solar energy, Wind energy, pumped hydro energy, fuel cells. Energy storage in Micro-grid and Smart grid. Energy Management with storage systems, Battery SCADA, Increase of energy conversion efficiencies by introducing energy storage. *Practice* *8: Experiment on Hydrogen generation Measurement (PEM-Water Electrolyser) 0.5 Nm3/h* *9:Wind Power-Electrolyser Hybridization*	
Module-5 - Energy Storage Management System	**15 Hour**
Recent Advancement in Energy Storage and Management Systems: Simulation of energy storage systems and its management, smart park, Electric Vehicle charging facility, HESS in micro-grid and smart grid, microbial fuel cell, hydrogen fuel cell. *Practice* *10:Electro chemical Modelling of Battery Fuel Cells* *11:Modellingof Thermal Management in Fuel Cells*	

Learning Resources	*1.A.G.Ter-Gazarian, "Energy Storage for Power Systems", Second Edition, The Institution of Engineering and Technology (IET) Publication, UK, (ISBN – 978-1-84919-219-4), 2011* *2.Francisco Díaz-González, Andreas Sumper, Oriol Gomis-Bellmunt," Energy Storage in Power Systems" Wiley Publication, ISBN: 978-1-118-97130-7, Mar 2016* *3. A. R. Pendse, "Energy Storage Science and Technology", SBS Publishers & Distributors Pvt. Ltd., New Delhi, (ISBN – 13:9789380090122), 2011*	*4. Electric Power Research Institute (USA), "Electricity Energy Storage Technology Options: A White Paper Primer on Applications, Costs, and Benefits" (1020676), December 2010* *5.Paul Denholm, Erik Ela, Brendan Kirby and Michael Milligan, "The Role of Energy Storage with Renewable Electricity Generation", National Renewable Energy Laboratory (NREL) – A National Laboratory of the U.S. Department of Energy – Technical Report NREL/ TP6A2-47187, January 2010*

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

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr.Sundar Pethiah, Singapore Power group, sundar.energy@gmail.com	1. Dr. S.Nataraj, SVCE, natraj@svce.ac.in	1. Dr. C.Prabhu, SRMIST
2. Mr. E. Joshua Paul, Senior Engineer, L & T Technology services, Joshua.paul@ltts.com	2. Mr. Arockiya Vijay, SRMIST, arockiaj1@srmist.edu.in	2. Dr.T.Prakash, SRMIST

Course Code	21AUC524J	Course Name	EMBEDDED SYSTEM AND COMMUNICATION FOR AUTOMOTIVE APPLICATIONS	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	2	4

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*provide knowledge for understanding of automotive embedded system*
CLR-2:	*provide knowledge for understanding of automotive hardware module*
CLR-3:	*provide knowledge for understanding of automotive software module.*
CLR-4:	*provide knowledge for understanding fundamentals of vehicular communication systems.*
CLR-5:	*provide knowledge of automotive communication protocols*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Programme Outcomes (PO)		
		1	***2***	***3***
CO-1:	*identify the need, requirement and fundamentals of automotive embedded system*	*3*	*1*	
CO-2:	*identify the need and requirement automotive hardware module*	*3*		*3*
CO-3:	*identify the need and requirement automotive software module*		*2*	*3*
CO-4:	*identify the need, requirement and working of vehicular communication systems*	*3*		
CO-5:	*describe automotive communication protocols*	*3*		

Module-1 -Automotive Embedded System Overview ***15 Hour***

Automotive Embedded System Technology - Overview of Embedded System Categories - Various Embedded Sub Systems - Future Trends in Automotive Embedded – Systems - Drive by Wire – Autopilot - Robotics. Practice:

1. *Assembly level programming – Basic Arithmetic and logical operations.*
2. *Study of implementation, analysis and interfacing of seven segment display*

Module-2 -Automotive Hardware Module ***15 Hour***

Concept to Market: Understanding Automotive Product Design Cycle – Microcontroller - Architecture, Memory map - I/O map - Building Blocks of Automotive Electronic Product: Actuators Sensors, Semiconductor Components - Devices, Integrated Circuits (ICs) - Relay, Stepper motor, PCBs etc

Practice:

3. *Microcontroller program for Finding 2's complement of a number*
4. *Study of implementation of servo motor for position control application*

Module-3 -Automotive Software ***15 Hour***

Structure of embedded program - Linking and locating - Downloading and debugging - Intra processor Communication Protocols: I2C & I2S - IDB-1394 (Automotive Firewire) - SPI & USB, LIN and CAN - Coding Standards and Guidelines: MISHRA C & Automotive Operating System: OSEK/VDX, AUTOSAR

Practice:

5. *Introduction to Embedded C Programming and IDE-Tool chains - AVRATMEGA328 operation on bits Blinking with Digital Outputs –Delay functions*
6. *ATMEGA328- Programming Interrupts and Timers*
7. *Study of implementation of DC Motor control using PWM method*

Module-4 -Basics of Vehicular Communication	**15 Hour**
Fundamental concepts - Power Measurement - Signal-to-Noise ratio - Transmission rate constraints - Radio-frequency spectrum allocation - RADAR: operation and types, - Wireless networking: transmitter and receiver, GPS, cellular transmission, Data recorder - IEEE Wireless LANs & IEEE standards *Practice:* *8. ATMEGA328- Configuring on-chip ADC –Interfacing sensors* *9. ATMEGA328- Programming for timers*	
Module-5 -Automotive Communication Protocols	**15 Hour**
Controller Area Network (CAN): Introduction, history, types, and architecture - CAN Transceiver, frame, applications - Automotive Ethernet and applications of different communication protocols - Inter-vehicle communication - Operational modes, and vehicle applications - Adhoc Networking, communication technologies - Vehicle frequency utilization for different devices - Infrastructure-to-vehicle communication - Vehicle-to-Vehicle communication *Practice:* *10. ATMEGA328- Programming Interrupts and Timers* *11. ATMEGA328-Working with RTC and I2C* *12. Mini Project in Communication protocol*	

Learning Resources	*1. Miroslaw Staron, "Automotive Software Architectures: An Introduction", Springer, 2017. (ISBN: 978-3-319-58609-0)* *2. Nicolas Navet and Francoise Simonot-Lion, "Automotive Embedded Systems Handbook", CRC Press, 2009. (ISBN: 978- 0-8493-8026-6)* *3. Ronald K. Jurgen, "Distributed Automotive Embedded Systems", SAE International, 2007. (ISBN: 978-0-7680-1966-7)*	*4. Ronald K. Jurgen, "Automotive Software", SAE International, 2006. (ISBN: 978-0-7680-1714-4).* *5. Sloss Andrew N, Symes Dominic, Wright Chris, —ARM System Developer's Guide: Designing and Optimizing, Morgan Kaufman Publication,2004.* *6. Tom Weather Jr. &Cland c. Ilunter, "Automotive computers and control system" Prentice Hall Inc., New Jersey Bechhold, "Understanding Automotive Electronic", SAE,1998.*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. Muzakkir Sharieff, CTO, Marlin Moto Corp Pvt, Ltd., muzakkirsharieff@gmail.com	*1. Prof. S.Jeevananthan, PTU Puducherry, drsj_eee@pec.edu*	*1. Dr. C. Carunai Selvane, SRMIST*
2. Mr. Dhinesh Natarajan, CTO, Welkinrim Technologies Pvt. Ltd., dineshnatarajan@welkinrim.com	*2. Prof. Dr. S. Chitra Selvi, Anna University Dindugal, r.s.chitraselvi@auucedgl.ac.in*	*2. Dr. T. Praveenkumar, SRMIST*

ACADEMIC CURRICULA

Automotive Hybrid Systems Engineering
Automotive Technology
Electric Vehicle Technology

Professional Elective Courses

Regulations 2021

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

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

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

Course Code	21AUE501T	Course Name	COMBUSTION AND HEAT TRANSFER IN INTERNAL COMBUSTION ENGINES	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	*Automobile Engineering*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the SI engine combustion phenomenon, emission formation and control strategies*
CLR-2:	*understand the spray formation and combustion in CI engines, emission formation and control strategies*
CLR-3:	*provide an insight on various fuel injection and combustion strategies*
CLR-4:	*understand the impact of heat transfer on IC engine process*
CLR-5:	*attain familiarity on the properties and combustion characteristics of alternate fuels*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Programme Outcomes (PO)		
		1	**2**	**3**
CO-1:	*comprehend the characteristics of SI engine combustion, emission formation mechanism and control.*	*3*	*2*	*1*
CO-2:	*comprehend the characteristics of CI engine combustion, emission formation mechanism and control.*	*3*		*2*
CO-3:	*identify and analyse the fuel injection and combustion Strategies*	*3*		*2*
CO-4:	*analyze and evaluate the impact of heat transfer on IC engine process*	*3*	*2*	
CO-5:	*comprehend the significance of fuel properties of alternate fuels and its effects on engine performance characteristics*	*1*		*3*

Module-1 -SI Engine Combustion	***9 Hour***
Engine operating characteristics - Mixture preparation in SI engines -Intake and exhaust processes - SI engine combustion – knocking – cycle to cycle variations – Effects of design and operating variables on the engine characteristics - Emission formation in SI engine – Emission norms – SI engine emission control strategies	
Module-2 -CI Engine Combustion	***9 Hour***
Introduction to CI engines - operating characteristics – Nature of charge – injection timing - Mixture formation and control – CI engine combustion - knocking - Effects pf design and operating variables on the engine characteristics - Emission formation in CI engine – CI engine emission control strategies	
Module-3 -Fuel injection and combustion Strategies:	***9 Hour***
Single point and multipoint fuel injection, CRDI, GDI Method of achieving - HCCI, PCCI, RCCI, SACI Merits and challenges	
Module-4 -IC engine heat transfer:	***9 Hour***
Impact of heat transfer on engine operation - Heat transfer environment, Energy flow in an engine, SI and CI engine heat transfer, Component temperature and heat flow - heat transfer across combustion chamber walls -convective and radiative heat transfer effects in SI and CI engines – heat transfer correlations	
Module-5 -Combustion Characteristics of Alternate Fuels	***9 Hour***
Biodiesel – Alcohols – CNG – hydrogen -physiochemical properties - Advantages and challenges - Combustion and emission.	

Learning Resources	*1. John .B. Heywood McGraw Hill Education; 1st edition (1 July 2017), 978-1259002076* *2. Kirkpatrick, A. T. (2020). Internal combustion engines: applied thermosciences. John Wiley & Sons.*	*3. Van Basshuysen, R., & Schäfer, F. (Eds.). (2016). Internal combustion engine handbook. SAE International.* *4. Internal Combustion Engine by Mathur & Sharma, [Paperback],2018, Dhanpat Rai Publications*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr. Suresh Kumar, General Manager, Ashok Leyland, suresh.alh1@ashokleyland.com*	1. *Prof. V. Edwin Geo, Istinye University, edwin.varuvel@istinye.edu.tr*	1. *Dr. C.Prabhu, SRMIST*
2. *Dr.Gunabalan,Manager, R&D Turbo Energy, Chennai*	2. *Prof. P.Senthil kumar, MIT Chennai, drpsk@mitindia.edu*	2. *Dr. T. Prakash, SRMIST*

Course Code	21AUE502T	Course Name	THERMAL MANAGEMENT OF HYBRID 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	*Automobile Engineering*	**Data Book / Codes / Standards**		*Heat and Mass Transfer Data Book*	

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*familiarize about the heat transfer phenomenon in electric vehicles*
CLR-2:	*understand the heat generation in the motor*
CLR-3:	*develop insight and the need of thermal management in traction batteries*
CLR-4:	*familiarize and execute controllers for various power electronics devices*
CLR-5:	*insight on the mechanical packaging, material selection, safety standards and testing*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*apply the heat transfer equations to understand the physics of heat generation.*	3	2	1
CO-2:	*perform thermal analysis on motors*	3		2
CO-3:	*perform thermal and electro chemical analysis on batteries*	3		2
CO-4:	*implement effective heat dissipation strategies for power conditioner*	3	2	
CO-5:	*understand the temperature limitation on components- evaluate the heat flow and assess the thermal management strategies in IC engine*	1		3

Module-1 -Fundamentals of Heat Transfer	***9 Hour***
Need for heat transfer study in automotive - criteria for heat transfer - Modes of heat transfer – Fundamental governing equations for conduction, convection and radiation - Factors governing all three modes of heat transfer - Thermodynamics and heat transfer – Fluid mechanics and heat transfer - Conjugate heat transfer – Significance of dimensionless numbers – Concept of Lumped system analysis	
Module-2 -Thermal Management of Motors	***9 Hour***
Motor Sizing versus Heat Generation - Operational Temperature Limitations of Electrical Insulation- Electromagnetic Effects on Temperature: Strategies (direct and indirect) and challenges in motor thermal management - Modelling and simulation of heat transfer in motors - Sensors and Protection solutions.	
Module-3 -Thermal Management of Batteries	***9 Hour***
Source of heat - Thermal control in vehicular battery systems: Impact of temperature on battery performance –Thermal runaway: Cause, impact and mitigation Thermal management strategies and factors considered - Coolants and required characteristics.	
Module-4 -Power Electronics Thermal Management	***9 Hour***
Relevance of thermal management in power electronics and controllers – Operational Temperature Limitations - Comparison of thermal conductivities of various materials used for PCB – heat sink configuration and design - Heat Pipe geometry, design and calculation - liquid cooled plates, materials for gap free interfacing- Micro fluids and nano fluids for cooling enhancement - impact of high junction temperature.	
Module-5 -Thermal Management in IC Engines	***9 Hour***

IC engine components and working fluids – temperature limitations for components - Combustion temperature range and evaluation of heat - Strategies for engine thermal management - Role of engine thermal management in vehicle Performance and durability. *Heat flow regulation inside the vehicle - System and environmental benefits of thermal management.*

Learning Resources	*1.Thermal Management of Electric Vehicle Battery Systems Ibrahim Dinçer, Halil S. Hamut, Nader Javani Print ISBN:9781118900246 |DOI:10.1002/9781118900239 © 2017 John Wiley & Sons Ltd* *2.Vehicle Thermal Management: Heat Exchangers & Climate Control Gurusaran D. Mathur ISBN:076801445X, Publiser : SAE 2004* *3.Electric Motor Thermal Management for Electric Traction Drives (Presentation).National Renewable Energy Laboratory (U.S.), United States. Department of Energy. Office of Scientific and Technical Information, Vehicle Technologies Program (U.S.), 2014* *4.Jerry Sergent, AlKrum, "Thermal Management Hand book: For Electronic Assemblies Hardcover", 1998, Mc Graw-Hill.*	*5."Vehicle thermal Management Systems Conference Proceedings",1st Edition;2013, Coventry Techno centre, UK* *6.Younes Shabany,"Heat Transfer: Thermal Management of Electronics Hardcover"2010, CRC Press.* *7.T.Yomi Obidi, "Thermal Management in Automotive applications",2015, SAE International.* *8. John .B. Heywood McGraw Hill Education; 1st edition (1 July 2017), 978-1259002076* *9. Heat and Mass Transfer: Fundamentals and Applications | 6th Edition Paperback – 5 August 2020, by Yunus A. Cengel (Author), Afshin J. Ghajar (Author), Mc Graw Hill Publications.*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr. Shanmuga Sundaram, RNTBCI, sankaran@rntbci.com*	1. *Dr.Arul Prakasha Jothi, Vel Tech University,*	1. *Dr. C. Prabhu, SRMIST*
2. *Dr.Gunabalan, Manager, R&D Turbo Energy ,Chennai*	2. *Dr.P.Nanthakumar, Amrita school of Engineering, p_nanthakumar@cb.amrita.edu*	2. *Dr. C. Carunaiselvane , SRMIST*

Course Code	21AUE511T	Course Name	THERMAL MANAGEMENT FOR ELECTRIC VEHICLE SYSTEMS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	1	0	3

Pre-requisite Courses	Nil	Co- requisite Courses	Nil	Progressive Courses	Nil
Course Offering Department	Automobile Engineering	Data Book / Codes / Standards	Heat and Mass Transfer Data Book		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*familiarize about the heat transfer phenomenon in electric vehicles*
CLR-2:	*understand the heat generation in the motor*
CLR-3:	*develop insight and the need of thermal management in traction batteries*
CLR-4:	*familiarize and execute controllers for various power electronics devices*
CLR-5:	*insight on the mechanical packaging, material selection, safety standards and testing*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*apply the heat transfer equations to understand the physics of heat generation.*	*3*	*2*	*1*
CO-2:	*perform thermal analysis on motors*	*3*		*2*
CO-3:	*perform thermal and electro chemical analysis on batteries*	*3*		*2*
CO-4:	*implement effective heat dissipation strategies for power conditioner*	*3*	*2*	
CO-5:	*understand and evaluate the requirements for mechanical packaging, material selection, safety standards and testing*	*1*		*3*

Module-1- Fundamentals of Heat Transfer	***9 Hour***
Need for heat transfer study in automotive - criteria for heat transfer - Modes of heat transfer – Fundamental governing equations for conduction, convection and radiation - Factors governing all three modes of heat transfer - Thermodynamics and heat transfer – Fluid mechanics and heat transfer - Conjugate heat transfer – Significance of dimensionless numbers – Concept of Lumped system analysis	
Module-2- Thermal Management of Motors	***9 Hour***
Motor Sizing versus Heat Generation - Operational Temperature Limitations of Electrical Insulation- Electromagnetic Effects on Temperature- Impact of Winding and Core temperatures in Electric Machine performance - Strategies (direct and indirect) and challenges in motor thermal management - Modelling and simulation of heat transfer in motors - Sensors and Protection solutions.	
Module-3- Thermal Management of Batteries	***9 Hour***
Source of heat - Thermal control in vehicular battery systems: Impact of temperature on battery performance –Thermal runaway: Cause, impact and mitigation Thermal management strategies and factors considered - Analyzing thermal behavior during charging and discharging cycles Coolants and required characteristics	
Module-4- Power Electronics Thermal Management	***9 Hour***
Relevance of thermal management in power electronics and controllers – Operational Temperature Limitations - Comparison of thermal conductivities of various materials used for PCB – heat sink configuration and design - Heat Pipe geometry, design and calculation - liquid cooled plates, materials for gap free interfacing- Micro fluids and nano fluids for cooling enhancement - impact of high junction temperature.	
Module-5- Mechanical Packaging, Material Selection, Safety Standards and Testing	***9 Hour***
Module Designs - Materials used in Battery packs, MDS and Electronics system, Overview of safety issues related to battery thermal runaway Strategies for preventing and mitigating thermal runaway- safety standards in Industry - General Tests associated with Battery pack and MDS Failure modes of system (Characterization and Performance Testing for calibration and Safety) - Abuse testing	

Certification testing. Fundamentals and recent advancements in Numerical and 3D Simulation as applied to EV thermal management.

Learning Resources	*1.Thermal Management of Electric Vehicle Battery Systems, Ibrahim Dinçer, Halil S. Hamut, Nader Javani, ISBN:9781118900239 |DOI:10.1002/9781118900239,© 2017 John Wiley & Sons Ltd* *2. Vehicle Thermal Management : Heat Exchangers & Climate Control Gurusaran D. Mathur, ISBN:076801445X, Publiser : SAE 2004* *3. Electric Motor Thermal Management for electric Traction Drives (Presentation). National Renewable Energy Laboratory (U.S.), United States. Department of Energy. Office of Scientific and Technical Information, Vehicle Technologies Program (U.S.), 2014* *4. Jerry Sergent, AlKrum, "Thermal Management Handbook: For Electronic Assemblies Hardcover", 1998, Mc Graw-Hill.* *5. Vehicle thermal Management Systems Conference Proceedings",1stEdition;2013, Coventry Techno centre, UK*	*6. Younes Shabany,"Heat Transfer: Thermal Management of Electronics Hardcover"2010, CRC Press.* *7.T.Yomi Obidi, "Thermal Management in Automotive applications",2015, SAE International.* *8.F.A.Silva and M.P.Kazmierkowski," Energy Storage Systems for Electric Vehicles ,"in IEEE Industrial Electronics Magazine,vol.15,no.4,pp.93-94, Dec. 2021.* *9.Advances in Battery Technologies for Electric Vehicles, 1st Edition, Editors: Bruno Scrosati Jurgen Garche Werner Tillmetz, Hard cover ISBN: 9781782423775, e-Book ISBN: 9781782423980, Imprint: Wood head Publishing, Published Date: 21st May 2015.* *10.Iqbal Husain, —Electric and Hybrid Vehicles Design Fundamental, Published by: CRC Press, Boca Raton, Florida, USA, Second Edition, 2011.* *11.Tong, W. (2014). Mechanical Design of Electric Motors (1st ed.). CRC Press. https://doi.org/10.1201/b16863*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr. Shanmuga Sundaram , RNTBCI, sankaran@rntbci.com*	1. *Dr.Arul Prakasha Jothi, Vel Tech University,*	1. *Dr. C. Prabhu, SRMIST*
2. *Dr.Gunabalan,Manager, R&D Turbo Energy ,Chennai*	2. *Dr.P.Nanthakumar, Amrita school of Engineering, p_nanthakumar@cb.amrita.edu*	2. *Dr. C. Carunaiselvane , SRMIST*

Course Code	21AUE512T	Course Name	INSTRUMENTATION AND CONTROL SYSTEMS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	1	0	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*equip students with a solid foundation in measurement and control principles.*
CLR-2:	*cultivate a strong understanding of industrial processes*
CLR-3:	*troubleshoot and maintain instrumentation and control system*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Programme Outcomes (PO)		
		1	**2**	**3**
CO-1:	*design and analyze advanced control systems using modern control techniques*	*3*	*1*	*2*
CO-2:	*understand the principles of sensor fusion and multi-sensor data integration*	*3*	*2*	*1*
CO-3:	*develop problem-solving and analytical skills in control system*	*2*	*3*	*1*
CO-4:	*apply advanced control strategies such as model predictive control, adaptive control, and machine learning*	*3*	*1*	*3*

Module-1- Advanced Sensors and Transducers	**9 Hour**
Optical sensors and fiber optic sensors (Point sensor, Distributed sensor, Extrinsic sensor, Intrinsic sensor, Through Beam Sensor, Diffuse reflective Sensor and Retro-reflective sensor.)-MEMS sensors and micro-sensors (variable capacitive and piezoresistive) -Advanced temperature and pressure sensors (piezoelectric and strain gauge)-Sensor fusion and multi-sensor data integration	
Module-2- Advanced Control Strategies	**9 Hour**
Model predictive control (MPC) –(iterative, finite-horizon optimization)Adaptive control and self-tuning control Fuzzy logic control and neural networks Machine learning and deep learning in control systems	
Module-3- Microcontrollers and Embedded Systems	**9 Hour**
Microcontroller architecture and programming (ARM, AVR, PIC) Embedded systems and real-time operating systems Interfacing sensors and actuators with microcontrollers (Accelerometers-Digital-to-analog converters-GPS modules, RFID readers, Bluetooth modules)	
Module-4- Industrial Automation and Control Systems	**9 Hour**
Industrial automation and control systems (SCADA, DCS, PLC) Industrial communication protocols (Modbus, Profibus, Ethernet/IP) Advanced control systems in industrial applications (Remote Diagnostics and Maintenance-(HMI)Remote Terminal Unit (RTU)	
Module-5- Advanced Topics in Instrumentation and Control Systems	**9 Hour**
Digital signal processing in control systems Advanced control systems in Automotive applications Emerging trends in instrumentation and control systems (IoT, AI, etc.)	

Learning Resources	*1."Instrumentation and Control Systems" by William Bolton 978-0-12-823471-6 Published-2021Copyright © 2021 Elsevier Ltd.* *2. Control Systems Engineering, 8th Edition Norman S. Nise ISBN: 978-1-119-47422, 2019*	*3. Sensors and Actuators: Engineering System Instrumentation, Second Edition Hardcover – CRC Press; 2nd edition (28 July 2015).*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr. Devanathan, Software Function Developer, RNTBCI Devanathan.kannan@rntbci.com*	1. *Mr.V.Manoj Kumar,(Mech)SRMIST*	1. *Mr.S.Madhan Kumar, SRMIST*
2. *Mr. E. Joshua Paul, Senior Engineer, L & T Technology services, Joshua.paul@ltts.com*	2. *Dr.M.Sadees (EEE)SRMIST*	2. *Dr.AJD Nanthakumar, SRMIST*

Course Code	21AUE513T	Course Name	ELECTRIC VEHICLE TESTING, STANDARDS AND LEGISLATION	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	*Automobile Engineering*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*have an insight on government policies pertaining to EV*
CLR-2:	*advice policy holders to formulate regulations inline to Indian context*
CLR-3:	*know the standards for test procedure and infrastructure*
CLR-4:	*develop a road map to sustainable future – Road map*
CLR-5:	*create of job opportunities and entrepreneurship prospective in EV domain*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Programme Outcomes (PO)		
		1	**2**	**3**
CO-1:	*understand on EV regulation can be acquired*	2	3	
CO-2:	*become aware of the challenges and to set goals a sustainable mobility*		3	
CO-3:	*get an insight about various national and international standards for EV*			2
CO-4:	*acquire knowledge on various EV test facility and homologation requirements*	3		2
CO-5:	*ensure safe operation of EV system and to gain insight on type approval procedure*	3		2

Module-1- Regulations And Homologations Framework	**9 Hour**
Introduction of Regulatory framework from policy decisions - International Standards and Homologation - National Mission on Electricity mobility - Central, state and implementation agency, Role of CMVR - Understanding of testing agencies and test facilities in India - Introduction to imports and exports homologation requirements - Regulations pertaining to battery swapping and charging - Scheme for Faster Adoption and manufacturing of electric and hybrid vehicles (FAME) – Phase I and II - Administration of FAME II-Charging Infrastructure for Electric Vehicles in India-Policy - Government Incentives and Support Programs - Subsidies: From Consumers to Manufacturers - Tax Subsidies for Consumers - Subsidies for charging station - Subsidies for electric drive OEM and Battery Manufacturers - Public Perception and Acceptance of Electric Vehicles under Regulatory Framework	
Module-2- EV Standards	**9 Hour**
Definition, role and significance of Standards - Material Standards and Homologation - ARAI Standards for EVs - CMVR Type Approval for Battery Operated Vehicles (BOV) - Performance and Abuse Testing for Traction Batteries - Performance and Abuse Testing for Traction Batteries - International Standards for Motors Design, Testing, and Homologation - International Standards for Motors Design, Testing, and Homologation - ARAI's Standards for Conductive AC Chargers for EV - Fast Charger Design Factors - Fast Charger Design Factors - Slow chargers Vs. Fast chargers - Bharat DC-001 and Bharat AC-001 standards	
Module-3- Electric Vehicle Homologation	**9 Hour**
Homologation: Fundamentals - Power, Torque, Gradient & Energy consumptions - Vehicle Homologation Protocols - Retro fitment EV Homologation Procedures - Standards and testing related to EV Homologation - Introduction to EMI/EMC Testing - Vehicle and Electronic Components Shielding Requirements - Functional Safety in Power Electronics - Case studies on Homologation.	
Module-4- Component Approval and Life Cycle Assessment	**9 Hour**
Testing facilities related to Power electronics components type approval - Test bench set up - Understanding HIL and SIL simulations - Advanced testing equipments and testing methods, protocols - Safety Requirements in High Voltage handling - Tools and equipment for High Voltage Handling - Circular Economy in Component Manufacturing - Global Standards for Component Approval -	

Extension approval procedure - Non-regulatory aspects – PPAP and FMEA - Well to Wheel Analysis - Life Cycle Assessment of motors, batteries and PCB - Life Cycle Assessment of Mechanical Sub-System components - Saving Energy and Carbon Footprint Reduction with Electric Components - Recycling EV Parts
Module-5- Grid Integration Standards **9 Hour**
Establishment of network of charging stations - Network Service Providers, Data Privacy and Nodal agencies - Available infrastructure - Role of Government in Infrastructure Development - International Practices - Public – Private and restricted public use - Future goals - Promote faster adoption of EVs by ensuring safe, reliable, affordable and accessible - Interoperability between different charging networks and standards - Affordable tariff chargeable and uniformity - Battery swapping - Support creation of EV Charging Infrastructure - Economic Viability of Charging Stations - Employment or income opportunities for small entrepreneurs - Smart Charging Solutions

Learning Resources	1. *Electric Vehicle Technology Explained - Author(s):James Larminie, John Lowry; ISBN:9781118361146 |DOI:10.1002/9781118361146* 2. *Mi, Chris, and M. Abul Masrur. Hybrid electric vehicles: principles and applications with practical perspectives. John Wiley & Sons, 2017.*	3. *Husain, Iqbal. Electric and hybrid vehicles: design fundamentals. CRC press, 2021.* 4. *Willis, H. Lee, and Lorrin Philipson. Understanding electric utilities and de-regulation. CRC Press, 2018.*

Learning Assessment

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

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Mr. Muzakkir Sharieff, CTO, Marlin Moto Corp Pvt, Ltd., muzakkirsharieff@gmail.com*	1. *Prof. S.Jeevananthan,* PTU Puducherry, *drsj_eee@pec.edu*	1. *Dr. C. Carunai Selvane, SRMIST*
2. *Mr. Dhinesh Natarajan, CTO, Welkinrim Technologies Pvt. Ltd., dineshnatarajan@welkinrim.com*	2. *Prof. Dr. S. Chitra Selvi, Anna University Dindugal, r.s.chitraselvi@auucedgl.ac.in*	2. *Dr. T. Praveenkumar, SRMIST*

Course Code	21AUE514J	Course Name	DESIGN AND SIMULATION OF MOTORS FOR ELECTRIC VEHICLE APPLICATION	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	0	2	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the operation of permanent magnet motors and their selection criteria.*
CLR-2:	*impart knowledge in magnetic circuits and materials for design.*
CLR-3:	*comprehensive design approaches for radial flux motors and magnetic circuits.*
CLR-4:	*compare and contrast the effect of stator and rotor variations on the performance of motor.*
CLR-5:	*understand designing and optimizing rotor and stator variations.*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Programme Outcomes (PO)		
		1	**2**	**3**
CO-1:	*analyze motor types, performance, and selection criteria for electric vehicles.*	*3*		
CO-2:	*design and analyze magnetic circuits, materials, and core components effectively.*		*3*	
CO-3:	*design radial flux motors, including magnetic and electrical parameters effectively.*		*3*	
CO-4:	*able to design and analyze rotor/stator configurations, including heat loss reduction.*		*3*	
CO-5:	*perform testing, validation, and simulation for permanent magnet motor designs*			*3*

Module-1- Permanent Magnet Motors	**12 HOUR**
Permanent magnet motors: Types- axial and radial air gap Motors; Construction-square and sine wave motor- Shape, Torque Motor Action, Magnet Poles and Motor Phases, Poles, Slots, and Teeth, Electrical Vehicle Motor selection criteria: Mechanical and Electrical Measures and Motor Size; Phasor diagram; Torque and EMF equation; Speed characteristics; Performance and efficiency; Alternative formulation of torque and emf; Motor with 120 and 180 magnet arcs- commutation.	
Module-2- Magnetic Systems	**12 HOUR**
Magnetic Circuit Concepts, Basic relationships, Magnetic field sources, Air gap modeling, Slot modeling, Magnetic Materials, Permeability, Ferromagnetic materials, Core loss, Permanent magnets, PM magnetic circuit model; Examples. Magnetic materials Assigning; Basic design procedure -winding, stacking and slot space factor, current density, specific loading, number of magnetic poles, length of air gap winding inductance and armature reaction.	
Module-3- Fundamental Design and Equations	**12 HOUR**
Design Approach, Radial Flux Motor Design, Fixed parameters, Geometric parameters, Magnetic parameters, Electrical parameters; Design procedure; Winding configurations. *Magnetic Design- Magnetic parameters, Magnetic circuits – Linear and Non Linear calculation of magnetic circuit, Armature reaction and De-magnetization; Rotor Leakage calculation; Cogging.* *Electrical design- Electric parameters – Basic windings, Wye and Delta connections; EMF and Torque constants – Number of turns calculation – Winding inductance and armature reaction. Slotless windings.*	
Module-4- Design Variations	**12 HOUR**

Rotor Variations; Stator Variations; Shoes and Teeth; Slotted Stator Design- Fractional pitch combination, Back emf smoothing, Distribution factor, Pitch factor; calculation of force, calculation of torque, Shoes, Fractional pitch winding, Air gap lengthening, magnet pole arcs design, dummy slots, Skewing, Magnet shaping; Sinusoidal versus trapezoidal motors; Calculation and reduction of heat losses, Identification of critical parameters.
Module-5- Performance Evaluation **12 Hour**
Testing of Permanent magnet motor – Back EMF testing, Resistance and Inductance, Speed/Torque curve and load tests, Thermal resistance, Torque linearity, Torque ripple – Magnetization testing – Precision dynamometer. Case study: Design of typical 3 HP Permanent magnet motor and validations; Understanding and measuring speed, force, torque, energy and co-energy using Multiphysics software. CAD results by FEA, CAD of surface mounted radial flux permanent magnet motor, computer simulation, post processing and preprocessing.

Learning Resources	*1. R. Hendershot Jr. and TJE Miller, Design of Brushless Permanent-Magnet Motor. Magna Physics Publications & Clarendon Press, 1994, Oxford* *2. D. Hanselman, Brushless Permanent-Magnet Motor Design. McGraw-Hill, 2012.*	*3. TJE Miller, Brushless permanent-magnet and reluctance motor drives, Oxford University Press, ISBN 0-19-859369-4.*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. Muzakkir Sharieff, CTO, Marlin Moto Corp Pvt, Ltd., muzakkirsharieff@gmail.com	*1. Prof. S.Jeevananthan, PTU Puducherry, drsj_eee@pec.edu*	*1. Dr. C. Carunai Selvane, SRMIST*
2. Mr. Dhinesh Natarajan, CTO, Welkinrim Technologies Pvt. Ltd., dineshnatarajan@welkinrim.com	*2. Prof. Dr. S. Chitra Selvi, Anna University Dindugal, r.s.chitraselvi@auucedgl.ac.in*	*2. Dr. T. Praveenkumar, SRMIST*

Course Code	21AUE515T	Course Name	INTERNET OF THINGS FOR ELECTRIC VEHICLE APPLICATION	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	*Automobile Engineering*	**Data Book / Codes / Standards**		*Nil*	

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*analyze the components and systems of electric vehicles*
CLR-2:	*evaluate the security challenges in IoT-enabled electric vehicles*
CLR-3:	*compare different wireless communication technologies for IoT in electric vehicles*
CLR-4:	*synthesize data collection methods for electric vehicle monitoring*
CLR-5:	*examine the ethical considerations in IoT for electric vehicles*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*develop a predictive maintenance system for electric vehicles*	*3*	*2*	
CO-2:	*design a prototype IoT-enabled charging station*	*3*		*3*
CO-3:	*implement blockchain for secure charging transactions in electric vehicles*	*2*	*3*	
CO-4:	*construct an IoT sensor network for electric vehicle monitoring*	*1*	*3*	
CO-5:	*build a comprehensive IoT solution for electric vehicle management and optimization*	*2*	*3*	

Module-1- Introduction to IoT in Electric Vehicle.	***9 Hour***
Introduction to IoT and its Applications in Electric Vehicles, Overview of IoT Platforms and Protocols, IoT-enabled Charging Infrastructure, Case Study: Tesla's IoT Integration in Electric Vehicles, Designing a Prototype IoT-enabled Charging Station, Data Collection and Analysis for Electric Vehicle Monitoring, Security Challenges and Ethical Considerations	
Module-2- IoT Sensors and Connectivity	***9 Hour***
Types of Sensors Used in Electric Vehicles, Data Acquisition and Signal Processing, Wireless Communication Technologies, IoT-enabled Vehicle-to-Grid (V2G) Communication, Case Study: Nissan Leaf's Sensor Integration for Autonomous Driving, Developing an IoT Sensor Network for Electric Vehicle Monitoring, Real-time Data Transmission and Processing, Energy-efficient Communication Protocols, Challenges and Solutions in Sensor Integration for Electric Vehicles	
Module-3- Electric Vehicle Management	***9 Hour***
IoT-enabled Fleet Management for Electric Vehicles, IoT based Predictive Maintenance, Remote Diagnostics and Troubleshooting, Vehicle-to-Vehicle (V2V) Communication in IoT-enabled Electric Vehicles, Case Study: Ford's Implementation of IoT for Vehicle Management, Building a Predictive Maintenance System, Smart Charging Strategies, IoT-based Driver Behavior Monitoring, Regulatory and Compliance Issues in IoT for Electric Vehicle Management.	
Module-4- Data Analytics and Machine Learning .	**9 Hour**
Introduction to Data Analytics and Machine Learning in Electric Vehicles, Data Preprocessing Techniques for IoT Data, Predictive Modeling for Battery Health Monitoring, Anomaly Detection and Fault Diagnosis using Machine Learning, Case Study: BMW's Data Analytics Approach for Electric Vehicle Optimization, Developing a Predictive Model for Range Estimation in Electric Vehicles, Real-time Decision-Making using Machine Learning, Optimization Techniques for IoT-enabled Electric Vehicle Operations, Privacy Concerns and Data Protection in IoT Analytics	

Module-5- Advancements in EV applications	***9 Hour***
Edge Computing for Real-time Processing in Electric Vehicles, Blockchain Applications in Electric Vehicle Charging and Transactions, Autonomous Driving and IoT Integration, IoT-enabled Vehicle-to-Everything (V2X) Communication, Case Study: Volkswagen's Future Vision of IoT in Electric Vehicles, Implementing Blockchain for Secure Charging Transactions, Environmental Impact and Sustainability of IoT-enabled Electric Vehicles, Emerging Technologies and Innovations in IoT for Electric Vehicles, Designing a Comprehensive IoT Solution for Electric Vehicle Management and Optimization.	

Learning Resources	*1.Naveenkumar Marati, "AI Enabled IoT for Electrification and Connected Transportation", Springer Nature, 2022.* *2.Hadis Karimipour, "AI-Enabled Threat Detection and Security Analysis for Industrial IoT", Springer Nature, 2021.*	*3. Hoque, A. H. E. "Internet of Things Applications in Electric Vehicles—A Review". Springer Singapore, 2021.* *4. Emodi, N. V., "The role of Internet of Things on electric vehicle charging infrastructure and consumer experience." MDPI: Energies, 2023.*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Dr.Akhila Kumar Sahu, CECRI, Chennai.*	1. *Dr S Suresh., NIT Trichy, ssuresh@nitt.edu*	1. *Mr. G.Naresh, SRMIST*
2. *Mr.S.Vengatesan, RNTBCI, Chennai*	2. *Dr. K. Shanmuga Sundaram, College of engineering, Guindy, Chennai. drkshanmugasundaram@annauniv.edu*	2. *Dr. K. Kamalakkannan, SRMIST*

Course Code	21AUE516T	Course Name	ALTERNATE POWERTRAIN 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	*Automobile Engineering*	**Data Book / Codes / Standards**		*Nil*	

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*equip students with knowledge of gasoline and alcohol blends, and alternative fuels like CNG, LPG, and hydrogen for SI engine performance and emissions.*
CLR-2:	*provide students with an understanding of the performance characteristics and stability of biodiesel and alcohol blends in CI engines, as well as the construction and functioning of different fuel cells.*
CLR-3:	*comprehend the requirements, construction, and operation of automated manual and automatic transmission systems for electric vehicles.*
CLR-4:	*develop knowledge of the components and functionality of transmission control systems in EVs, focusing on sensors, actuators, and system optimization.*
CLR-5:	*gain insights into design considerations, performance parameters, and configurations of transmissions in electric and hybrid vehicles.*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*understand the performance and emission characteristics of gasoline and alcohol blends, including CNG, LPG, and hydrogen-fueled SI engine*	*1*	*1*	*3*
CO-2:	*analyze the performance and stability of various biodiesel and alcohol blends, along with the operation and efficiency of different types of fuel cells.*	*3*		*3*
CO-3:	*understand various types of transmission such as AT, AMT, MT.*	*3*		*3*
CO-4:	*develop an understanding of the components, functionality, and optimization strategies of transmission control systems for electric vehicles.*	*2*	*1*	*3*
CO-5:	*evaluate the design considerations, performance parameters, and configurations of transmissions in EVs and HEVs.*		1	3

Module-1- SI Engine Fuel Blends	***9 Hour***
Gasoline and alcohol blends, CNG, LPG, Hydrogen fuelled SI engine performance and characteristics, stability of petrol alcohol blends – Hydrogen and ammonia production, storage and transportation.	
Module-2- CI Engine and Fuel Cell	***9 Hour***
Various biodiesel and alcohols blends, CNG, LPG, Hydrogen fuelled CI engine performance and characteristics, stability of diesel biodiesel, Fuel cell types, construction, working, performance.	
Module-3- Automated Manual Transmission (AMT) and Automatic Transmission (AT):	***9 Hour***
Requirements of transmission in electric vehicle, Automated manual transmissions for EVs, working and construction, different configurations of AMT, actuators in AMT, CVT, Automatic transmission, working and construction, shifting strategies, features of AMT & AT, comparison with MT, iMT overview.	
Module-4- Transmission Control System for EVs	***9 Hour***
Transmission Control System, Transmission control unit, Function Development of Transmission Control System, Sensors and Actuators.	
Module-5- EV and Hybrid Vehicle Transmissions	***9 Hour***
FCEV power train systems, features of EV transmission, types, configurations, performance parameters, design consideration for EV transmission, HEV requirements of torque, different types of configurations in HEV, performance of hybrid transmissions, design parameters of HEV transmission systems.	

Learning Resources	1. *Alternative Powertrains and Extensions to the Conventional Powertrain, M Hilgers, Springer Vieweg, May 2019* 2. *Vehicle Powertrain Systems, BehroozMashadi , David Crolla, John Wiley & Sons, Ltd, 2012* 3. *Automotive Engineering Powertrain, Chassis System and Vehicle Body, David Crolla, Butterworth-Heinemann, 2009.*	4. *Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives 1st Edition, Chris Mi , M. AbulMasrur , David Wenzhong Gao , Wiley; 2011* 5. *Electric Vehicle Technology Explained 1st Edition, James Larminie, John Lowry , Wiley; 2003.*

Learning Assessment

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

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Mr. Nava kumar.M, TVS Sundram Fasteners, navakumarmech@gmail.com*	1. *Prof. S. Sunil, MIT Campus, Anna University, ssunil@mitindia.edu*	1. *Dr. D. Boopathi, SRMIST*
2. *Dr. M. Parthasarthy, Sankar Advanced Mobility Solutions, msarathymech@gmail.com*	2. *Prof. R. Silambarasan, Annapoorana Engineering College, simbu2explore@gmail.com*	2. *Dr. C. Prabhu, SRMIST*

Course Code	21AUE517T	Course Name	ELECTRO HYDRAULIC TRANSMISSION 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	*Automobile Engineering*	Data Book / Codes / Standards		*Nil*	

Course Learning Rationale (CLR):	The purpose of learning this course is to:
CLR-1:	*be familiar with the principles and components of electro hydraulic systems*
CLR-2:	*be familiar with hydraulic components: pumps and valves and actuators*
CLR-3:	*understand the proportional, servo valves and PLC based hydraulic control system*
CLR-4:	*be familiar with hydraulic system maintenance and trouble shooting*
CLR-5:	*apply electro hydraulics into various applications and case studies*

Course Outcomes (CO):	At the end of this course, learners will be able to:	Programme Outcomes (PO)		
		1	2	3
CO-1:	*understand the principles and components of electro hydraulic systems*	*1*	*2*	
CO-2:	*understand the principles and working of hydraulic components: pumps and valves and actuators*	*1*	*2*	
CO-3:	*design systems using proportional, servo valves and PLC based hydraulic control system*			*3*
CO-4:	*apply the knowledge on hydraulic system maintenance and trouble shooting*		*3*	
CO-5:	*have cognizance on electro hydraulics system design for various applications*			*3*

Module-1- Introduction to Electro-Hydraulic Systems	**9 Hour**
Principles, Applications, and Various Layouts of electro-hydraulic Systems, Comparison with Other Transmission Systems	
Module-2- Hydraulic Components	**9 Hour**
Pumps: Types and characteristics, Valves: Directional control, pressure control, and flow control valves, Actuators: Cylinders and hydraulic motors	
Module-3- Electro-Hydraulic Control Systems	**9 Hour**
Electrical control of hydraulic systems, Proportional and servo valves, PLCs (Programmable Logic Controllers) in hydraulic systems	
Module-4- Transmission Systems and its Maintenance	**9 Hour**
Open loop vs. closed loop systems, Transmission of power through hydraulic systems, Electro-hydraulic transmission in vehicles and industrial machinery, Common issues in electro-hydraulic systems, Diagnostic techniques, Maintenance practices	
Module-5- Design and analysis of an electro-hydraulic system	**9 Hour**
Implementation and testing, Real-world examples of electro-hydraulic systems Case studies from automotive, aerospace, and manufacturing industries, Presentation of findings and conclusions	

Learning Resources	1. *Title: Hydraulic Control Systems Author: Herbert E. Merritt Publisher: Wiley-Blackwell Year: 2015* 2. *Title: Fluid Power with Applications Author: Anthony Esposito Publisher: Pearson Year: 2013*	3. *Anthony Esposito, "Fluid Power with applications", Prentice Hall International, 2009.*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr. N. Vijayakumar, Head – Test Labs, MRV, MWC. VIJAYAKUMAR.N@mahindra.com*	1. *Dr. Shubhankar Chakraborty, Assistant Professor, IIITDM Kancheepuram shubhankar@iiitdm.ac.in*	1. *Dr. P. Baskara Sethupathi, SRMIST*
2. *Mr. Ravikanth, R&D Principal Member, TAFE, Chennai. ravikanths@tafe.com*	2. *Dr. S. Renold Elsen, Associate Professor, VIT, Vellore. renoldelsen.s@vit.ac.in*	2. *Dr. R. Murugesan, SRMIST*

Course Code	21AUE518T	Course Name	ADVANCED HYDRAULIC 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	*Automobile Engineering*	Data Book / Codes / Standards		*Nil*	

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*be familiar with the principles and components of hydraulic systems*
CLR-2:	*understand the various control strategies used in hydraulic systems*
CLR-3:	*be familiar with hydraulic system design and simulation*
CLR-4:	*be familiar with advanced hydraulic applications*
CLR-5:	*apply the advancements of hydraulic systems into real world applications*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Programme Outcomes (PO)		
		1	**2**	**3**
CO-1:	*understand the principles and components of hydraulic systems*	*1*	*2*	
CO-2:	*apply the various control strategies in hydraulic systems*		*3*	
CO-3:	*design and simulate hydraulic systems*			*3*
CO-4:	*provide solutions for real word applications through hydraulics*			*3*
CO-5:	*design hydraulic circuits for different applications*			*3*

Module-1- Hydraulic Principles and its Components	***9 Hour***
Fundamentals of hydraulics, Fluid properties and behaviour, Hydraulic components and their functions, Proportional and servo valves, Electro-hydraulic actuators, Hydraulic accumulators and intensifiers	
Module-2- Hydraulic Control Strategies	***9 Hour***
Proportional, integral, derivative (PID) control, Adaptive control strategies Model-based control approaches	
Module-3- Hydraulic System Design Considerations- Modelling and Simulation	***9 Hour***
Design methodologies for complex hydraulic systems, System optimization techniques, Integration of sensors and feedback mechanisms, Computational fluid dynamics (CFD) in hydraulic systems Virtual prototyping and simulation techniques	
Module-4- Advanced Hydraulic Applications	***9 Hour***
High-performance hydraulic systems Applications in Aerospace, Automotive, Robotics, automation, Offshore and marine systems	

Module-5- Modern Advancements and Case Studies	**9 Hour**
Trends in hydraulic component design and manufacturing, Emerging technologies such as electro-hydrostatic actuators (EHAs) Sustainable hydraulic systems and eco-friendly fluids, Case Studies Analysis of advanced hydraulic systems in real-world applications- Design and simulation	

Learning Resources	1. *Advanced Hydraulic Control Author: Peter Harriott Publisher: Wiley-Blackwell Year: 2017* 2. *Title: "Hydraulic Control Systems" Author: Herbert E. Merritt Publisher: Wiley-Interscience Year: 2014*	3. *Anthony Esposito, "Fluid Power with applications", Prentice Hall International, 2009.*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr. R Raja, Senior Manager, MRV, MWC R.RAJA@mahindra.com*	1. *Dr. Kashfull Orra, Assistant Professor, IIITDM Kancheepuram orra@iiitdm.ac.in*	1. *Dr. P. Baskara Sethupathi, SRMIST*
2. *Mr. K. Saravanan, R&D Principle Member, TAFE, Chennai, ksaravanan@tafe.com*	2. *Dr. V. Rajkumar, Assistant Professor, IIT Jammu. rajkumar.v@iitjammu.ac.in*	2. *Dr. R. Murugesan, SRMIST*

Course Code	21AUE519T	Course Name	AUTOMOTIVE AIR CONDITIONING AND HEATING 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	*Automobile Engineering*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*describe the working of air conditioning system.*
CLR-2:	*explore the components required in order to maintain the required temperature in both heating and cooling systems.*
CLR-3:	*study the various refrigerant and its properties, controls and delivery systems.*
CLR-4:	*understand the automatic temperature control systems*
CLR-5:	*compute the issues found in air conditioning system*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*identify the various refrigeration components in air conditioning system and understand the thermal condition of psychrometry process*		*2*	*2*
CO-2:	*select the type of compressor based on specific requirements*		*2*	*3*
CO-3:	*discuss the control, delivery devices, charge and leakage detections*	*2*	*2*	
CO-4:	*recognize the fixed and variable displacement temperature control systems*	*3*		*2*
CO-5:	*interpret the systems to find the special tools for servicing and testing*			*2*

Module-1- Fundamentals of Automotive Air-conditioning	***9 Hour***
Schematic layout of a vehicle compression refrigeration system - Location of air conditioning components in a car. Psychrometry – terminology, mixtures and chart. Purposes of Heating, Ventilation and air Conditioning - Environmental Concerns - Ozone layer depletion.	
Module-2- Vehicle Cooling and Heating System	***9 Hour***
Types of compressors - Compressor clutches- Compressor Clutch electrical circuit Compressor lubrication- Condensers - Evaporators - Expansion devices - Evaporator temperature and Pressure controls- Receiver - drier- Accumulators- Refrigerant hoses, Connections and other assemblies- Heating system, Vehicle Refrigeration System and related problems - fixed thermostatic and Orifice tube system - variable displacement thermostatic and Orifice tube system.	
Module-3- Air-Conditioning Controls, Delivery System and Refrigerants	***9 Hour***
Types of Control devices - Compressor and subsystems damage prevention, maintaining drivability - ram air ventilation overheating prevention - Air delivery components- Control devices - Vacuum Controls Containers – Handling refrigerants – Discharging, Charging & Leak detection – Refrigeration system fault diagnosis – Diagnostic procedure – Ambient conditions affecting system pressures.	
Module-4- Automatic Temperature Control	***9 Hour***
Different types of sensors and actuators used in automatic temperature control- Fixed and variable displacement temperature control - Semi Automatic - Controller design for Fixed and variable displacement type air conditioning system.	
Module-5- System Servicing and Testing	***9 Hour***
Special tools for servicing vehicle air conditioning – Diagnosing components and air conditioning systems - Diagnosing cooling system- Air delivery system - Automatic temperature Control system diagnosis and service, Influence of Air Conditioning System in Battery Management System.	

Learning Resources	1. *Steven Daly, "Automotive Air Conditioning and Climate Control Systems", Elsevier, 2011.* 2. *Warren Farnell and James D. Halderman, "Automotive Heating, Ventilation, and Air Conditioning systems", Classroom Manual, Pearson Prentice Hall, 2004.*	3. *Goings, L.F., "Automotive Air Conditioning", American Technical services, 1974.* 4. *Mitchell Information Services, Inc., "Mitchell Automatic Heating and Air Conditioning Systems", Prentice Hall Inc., 1989.* 5. *McDonald, K.L., "Automotive Air Conditioning", Theodore Audel series, 1978.* 6. *Paul Weisler, "Automotive Air Conditioning", Reston Publishing Co. Inc., 1990.*

Learning Assessment

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

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Mr. Kumar, ETA India Pvt Ltd, kumar.s@eta-engg.com*	1. *Prof. M.R. Swaminathan, Anna univ,* swami774@annauniv.edu	1. *Mr. S. Logeshwaran, SRMIST*
2. *Mr. Ranijth rao, amnear India pvt td, ranjith.rao@amnear.com*	2. *Prof. Gurubalan, IIT Bombay, guru.a@iitb.ac.in*	2. *Dr. C. Prabhu, SRMIST*

Course Code	21AUE521J	Course Name	AUTOMOTIVE TRANSDUCERS AND SIGNAL CONDITIONERS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	0	2	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*know the importance and use of sensors and actuators in vehicular applications*
CLR-2:	*understand the basic principles and working of sensors and actuators*
CLR-3:	*control an actuator for automotive application.*
CLR-4:	*design a signal conditioning circuit using operational amplifier.*
CLR-5:	*design and implement an analog to digital conversion circuit*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*identify the need, requirement and fundamentals of sensors and actuators.*	3	3	
CO-2:	*identify the need, requirement and working of sensors and actuators*	3	3	
CO-3:	*describe the automotive applications of sensors in EHV system requirements.*		3	
CO-4:	*identify the need, requirement and working of various Conversion circuits.*	3	3	

Module-1 -Sensing and Actuation	***12 Hour***
Classification of Sensor-Input Signals and Signal Conversion - Signal conversion methods and their applications - Different types of signals (analog, digital) – *Practice 1: Introduction to Sensors and Transducers - Different methods of sensing-* *Practice 2: TPS, MAF Sensor Characteristic Study - Understanding the output signals from sensors - Role of actuators in automotive systems* *Practice 3: RPM, CT, Lambda Sensor Characteristic Study - Identification of variables to be controlled by actuators - Different types of actuators: electrical, electromechanical - Factors influencing actuator selection for specific applications - cutting-edge sensors and actuators technologies - Sensor calibration* *Practice 4: Parking, TPMS, Torque, Rain Sensor Characteristic Study.*	
Module-2 -Automotive Sensors	***12 Hour***
Sensors and Its Types – Accelerometers - Yaw-Rate Sensors - Tire-Pressure and Temperature Sensors - Hall-effect Sensors - Mass-Flow Sensors - Radar, Lidar, Sonar Sensors *Practice 5: Accelerometer, Gyroscope, IMU, Airbag Sensor Characteristic Study - Vision and GPS Sensors – Gyroscope* *Practice 6: LIDAR, SONAR, RADAR, CAMERA Characteristics Study of Cam and Crank-Angle Sensors, Steering-Angle Sensors - Force and Torque Sensors* *Practice 7: GPS and Vision Sensor Characteristic Study - Light Sensors and Rain Sensors - Chemical Sensors for Oxygen Detection and Air/Fuel Ratio - Sensors for In-cabin monitoring - Electric-Current and voltage Sensing* *Practice 8: Realization Relay, Throttle Valve actuator, Power Window, Wiper, Power Steering - Sensor Integration and Testing*	
Module-3 -Signal Conditioning Characteristics and Application	***12 Hour***
Ideal OP-AMP Open Loop - feedback in OP-AMP operation - Inverting amplifier - Non-inverting amplifier - Voltage follower - Differential amplifiers *Practice 9: Op-Amp V-I and I-V convertor - CMRR - Signal amplification using IC 741* *Practice 10: Sample and Hold Circuit - OP-Amp D.C characteristics - Basic OP-AMP applications*	

Practice 11 & 12: Op-Amp Instrumentation Amplifier Realization - Instrumentation amplifier.- Sample and Hold Circuit V-I and I-V convertor - Multiplier, Divider Integrator and Differentiator - Introduction to digital filters - Filters -Types- Low pass, high pass, band pass *Practice 13: ADC Realization–Flash ADC, Successive approximation ADC*
Module-4 -Automotive Actuators ***12 Hour***
Engine control actuators - Fuel injector (Solenoid, Piezo electric type) - Ignition coil operation - EGR Actuator - Electric actuators - Relays and switches *Practice 14: Introduction to Operational Amplifier IC741 - D.C motor - Brushless D.C Motor* *Practice 15: Op-Amp Linear Applications: Adder, Subtractor, Comparator, Differentiator, Integrator. - PMS Motor Stepper Motor and Servo mechanism.- Pulse width Modulated signal- Basics and generation principles* *Practice 16: Op-Amp Instrumentation Amplifier Realization - Pulse width Modulated signal application-DC motor - Fundamentals of H-bridge - H-bridge circuit- speed and direction control - H-bridge circuit- speed and direction control- Case study - Advanced Actuator Control Strategies* *Practice 17: OP-Amp Non Linear Applications: Clipper, Clamper, Peak detector*
Module-5 -Waveform Generators and Analog – Digital Convertors ***12 Hour***
Fundamental of Waveform generation - square-wave, sinewave, triangular-wave - Wave characteristic study - introduction to Comparator and its Applications - introduction to Comparator and its Applications *Practice 18: DAC Realization –Weighted resistor,R-2R ladder and inverted R-2R ladder - Voltage-Controlled Oscillators (VCO) and Frequency Synthesis - Fundamentals of ADC* *Practice 19: Comparator Realization - Direct Type ADC's/Flash ADC - Successive approximation ADC* *Practice 20: Wave generation and realization - ADC applications - DAC fundamentals - Types- R-2R ladder and inverted R-2R ladder.- Weighted resistor-Types - DAC Applications*

Learning Resources	1. *J.Marek "Sensors Applications Volume 4 Sensors for Automotive Applications"-Volume 4, WILEY-VCH GmbH and Co. KGaA,2006* 2. *Sergio Franco, "Design with Operational Amplifiers and Analog Integrated Circuits", 3rd Edition, 3rd edition (1 July 2017), ISBN-13 : 978-0070530447* 3. *Ribbens W. Understanding automotive electronics: an engineering perspective. Butterworth-heinemann; 2017.*	4. *Carter, Bruce, and Ron Mancini. Op Amps for everyone. Newnes, 2017.* 5. *Bosch' Automotive Handbook, 8thEdition William.B.Ribbens, "Understanding Automotive Electronics" 7th edition Butterworth-Heinemann publications, 2012.*

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

Course Designers		
Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Mr. Muzakkir Sharieff, CTO, Marlin Moto Corp Pvt, Ltd., muzakkirsharieff@gmail.com*	1. *Prof. S.Jeevananthan, PTU Puducherry, drsj_eee@pec.edu*	1. *Dr. C. Carunai Selvane , SRMIST*
2. *Mr. Dhinesh Natarajan, CTO, Welkinrim Technologies Pvt. Ltd., dineshnatarajan@welkinrim.com*	2. *Prof. Dr. S. Chitra Selvi, Anna University Dindugal, r.s.chitraselvi@auucedgl.ac.in*	2. *Dr. T. Praveenkumar, SRMIST*

Course Code	21AUE522J	Course Name	INTELLIGENT ALGORITHMS AND CONTROL	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	0	2	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*comprehend systems engineering concept with respect to control systems.*
CLR-2:	*learn about the stability analysis of control systems.*
CLR-3:	*know about the various types of optimization techniques.*
CLR-4:	*enable the understanding of cope and implications of machine learning.*
CLR-5:	*learn about the concepts of deep learning.*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*apply systems engineering approach for control system analysis.*	3	2	1
CO-2:	*formulate an appropriate control algorithm for the given application.*	3	1	2
CO-3:	*apply the appropriate optimization algorithm for the given problem.*	3	1	2
CO-4:	*apply statistical concepts in machine learning problems.*	3	1	2
CO-5:	*apply neural network model for deep learning problems.*	3	1	2

Module-1 - Systems Engineering and Control	***12 Hour***
System Engineering concept – Significance of systems engineering approach, Systems and Models. Control systems, Basic elements, Signals and their types, Open loop and Closed loop control systems, Simple examples, Analysis and Design objectives of Control systems. Time domain analysis – Poles, Zeros, System response of first order systems and second order systems. Frequency Domain analysis – Transfer function analysis. Practice 1: Introduction to modelling and Simulation software like MATLAB, Modelica based tools, Practice 2: Determine the poles and zeros for a given transfer function. Analyse the given control problem in time domain and frequency domain. Practice 3: Obtain the root locus plot, Bode plot for a system with a transfer function.	
Module-2 -Advanced Control Engineering	***12 Hour***
Stability analysis of control systems – Concept of stability, Routh Hurwitz criteria, Root locus method, Bode plot, Nyquist stability criteria, Nyquist plot, Ziehler Nocholas method, State space analysis – Approach, state space equations, Simple automotive examples. PID controller – PID logic, PID implementations, Basic control cases using PID control. Adaptive Control – Types, Applications, Real time parameter estimation, Model reference adaptive control. Model predictive control – Methodology and Structure, Elements of MPC, MPC algorithms, Practice 4: Simulate the response for a given first order / second order system for different inputs (Step / Ramp / Impulse), Practice 5: Design a PID controller for the given plant model to meet specified performance criteria.	
Module-3 -Optimization and Algorithms	***12 Hour***
Optimization – Definition, Types, Modelling and formulation, Unconstrained optimization and Constrained optimization, Linear Programming, Integer Programming, Classification of optimization algorithms, Multi Objective Optimization. Optimization Algorithms – Genetic Algorithm, Particle Swarm Optimization, Ant Colony Optimization. Filtering – Introduction to Filtering, Moving average filter, Kalman filter, Extended Kalman filter. Practice 6: Implement a genetic algorithm/particle swarm optimization algorithm to solve the given optimization problem, Practice 7: Implement a Kalman filter for state estimation of the given dynamic system	
Module-4 - Introduction to Machine Learning	***12 Hour***

Introduction: Definition and scope, Historical overview and milestones, Types of machine learning: supervised, unsupervised, reinforcement learning, Overview of various applications. Mathematical concepts - Probability theory basics, Statistical concepts of mean, variance, standard deviation, Probability distributions: Gaussian, Bernoulli and multinomial, Bayesian inference. Expectation, Variance and Covariance. Supervised learning - Regression: linear regression, polynomial regression, Classification: logistic regression, decision trees, random forests, Model evaluation metrics: accuracy, precision, recall, F1-score, Overfitting, underfitting, bias-variance tradeoff. Unsupervised learning - Clustering: K-means, hierarchical clustering, Dimensionality reduction: Principal Component Analysis (PCA), t-SNE, Association rule learning: Apriori algorithm, Evaluation methods for unsupervised learning. Practice 8: Implement linear regression and polynomial regression using Python or MATLAB Evaluate model performance using metrics such as accuracy, precision, recall, and F1-score. Practice 9: Apply K-means and hierarchical clustering algorithms to group similar data points in the given data set.
Module-5 -Artificial Intelligence ***12 Hour***
Deep Learning - Introduction to neural networks: perceptrons, activation functions, Feed forward neural networks, Convolutional Neural Networks (CNNs) for computer vision Recurrent Neural Networks (RNNs) for sequence data, Training neural networks: backpropagation, optimization algorithms (SGD, Adam). Reinforcement Learning - Overview of reinforcement learning, Deep Q-Networks (DQN), Policy gradients and actor-critic methods. Integration of AI and Control - Motivation for integrating AI techniques with control, Fuzzy logic and Control, Autonomous vehicles and transportation systems. Ethical considerations and societal impacts of Artificial Intelligence,vPractice 10: Build a simple feed forward neural network model using Python / MATLAB for the given problem. *Practice 11: Implement a fuzzy logic controller for the given control task problem.*

Learning Resources	1. *Benjamin S. Blanchard and Wolter J. Fabrycky, "Systems Engineering and Analysis", Pearson, 2010.* 2. *Norman S. Nise, "Control Systems Engineering", Wiley, 2020.* 3. *Marc Peter Deisenroth, A Aldo Faisal, and Cheng Soon Ong, "Mathematics for Machine Learning", Cambridge University Press, 2020.*	4. *Ethem Alpaydin, "Introduction to Machine Learning", MIT Press, 2014.* 5. *Pradeep Singh, "Fundamentals and Methods of Machine and Deep Learning, Algorithms, Tools, and Applications" , Wiley, 2022.*

Learning Assessment

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

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr. G. Dhivakar, Lead Geometric Architect, Vehicle Engineering, Volvo Group, Bangalore.*	1. *Dr. J. Preetha Roselyn, Professor, Electrical and Electronics Engineering, SRMIST.*	1. *Dr. AJD Nanthakumar, SRMIST*
2. *Mr. Dhinesh Natarajan, CTO, Welkinrim Technologies Pvt. Ltd., dineshnatarajan@welkinrim.com*	2. *Dr. M. Sadees, Assistant Professor, Electrical and Electronics Engineering, SRMIST.*	2. *Dr. C. Carunai Selvane, SRMIST*

Course Code	21AUE523J	Course Name	CONTROL SYSTEMS ALGORITHM	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	0	2	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*broaden the understanding of control engineering fundamentals*
CLR-2:	*understand the basic control algorithm design techniques*
CLR-3:	*acquire knowledge about neural network fundamentals*
CLR-4:	*enable the understanding of fuzzy sets and fuzzy logic.*
CLR-5:	*learn about the concepts of evolutionary algorithms.*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Programme Outcomes (PO)		
		1	**2**	**3**
CO-1:	*conduct stability analysis of control systems.*	*3*	*2*	*1*
CO-2:	*formulate an appropriate control algorithm for the given application.*	*3*	*2*	*1*
CO-3:	*formulate a neural network model for the given problem with hidden layers.*	*3*	*1*	*2*
CO-4:	*formulate a fuzzy logic controller for the given control problem.*	*3*	*1*	*2*
CO-5:	*select an appropriate evolutionary algorithm for the given control problem.*	*3*	*1*	*2*

Module-1 - Introduction	***12 Hour***
Control Systems - History and applications, open-loop and closed-loop systems, Dynamic Systems – Modelling and Control, Differential equations, Modelling mechanical, electrical, and thermal systems, Transfer functions, State space representation. Time Domain analysis - Transient and steady-state response, Stability analysis, Time-domain specifications. Frequency Domain analysis - Bode plots, Nyquist criterion, Frequency Response Analysis. Stability analysis - Routh-Hurwitz Criterion, Root Locus Method, Gain and Phase Margins. *Practice 1: Introduction to modelling and Simulation software like MATLAB, Modelica based tools* *Practice 2: Determine the poles and zeros for a given transfer function. Analyse the given control problem in time domain and frequency domain.* *Practice 3: Obtain the root locus plot, Bode plot for a system with a transfer function.*	
Module-2 - Control Design Techniques	***12 Hour***
Classical Control Design Techniques - PID Controllers, Lead-Lag Compensation, Design via Root Locus State-Space Analysis and Design - State-Space Representation, Controllability and Observability, State Feedback and Observer Design. Optimal Control Techniques - Linear Quadratic Regulator (LQR), Quadratic Gaussian (LQG), State estimation through Kalman filter. *Practice 4: Simulate the response for a given first order / second order system for different inputs (Step / Ramp / Impulse)* *Practice 5: Design a PID controller for the given plant model to meet specified performance criteria.*	
Module-3 - Neural Control	***12 Hour***
Artificial Neural Networks – Basic structure, Feed forward / Back propagation neural networks, Radial Bassis function networks, Recurrent Neural networks. Dynamic system modelling - System Identification Using Feedforward Networks, System Modeling by Radial Basis Function neural networks, System Representation by Recurrent Neural networks. Neural Control - Supervised Control, Direct Inverse Control, Model Reference Adaptive Control, Internal Model Control, Model Predictive Control, Feedforward Control.	

Practice 6: Study the mathematical formulation of a perceptron and implement a single-layer perceptron in Python. *Practice 7: Create a neural network for the given problem with two hidden layers, implement the network in Python / MATLAB.*
Module-4 - Fuzzy Control **12 Hour**
Fuzzy Logic - Fuzzy Sets, Fuzzy Operations, Fuzzy Relations, Fuzzy Inference System, Fuzzifier, Fuzzy Rule Base, Fuzzy Inference Engine, Defuzzifier, Fuzzy membership functions. Knowledge-Based Fuzzy Control - Fuzzy PID Control, Hybrid Fuzzy Control, Supervisory Fuzzy Control, Self-Organizing Fuzzy Control, Fuzzy Model Reference Learning Control. Model–Based Fuzzy Control - Fuzzy Inverse Control, Fuzzy Inverse Control for a Singleton Fuzzy Model, Fuzzy Model–Based Predictive Control, Fuzzy Internal Model Control. *Practice 8: Design a fuzzy logic controller for the given control system. Compare the performance of the fuzzy controller with a PID controller.*
Module-5 - Evolutionary Algorithms **12 Hour**
Evolutionary Algorithms -Exploration versus exploitation, Computational and optimization problems, Objective function, Representation, Constraints, Variation operators, Selection and elimination operators. Local search operators - Steepest descent, Monte Carlo sampling, k-opt. Genetic Algorithm – Introduction, Basic concepts, working principle, procedures of GA, flow chart of GA, Genetic representations, (encoding) Initialization and selection, Genetic operators, Mutation, Generational Cycle. Swarm intelligence - Particle swarm optimization (PSO) Ant colony optimization (ACO). Bees colony algorithm (BCO). Practice 9: Build a multi-objective genetic algorithm for the given problem and implement through a software code. *Practice 10: Build a multi-objective swarm intelligence algorithm for the given problem and implement through a software code. .*

Learning Resources	*1. Yung C. Shin, Chengying Xu, "Intelligent Systems Modeling, Optimization, and Control", ISBN: 9781420051766 452, CRC Press, 2009.* *2. A.E. Ruano, "Intelligent Control Systems using Computational Intelligence Techniques", ISBN: 978-0-86341-489-3, IET Press, 2005.*	*3. Dan Simon, "Evolutionary Optimization Algorithms: Biologically Inspired and Population-based Approaches to Computer Intelligence", ISBN: 978-0-470-93741-9, Wiley, 2013.* *4. James Kenndey and Rusell C. Eberhart. - "Swarm Intelligence" , ISBN: 978-1-55860-595, Mkf, 2001.*

Learning Assessment

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

Course Designers		
Experts from Industry	***Experts from Higher Technical Institutions***	***Internal Experts***
1. *Mr. G. Dhivakar, Lead Geometric Architect, Vehicle Engineering, Volvo Group, Bangalore.*	1. *Dr. J. Preetha Roselyn, Professor, Electrical and Electronics Engineering, SRMIST.*	1. *Dr. AJD Nanthakumar, SRMIST*
2. *Mr. Muzakkir Sharieff, CTO, Marlin Moto Corp Pvt, Ltd., muzakkirsharieff@gmail.com*	2. *Dr. M. Sadees, Assistant Professor, Electrical and Electronics Engineering, SRMIST.*	2. *Dr. C. Carunai Selvane, SRMIST*

Course Code	21AUE524J	Course Name	ADVANCED COMMUNICATION PROTOCOLS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	0	2	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*provide knowledge for understanding of automotive embedded system*
CLR-2:	*provide knowledge for understanding of automotive hardware module.*
CLR-3:	*provide knowledge for understanding of automotive software module.*
CLR-4:	*provide knowledge for understanding fundamentals of vehicular communication systems.*
CLR-5:	*provide knowledge of automotive communication protocols.*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Programme Outcomes (PO)		
		1	**2**	**3**
CO-1:	*identify the need, requirement and fundamentals of automotive embedded system.*	*3*		*2*
CO-2:	*identify the need and requirement automotive hardware module*	*3*		*1*
CO-3:	*identify the need and requirement automotive software module*	*3*		*2*
CO-4:	*identify the need, requirement and working of vehicular communication systems.*	*3*		*3*
CO-5:	*describe automotive communication protocols.*	*3*	*3*	

Module-1 -Basics of Vehicular Communication	***12 Hour***
Fundamental concepts – Bandwidth - Power Measurement - Signal-to-Noise ratio - Transmission Rate Constraints - Radio-frequency spectrum allocation - RADAR: operation and types. - Forward radar - Side radar - Wireless networking: transmitter and receiver. GPS, Cellular transmission, Data recorder, IEEE wireless LAN's and IEEE standards *Practice: 1. Radio-frequency spectrum allocation, 2. Wireless networking: transmitter and receiver.*	
Module-2 -Automotive Communication Protocols	***12 Hour***
Controller Area Network (CAN): Introduction - CAN Transceiver, frame, applications - Local Interconnect Network - FlexRay, MOST - Automotive Ethernet and applications of different communication protocols. - Wireless Communications: Bluetooth, evolution. - Classes, Operation. - Spectrum Utilization. - Operational Modes, And Vehicle applications - Vehicle interior system. - Adhoc Networking - Communication Technologies. - Vehicle frequency utilization for different devices. Infrastructure-to-Vehicle communication. - Vehicle-to-Vehicle communication. *Practice: 3. Local Interconnect Network, 4. Spectrum Utilization*	
Module-3 -Safe-by-Wire	***12 Hour***
Motorola Interconnect (MI) - Distributed Systems Interface (DSI) - [Multimedia] DB2 (similar to MOST) - Domestic Digital Bus (D2B) - Mobile Multimedia Link (MML) - IDB-1394 (Automotive Firewire) – USB - Wired Technologies – TDMA-based networks – TTP, TT-CAN - FlexRay; TTEthernet. *Practice:5. Distributed Systems Interface, 6. IDB-1394*	
Module-4 -Wireless Technologies	***12 Hour***

Bluetooth (IEEE 802.15.1) - ZigBee (IEEE 802.15.4) - Wi-Fi (IEEE 802.11) - UWB (IEEE 802.15.3a) - C2C-CC - Introduction to wireless Networks, Advantages and disadvantages of Wireless Local Area Networks, WLAN Topologies, WLAN Standard IEEE 802.11, IEEE 802.11 Medium Access Control, Comparision of IEEE 802.11 a,b,g and n standards, IEEE 802.16 and its enhancements, Wireless PANs, Hiper Lan, WLL. *Practice: 7. ZigBee, 8. Wi-F, UWBi*
Module-5 -DSRC ***12 Hour***
Security And Privacy Protection - Low Latency - Coverage with scalability, 5.850ghz – 5.925ghz – band -Basic Safety messaging. - Collective Perception Messaging - Maneuver coordination - Platooning messaging, vulnerable road users - NPRM, LTE-V2X, AFAI (Alliance For - Automotive Innovation) - OSEK/VDX *Practice: 9. Coverage with scalability, 10. Maneuver coordination*

Learning Resources	1. *Miroslaw Staron, "Automotive Software Architectures: An Introduction", Springer, 2017. (ISBN: 978-3-319-58609-0)* 2. *Nicolas Navet and Francoise Simonot-Lion, "Automotive Embedded Systems Handbook", CRC Press, 2009. (ISBN: 978- 0-8493-8026-6)* 3. *Ronald K. Jurgen, "Distributed Automotive Embedded Systems", SAE International, 2007. (ISBN: 978-0-7680-1966-7)*	4. *Ronald K. Jurgen, "Automotive Software", SAE International, 2006. (ISBN: 978-0-7680-1714-4).* 5. *Sloss Andrew N, Symes Dominic, Wright Chris, —ARM System Developer's Guide: Designing and Optimizing, Morgan Kaufman Publication,2004.* 6. *Tom Weather Jr. &Cland c. Ilunter, "Automotive computers and control system" Prentice Hall Inc., New Jersey* 7. *Bechhold, " Understanding Automotive Electronic", SAE,1998.*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr. E. Joshua Paul, Senior Engineer, L & T Technology services, Joshua.paul@ltts.com*	1. *Dr.P.Sathish Kumar, Asst. Professor, NIT Puducheryy, Karaikkal, Sathish.p@nitpy.ac.in*	1. *Dr.Sanjay A. Patil, ARAI*
2. *Mr. Devanathan, Software Function Developer, RNTBCI, Devanathan.kannan@rntbci.com*	2. *Dr. Ilango M. Assistant Professor, NIT Calicut, ilango@nitc.ac.in*	2. *Mr. Jerome Stanley M, SRMIST*

Course Code	21AUE611T	Course Name	ARTIFICIAL INTELLIGENCE FOR ELECTRIC VEHICLE APPLICATION	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	*Automobile Engineering*	**Data Book / Codes / Standards**		*Nil*	

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the Interplay between AI and EV Technology*
CLR-2:	*master AI and ML-Driven Optimization Techniques for EVs*
CLR-3:	*implement AI-driven solutions for optimizing energy consumption and management in EVs*
CLR-4:	*design and analyze AI systems that enable autonomous driving functionalities EV dynamics*
CLR-5:	*educate on employing AI on predictive maintenance for enhancing EV reliability and to understand and solve the various challenges associated with AI deployment in the EV sector.*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*understand on fundamental principles and roles of AI in EV technology.*		*3*	
CO-2:	*apply ML techniques to solve specific problems and enhance the functionality and efficiency of EVs.*	*3*		
CO-3:	*implement AI-driven solutions to optimize energy management, consumption, and efficiency in EVs.*	*3*	*2*	
CO-4:	*design and analyze AI systems that enable advanced autonomous driving capabilities tailored to the specific requirements of EVs.*	*3*		*3*
CO-5:	*utilize AI for predictive maintenance & effectively address the implementation challenges of AI in EVs.*		*3*	*3*

Module-1- Introduction to AI in EVs	**9 Hour**
Evolution of AI in the automotive industry Role of AI in the transition from traditional automobiles to EVs - Definition and key concepts in AI focusing on relevance to EVs - Introduction to the basic components of AI systems, such as algorithms, models, and data inputs for EV applications - Different types of AI models and their relevance to EVs - Introduction to data acquisition, processing, and management specific to EVs - Overview of hardware requirements for supporting AI functionalities in EVs - AI software platforms used specifically in EV contexts and their integration with vehicle systems - Case studies on successful integration of AI into existing EV technologies.	
Module-2- Machine Learning in EVs	**9 Hour**
Core concepts, types of machine learning: supervised, unsupervised, and reinforcement learning - Python, R, TensorFlow, and PyTorch - Supervised Learning in EVs - Regression Models: Use in predicting battery life and vehicle range - Classification Models: Applications in fault detection and diagnostic systems - Clustering: Usage in analyzing driving patterns and vehicle usage statistics - Dimensionality Reduction Techniques (PCA) to improve model performance and data visualization - Basics of reinforcement learning and its use in dynamic decision for EV cruise control - Reinforcement learning in optimizing charging station visits and routes - Understanding the architecture and function of neural networks in image recognition and processing for EVs - Hardware limitations and computational demands of deploying ML models in EVs.	
Module-3- Energy Optimization using AI for EV	**9 Hour**
Use of AI in monitoring battery health, state-of-charge (SOC) and state-of-health (SOH) predictions - Techniques for predicting battery degradation and lifecycle management - Machine learning algorithms to optimize charging times and techniques to extend battery life - Use of AI in developing energy-efficient routing, considering factors such as topography and traffic - AI in managing charging load based on grid demand and renewable energy availability - AI facilitation for the integration of EVs into smart grids - Application of AI in managing the thermal conditions of batteries - Technical, economic, and regulatory challenges in applying AI for energy optimization.	

Module-4-AI and EV Autonomous Drive System	**9 Hour**
Levels of autonomy, key concepts, and terminologies - EV factors affecting autonomous driving - AI to enhance route planning algorithms - Techniques for interpreting sensor data using AI (image recognition, object detection) - ML model to predict driving behaviour based on energy consumption patterns, battery status, and charging infrastructure availability - AI algorithms for dynamic energy allocation between drive systems and battery management based on the autonomous driving mode - AI-driven safety protocols - Simulations to test and refine AI-driven autonomous systems - AI in vehicle control systems for real-time driving decisions - Battery safety and software standards for autonomous EVs - Deep reinforcement learning for optimizing route and energy usage in EVs..	
Module-5- Predictive Maintenance and Challenges of AI in EVs	**9 Hour**
Understanding the importance of predictive maintenance in EVs for reducing downtime and maximizing efficiency - How AI technologies transform traditional maintenance strategies into predictive maintenance - Data based on onboard sensors, vehicle diagnostics, and external data feeds for predictive maintenance - Developing models using Prognostics and Health Management (PHM) to predict EV component failures. Utilizing AI algorithms to forecast the remaining useful life (RUL) of critical EV components - Utilizing AI-enabled remote diagnostics to diagnose and address issues in EVs remotely - Challenges of AI training models, algorithmic reliability, cybersecurity threats - Dependency on continuous connectivity for real-time data processing and AI decision-making - Computational demands of AI applications in EVs - Regulatory landscape for AI in EVs, including safety standards, certification processes, and international variations.	

Learning Resources	1. *Kumari, Aparna, Tanwar, Sudeep. Artificial Intelligence-Empowered Modern Electric Vehicles in Smart Grid Systems-Fundamentals, Technologies, and Solutions, Elsevier, 2024.* 2. *Angalaeswari, S., T. Deepa, and L. Ashok Kumar, eds. Artificial Intelligence Applications in Battery Management Systems and Routing Problems in Electric Vehicles. IGI Global, 2023.*	*3. Chitra, A., Jens Bo Holm-Nielsen, Padmanaban Sanjeevikumar, and S. Himavathi, eds. Artificial intelligent techniques for electric and hybrid electric vehicles. Wiley-Scrivener, 2020.* *4. Taghavipour, Amir, Mahyar Vajedi, and Nasser L. Azad. Intelligent control of connected plug-in hybrid electric vehicles. Springer International Publishing, 2019.*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr. Muzakkir Sharieff, CTO, Marlin Moto Corp Pvt, Ltd., muzakkirsharieff@gmail.com*	1. *Prof. S.Jeevananthan, PTU Puducherry, drsj_eee@pec.edu*	1. *Dr. T. Praveenkumar, SRMIST*
2. *Mr. Dhinesh Natarajan, CTO, Welkinrim Technologies Pvt. Ltd., dineshnatarajan@welkinrim.com*	2. *Dr.V.Karthikeyan, National Institute of Technology, Calicut, karthikeyan@nitc.ac.in*	2. *Dr. K. Kamalakkannan, SRMIST*

Course Code	21AUE612T	Course Name	MOTOR DRIVES AND CONTROL 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	*Automobile Engineering*	**Data Book / Codes / Standards**		*Nil*	

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand basic concepts of magnetically coupled circuits and electromechanical energy conversion principles*
CLR-2:	*understanding the fundaments and analogous of control systems*
CLR-3:	*understand and analyze DC motor and its control techniques in EV application.*
CLR-4:	*understand and analyze AC motor and its control techniques in EV application.*
CLR-5:	*understand and analyze the feedback and loop operations in EV application.*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*demonstrate a clear understanding of the basic concepts of magnetically coupled circuits, including magnetizing inductance and mutual inductance.*	*3*	*3*	
CO-2:	*analyze and model mechanical and electrical analogous of control systems*	*3*		
CO-3:	*design and perform DC motor and its control techniques*	*3*		*2*
CO-4:	*design and perform DC motor and its control techniques*	*3*		*2*
CO-5:	*design and perform feedback and loop operations in EV application*	*3*		*2*

Module-1- Electromagnetics of Electric Machinery	***9 Hour***
Magnetically coupled circuits: review of basic concepts, magnetizing inductance linear and nonlinear magnetic circuit - Electromechanical energy conversion: principles of energy flow, concept of field energy and co-energy, torque expression - principles of energy flow and the principle of co-energy.	
Module-2- Control System and Principles	***9 Hour***
Control system and examples, Mechanical translational system and rotational systems, Transfer function-rotating machine, Electrical analogous of Mechanical translational systems, Electrical analogous of Mechanical rotational systems. Block diagram representation of Drive systems, signal flow graph representation of the systems, Transfer functions - Simulation	
Module-3- Operation and Control of DC Drives	***9 Hour***
Principle of DC motor and speed control, Basic features of an Electric Drive- criteria for selection of drive components, dynamics of D.C. motor drives, Principle of operation of the chopper, Chopper controlled drives, Duty-ratio control, current-limit control, steady state analysis, four quadrant chopper circuit, chopper fed drive- Simulation	
Module-4- Operation and Control of AC Drives	***9 Hour***
Principle of AC motor and speed control, Variable voltage operation, Variable frequency operation, Constant flux operation, Torque-Slip characteristics, Constant Torque and Constant power operation, Implementation of V/f control with slip compensation scheme, Inverter fed Closed loop control schemes, dynamic and regenerative braking, speed reversal, vector control, Simulation	
Module-5- Controllers for EV Drives	***9 Hour***

Transfer function for EV motors – closed loop control with Current and sped feedback–armature voltage control and field control – Design of controllers; current controller and speed controller- Simulation - converter selection and characteristics

Learning Resources	1. *R. Krishnan, "Electric Motor Drives – Modelling, Analysis and Control", PHI.2015* 2. *C.V. Jones, "The unified Theory of Electrical Machines", Butterworth, -London.1967* 3. *P.S. Bhimbra, "The Generalised Theory of Electrical Machines", Tata McGraw Hill,2021*	4. *G.K.Dubey, Power Semiconductor controlled Drives, New Age Int. Pub., 2002* 5. *I. J. Nagarath and M. Gopal, Control system Engineering, New Age International (P) Ltd., seventh edition, 2021.*

Learning Assessment

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

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Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Mr. Muzakkir Sharieff, CTO, Marlin Moto Corp Pvt, Ltd., muzakkirsharieff@gmail.com*	1. *Prof. S.Jeevananthan, PTU Puducherry, drsj_eee@pec.edu*	1. *Dr. C. Carunai Selvane, SRMIST*
2. *Mr. Dhinesh Natarajan, CTO, Welkinrim Technologies Pvt. Ltd., dineshnatarajan@welkinrim.com*	2. *Prof. S. Chitra Selvi, Anna University Dindugal, r.s.chitraselvi@auucedgl.ac.in*	2. *Dr. T. Praveenkumar, SRMIST*

Course Code	21AUE613T	Course Name	ELECTRIC VEHICLE MODELLING AND DESIGN	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	1	0	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the fundamentals of electric vehicles and their conventional counterparts.*
CLR-2:	*learn about the forces and mechanics involved in electric vehicles.*
CLR-3:	*acquire knowledge about the requirements of energy storage systems for electric vehicles.*
CLR-4:	*enable the understanding of various electric motors used for electric vehicles propulsion.*
CLR-5:	*get introduced to the standards related to electric vehicles.*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Programme Outcomes (PO)		
		1	**2**	**3**
CO-1:	*compare the electric vehicles with conventional vehicles with respect to efficiency, pollution.*	*3*	*1*	*1*
CO-2:	*estimate the various forces acting in an electric vehicle during its motion.*	*3*	*2*	*1*
CO-3:	*determine a suitable power storage unit for the given electric vehicle operating conditions.*	*3*	*2*	*2*
CO-4:	*select an electric motor and design a controller for electric vehicle applications.*	*3*	*2*	*2*
CO-5:	*apply the corresponding standards related to electric vehicles in design phase.*	*3*	*2*	*2*

Module-1 -Introduction to Vehicle Architecture	***9 Hour***
Introduction – Electric Vehicles (EVs), Hybrid vehicles, Historical Developments, Recent trends, Subsidy criteria for Evs. Comparison of Electric Vehicles with IC engine vehicles – Efficiency comparison, Pollution comparison, Carbon footprint comparison, Capital and Operating cost comparison. Hybrid concept - Series HEVs, Parallel HEVs, Series–Parallel HEVs, Complex HEVs, Operating modes, Degree of hybridization, Comparison of HEVs, Plug-in hybrid electric vehicles (PHEVs).	
Module-2 -Electric Vehicle Mechanics	***9 Hour***
Introduction - Roadway fundamentals, Vehicle kinetics, Rolling Resistance, Aerodynamic Drag, Grading Resistance, Maximum tractive effort, Vehicle performance, Maximum speed, Gradeability. Tires - Tire/Road mechanics, Calculation of normal tire forces, calculation of effective tyre radius, static forces. Vehicle Dynamic analysis – Longitudinal dynamics analysis, Equation of motion, Vertical dynamics analysis, Quarter Car model, Simplified handling models, Single track linear handling model.	
Module-3 -Energy Storage	***9 Hour***
Energy storage requirements – Battery based energy storage analysis, Fuel cell based energy storage analysis, Super capacitor based energy storage analysis. Design parameters - Energy density, Amp hour density, Energy efficiency, Cost, Operating temperature, number of life cycles, recharge and self-discharge rates and commercial availability. Battery management system - Discharging control, Charging control, State-of-Charge Determination, State-of-Health Determination, Cell Balancing; BMS topologies: Distributed Topology, Modular Topology and Centralized Topology	

Module-4 -Powertrain Design	***9 Hour***
Propulsion motors - Block diagram of EV propulsion system, Single motor and multi-motor configurations, In wheel motor configuration, Classification of EV motors, Electric motors used in current vehicle applications. Induction motor - Open-loop v/f control, Basics of DC-AC power converters, Basic pulse width modulation techniques; Vector control of IM drives. SRM/PMSM drives - Magnetic circuits and reluctance, Switched Reluctance Motor; Modelling and control of switched reluctance motor, Modelling and control of PMSM drive.	
Module-5 -Standards and Regulations for EV Design	***9 Hour***
Introduction – Standards vs Regulations, Organizations – ISO, IEC, SAE. India specific regulations – ARAI standards, CMVR approval standards - Standard for Construction and Functional Safety of EVS, Measurement of Electrical Energy Consumption, Method of Measuring the Range, Measurement of Net Power, CMVR Type Approval. International Standards – List of standards for USA, Japan, China, Korea and UN regulations.	

Learning Resources	1. *Mehrdad Ehsani, Yimin Gao, Stefano Longo, Kambiz Ebrahimiu, "Modern Electric, Hybrid Electric, and Fuel Cell Vehicles", Routledge, 2018.* 2. *Chau KT, "Electric Vehicle Machines and Drives: Design, Analysis and Application", Wiley, 2015.*	3. *Chau KT, "Electric Vehicle Technology Explained", Wiley, 2012.* 4. *Ali Emadi, "Advanced Electric Drive Vehicles", Routledge, 2014.* 5. *Xiaojun Tan, Andrea Vezzini, Yuqian Fan, Neeta Khare, You Xu, Liangliang, "Battery Management System and its Applications" , Wiley, 2022.*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr. G. Dhivakar, Lead Geometric Architect, Vehicle Engineering, Volvo Group, Bangalore.*	1. *Dr. J. Preetha Roselyn, Professor, Electrical and Electronics Engineering, SRMIST.*	1. *Dr. AJD Nanthakumar, SRMIST*
2. *Mr. Muzakkir Sharieff, CTO, Marlin Moto Corp Pvt, Ltd., muzakkirsharieff@gmail.com*	2. *Dr. M. Sadees, Assistant Professor, Electrical and Electronics Engineering, SRMIST.*	2. *Dr. C. Carunaiselvane SRMIST*

Course Code	21AUE614T	Course Name	CHARGING STATION SYSTEM DESIGN	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	1	0	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understanding of PEV technologies, smart charging infrastructure, integration into the electric grid*
CLR-2:	*equip students to model and analyze PEV charging demand impacts*
CLR-3:	*understand integrating charging facilities into the electric grid effectively.*
CLR-4:	*knowledge on effectively plan and manage PEV charging facilities.*
CLR-5:	*understanding of communication and security in smart grids with PEVs.*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Programme Outcomes (PO)		
		1	**2**	**3**
CO-1:	*model, design, and implement effective PEV and WPT systems*		*3*	
CO-2:	*analyze voltage stability, apply power flow and voltage control techniques*		*3*	
CO-3:	*model and analyze EVCS integration schemes and their grid impacts*		*3*	
CO-4:	*develop skills in charging mode selection, demand forecasting, and facility planning.*			*3*
CO-5:	*analyze, detect and address data attacks, cyber threats, and intrusions in PEV communications*			*3*

Module – 1 – Plug-in Electric Vehicle Technologies	**9 *Hour***
PEV Technologies, PEV Systems, impacts, Smart Charging Infrastructure, Integration of PEVs to Electric Grid Promotional Programs on PEVs. Wireless Power Transfer (WPT) for Electric Vehicles (EVs): Wireless Energy Transfer Methods, Inductive Coupling Versus Magnetic Resonance Coupling, Modelling the WPT System, WPT for EV Charging, Stationary WPT for EV Charging, Dynamic WPT for EV Charging	
Module – 2 – Impact of Plug-in Electric Vehicles on Power System	**9 *Hour***
Probabilistic PEV Charging Demand, Fast Charging Points, Probabilistic Arrivals, Probabilistic PEV Charging Demand, Probabilistic Grid Impact of Fast Chargers. Modeling of PEV Charging Load, Introduction to Power System Load Characteristics, Modeling of the PEV Charging Load, Effects of Charger Resistances on Load Model Parameters, Newton Raphson Power Flow with PEV Load, Impact of PEV Charging Load on System Static Voltage Stability, Voltage Stability Theory, Static Voltage Stability Analysis, Mitigating PEV Charging Impacts through Voltage Control, Mitigating PEV Charging Impact through Proper Planning	

Module – 3 – Integration of EV Charging Facilities into the Grid	***9 Hour***
Main Considerations on the Integration of Charging Facilities into the Grid, Estimate of the EVCS's Reverse Discharge Capacity, Typical Schemes of the Integration of Charging Facilities into the Grid: Schemes of the Integration of EVCPs into the Grid, EVCSs Directly Integrated into or Adjacent to 110 kV Substations, EVCSs Integrated into the Tie Point of Looped Distribution Grid, Parallel Operation of EVCSs with the Special Important Load	
Module – 4 – Charging Infrastructure Planning	***9 Hour***
PEV Charging Facility, Stages of EV Charging Facility Planning, Charging Modes Selection and Demand Forecasting: Charging Modes Selection, Charging Demand Forecasting, Charging Facility Planning: Planning Principles and Process, Planning Model, Control and Management of PEV Parking Lots.	
Module – 5 – Cyber Security of Plug-in Electric Vehicles in Smart Grids: Application of Intrusion	***9 Hour***
Detection Methods, Smart Grids with PEVs, Communication Infrastructure, Communication Standards, Cyber Security Challenges, Data Attacks and Intrusions in PEV Communications, Intrusion Detection Methods, Application to the Detection of Malicious PEV Penetration Level.	

Learning Resources	1. *Sumedha Rajakaruna, Farhad Shahnia and Arindam Ghosh, "Plug In Electric Vehicles in Smart Grids Integration Techniques", Springer Science + Business Media Singapore Pte Ltd., 2015.* 2. *Canbing Li, Yijia Cao, YonghongKuang and Bin Zhou, "Influences of Electric Vehicles on Power System and Key Technologies of Vehicle-to-Grid", Springer-Verlag Berlin Heidelberg, 2016.*	3. *Qiuwei Wu, "Grid Integration of Electric Vehicles in Open Electricity Markets", John Wiley & Sons, Ltd, 2013.*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr. Muzakkir Sharieff, CTO, Marlin Moto Corp Pvt, Ltd., muzakkirsharieff@gmail.com*	1. *Prof. S.Jeevananthan, PTU Puducherry, drsj_eee@pec.edu*	1. *Dr. C. Carunai Selvane, SRMIST*
2. *Mr. Dhinesh Natarajan, CTO, Welkinrim Technologies Pvt. Ltd., dineshnatarajan@welkinrim.com*	2. *Prof. Dr. S. Chitra Selvi, Anna University Dindugal, r.s.chitraselvi@auucedgl*	2. *Dr. T. Praveenkumar, SRMIST*

Course Code	21AUE615T	Course Name	AUTOMOTIVE EMBEDDED SYSTEMS AND COMMUNICATION	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	*Automobile Engineering*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*develop a solid understanding of the principles and concepts that underlie electric mobility, including the operation of electric vehicles (EVs), different types of EV architectures, and the role of embedded systems in E-Mobility.*
CLR-2:	*acquire the skills necessary to design, implement, and optimize embedded system tailored for electric vehicles, including motor control, battery management, power electronics, and communication protocols.*
CLR-3:	*analyze the environmental and sustainability aspects of E-Mobility and explore to embedded systems contribute to the development of smart and energy-efficient electric transportation solutions.*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*demonstrate the ability to design, develop, and integrate embedded systems tailored for electric vehicles, showcasing proficiency in areas such as motor control energy management, and vehicle communication.*	3	3	
CO-2:	*understand the Application of Sustainable E-Mobility Solutions.*	2	2	
CO-3:	*apply the knowledge gained to create sustainable and environmentally friendly E- Mobility solutions, considering factors like energy efficiency, emissions reduction, and the integration of renewable energy sources.*	3		3
CO-4:	*demonstrate a strong knowledge in the advanced technologies related to E- Mobility.*	2		3
CO-5:	*understand various computing algorithms in the development of E-Mobility Solutions.*	1	3	

Module-1 -Automotive 32 bit applications and Multicores for E Mobility	**9 Hour**
Choosing for Automotive Applications, Atmel SMART ARM based MCU, ST- SPC5 32-bit Automotive MCU, NXP -Automotive MCU, Automotive microcontrollers for Electric Powertrain Control, Analog and digital interface. Overview of Single core processor Architecture and its limitations, Architectural Innovations, Need for Multi core Processor and its Limitations, Classification Multicores, Multicore system software stack, GPUs as Parallel computers architecture of a modern GPU, Overview of real-time operating systems and their role in embedded systems development. Understand concepts like task scheduling, synchronization, and memory protection.	
Module-2 -Embedded Systems in Automotive Applications	**9 Hour**
The concepts of ECU design for automotive applications, Need for ECUs, advances in ECUs for automotive (Zonal Control unit), design complexities of ECUs, V-Model for Automotive Architecture, On Board communication: SPI, I2C, UART ECU Supervision mechanisms : Watchdog ADC, DAC, GPIO (High & Low Side drivers, H-Bridge), I/O Diagnostics	

Module-3 -Automotive Embedded Rapid Prototyping	**9 Hour**
Introduction, Verification and validation, Model in Loop (MIL), Software in loop (SIL), Processor in Loop (PIL), Hardware in loop (HIL), Testing and simulation of embedded system through Speed goat and D- Space real time target machine. Testing methodologies for embedded systems Debugging techniques and tools with industry standard (Eg: JTAG based)	
Module-4 -Automotive Networking and Protocols	**9 Hour**
Overview of CAN transfer types-Error handling confinement-Bit time requirements, Introduction to LIN and Flexray, MOST- Introduction to Network diagnostic tools (CANalyzer, CANape, CAPL Programming). Basics of CCP & XCP Ethernet or Automotive Ethernet Wireless communication protocols: WiFi, BLE, NFC Basics of Automotive Diagnostics Lab: Engaging activities for a comprehensive grasp of the subject.	
Module-5 -Security in Embedded System	**9 Hour**
Product Development System Level-Product Development Hardware Level-Product Development Software Level-Production and Operation-Supporting Processes-ASIL Oriented and Safety Oriented Analysis- Guidelines on ISO26262 (Informative)-Case Studies to illustrate concepts, Hazard analysis and Risk Assessment-Safety Goals, Preliminary Architecture-Functional Safety Concept. *SW Quality : Standards like MISRC, SW Complexity. Overview on the Security Mechanism used in Automotive: RSA, Hashing. Secure Boot, SecOC, HSM Memory Error handling: RAM & ROM Checks, ECC Pre-Processing, Compilation, Linker Scripts, Make file, Understanding. elf & .map file, Writing the Linker and make scripts Overview on Boot SW, SW Download*	

Learning Resources	*1.Kathiresh, M., G. R. Kanagachidambaresan, and Sheldon S. Williamson E. -Mobility. Springer International Publishing, 2022.* *2.Kathiresh, M., and R. Neelaveni. Automotive Embedded Systems. Springer International Publishing, 2021.* *3.Navet, Nicolas, and Françoise Simonot-Lion, eds A. utomotive embedded systems handbook. CRC press, 2017.* *4.Marwedel, Peter. Embedded system design: embedded systems foundations of cyber-physical systems, and the internet of things. Springer Nature, 2021.*	*5.Barkalov, Alexander, Larysa Titarenko, and Malgorzata Mazurkiewicz. Foundation of embedded systems. Vol. 195. Cham, Switzerland: Springer International Publishing, 2019.* *6.Zurawski, Richard. Embedded Systems Handbook: Embedded systems design and verification. CRC press, 2018.* *7.Wang, Jiacun. Real-time embedded systems. John Wiley & Sons, 2017.* *8. "Programming Embedded Systems: With C and GNU Development Tools" by Michael Barr and Anthony Massa*

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

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr. Mothilal Nehru Harichandran, Senior Engineer, RNTBCI, mothilal-nehru.harichandran@rntbci.com*	1. *Dr. Jenoris Muthiya, Assistant Professor, Dayananda Sagar College of Engineering, jenorismuthiya-au@dayanandasagar.edu*	1. *Dr. R. Rajendran, SRMIST*
2. *Mr. T. Kasiraja, Global Senior Manager, Visteon, tkasiraj@visteon.com*	2. *Dr. Prabu K, Associate Professor Senior, VIT, prabu.k@vit.ac.in*	2. *Dr.K. Kamalakkannan, SRMIST*

Course Code	21AUE616T	Course Name	ADVANCED AUTOMOTIVE ELECTRONICS	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	*Automobile Engineering*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the role of electronics in modern vehicles*
CLR-2:	*design and develop electronic systems for automotive applications*
CLR-3:	*apply knowledge of vehicle systems to automotive electronics*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Programme Outcomes (PO)		
		1	**2**	**3**
CO-1:	*demonstrate a comprehensive understanding of advanced automotive electronic components and systems*	*3*	*1*	*2*
CO-2:	*utilize modern tools and software for the development and simulation of automotive electronic systems.*	*3*	*2*	*1*
CO-3:	*develop skills in programming and simulation tools for automotive electronics*	*3*	*2*	*1*
CO-4:	*stay updated with the latest trends and technologies in the automotive electronics industry.*	*2*	*1*	*3*

Module-1 -Architecture and Engineering	***9 Hour***
Overview of automotive electronics, History and evolution of automotive electronics, Current trends and future prospects, Vehicle electrical systems Electronic control units (ECUs) and microcontrollers, Sensors and actuators in automotive applications	
Module-2 -Control and Communication	***9 Hour***
Introduction to ADAS, Lane departure warning and assist systems, Adaptive cruise control and automatic emergency braking, Camera and radar sensors in ADAS, Introduction to V2X communication, V2X architecture and protocols, Applications of V2X communication in automotive electronics	
Module-3 -Automotive Electronics for Automobile Engineers	***9 Hour***
Application of vehicle systems to automotive electronics, Design considerations for automotive electronics, Case studies in automotive electronics for automobile engineers	
Module-4 -Safety and Security	***9 Hour***
Safety and security concerns in automotive electronics, Functional safety and ISO 26262, Cybersecurity in automotive electronics	
Module-5 -Emerging Trends and Innovations	***9 Hour***
Overview of emerging trends and innovations in automotive electronics, Electrification and hybridization of vehicles, Advanced materials and manufacturing techniques in automotive electronics, Introduction to autonomous vehicles, Levels of autonomy and vehicle automation, Sensor suites and perception systems in autonomous vehicles	

Learning Resources	1. *Automobile Electrical and Electronic Systems By Tom Denton Publisher : Routledge; 5th edition (12 September 2017)* 2. *Bosch Automotive Electrics and Automotive Electronics: Systems and Components, Networking and Hybrid Drive (Bosch Professional Automotive Information) 5th Edition Publisher : Springer Vieweg; 5th edition (24 September 2013)*	*3. Mechatronics: Electronic Control Systems In Mechanical and Electrical Engineering, 7th edition – Pearson Education (15 June 2023); Pearson India*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr. Devanathan, Software Function Developer, RNTBCI, Devanathan.kannan@rntbci.com*	1. *Mr.V.Manoj Kumar,(Mech)SRMIST*	1. *Mr.S.Madhan Kumar, SRMIST*
2. *Mr. E. Joshua Paul, Senior Engineer, L & T Technology services, Joshua.paul@ltts.com*	2. *Dr.M.Sadees (EEE)SRMIST*	2. *Dr.AJD Nanthakumar, SRMIST*

Course Code	21AUE621J	Course Name	VEHICLE DESIGN AND DYNAMICS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	0	2	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*broaden the importance of vehicle performance characteristics.*
CLR-2:	*enable the students to understand various automotive vehicle stability and handling.*
CLR-3:	*broaden the importance of vehicle ride conform characteristics.*
CLR-4:	*enable the students to understand various automotive aerodynamics and its effects*
CLR-5:	*enable the students to understand various automotive styling process.*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*apply knowledge of vehicle dynamics and design to improve performance.*	*3*		2
CO-2:	*apply knowledge of vehicle dynamics and design to improve stability and handling.*	*3*		2
CO-3:	*apply knowledge of vehicle dynamics and design to improve ride conform.*	*3*	1	2
CO-4:	*apply knowledge of aerodynamics to improve vehicle performance and handling.*	*3*	2	
CO-5:	*apply knowledge of automotive styling to design the vehicles.*	*3*	1	

Module-1 -Vehicle Performance Characteristics	**12 Hour**
Static load, dynamic load transfer, total road load, various forces and moments, resistive forces, tractive effort, power, maximum acceleration and braking performance on level road and gradient, design requirement of brake system and parameters: braking force, brake torque, deceleration, stopping distance, efficiency and heat dissipation etc. *Practice:* *1. Demonstration and design requirement of vehicle dynamics systems (steering, brake and suspension).* *2. Vehicle load distribution and transfer analysis using simulation tool.*	
Module-2 -Vehicle Stability and Handling	**12 Hour**
Steering systems design requirements, steering geometry, steering mechanism, evaluation of steering parameters, slip angle, lateral force, steady state cornering, cornering stiffness, bicycle modelling, understeer gradient, understeer and oversteer. Tyre dynamics, size and load rating, camber thrust, aligning moment, combined braking and cornering. *Practice:* *3. Vehicle longitudinal dynamics (acceleration performance analysis) using simulation tool.* *4. Vehicle longitudinal dynamics (braking system performance analysis) using simulation tool*	
Module-3 -Vehicle Ride Comfort	**12 Hour**
Design requirements of suspension systems: independent and dependent, sprung and un-sprung mass, ride, comfort, road input and human response to vibration (ISO 2631-1), design of leaf spring and coil spring, bouncing, pitching and rolling characteristics, anti-dive, anti-squat, anti-pitch and roll centre analysis, active suspension	

Practice: 5. Vehicle lateral dynamics (steering system performance analysis) using simulation tool. *6. Vehicle vertical dynamics (suspension system performance analysis) using simulation tool*
Module-4 -Automotive Aerodynamics **12 Hour**
SAE aerodynamic axis system, flow around automotive vehicles, aerodynamics forces (drag & lift) and their effects on performance and stability, effect of yaw angle, strategies for aerodynamic development, shape optimization techniques, effect of aerodynamic aids: spoiler, duct, wings, side skirt, air dam etc. platooning and active aerodynamics. *Practice: 7. Aerodynamic parameter analysis of simplified vehicle model.*
Module-5 -Automotive Styling **12 Hour**
Fundamentals of drawing perspective, aesthetics, ergonomics, anthropometry, vehicle proportions, styling process, sketching, clay modeling, rendering, digital visualization, designing of Interiors: R/H-Point, seating positioning, dashboard equipments arrangement, positioning of operational controls, visibility and vehicle packaging. *Practice: 8. Vehicle styling: Free hand sketching of concept vehicle model.*

Learning Resources	*1. Reza N. Jazar, "Vehicle Dynamics: Theory and Application", 3rd Edition, Springer International Publishing AG, Switzerland, 2017.* *2. Thomas D. Gillespie, "Fundamentals of Vehicle Dynamics (R114) Publisher: Society of Automotive Engineers Inc., 1992.* *3. William F. Milliken and Douglas L. Milliken, "Race Car Vehicle Dynamics", SAE, 1995.* *4. Rajesh Rajamani- "Vehicle Dynamics and Control"- 1st edition- Springer- 2005.* *5. W.H. Hucho, 'Aerodynamics of Road Vehicles', SAE Publications, 6th edition 2012*	*6. R.McCallen, Browand, Ross, "The Aerodynamics of Heavy Vehicles", Springer, 2014* *7. Pope "Wind Tunnel Testing"- John Wiley & Sons - 2nd Edition, New York - 1974.* *8. Julian Happian-Smith, "An introduction to modern vehicle design", Butterworth Heinmenn, 2001* *9. Fenton John, "Handbook of automotive body and system design", Wiley-Blackwell, 1998* *10. R.N. Bahl, "Automobile Design", Wiley.*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. Thanigai Arasu G, Deputy Manager, RNTBCI, Thanigai.arasu@rntbci.com	*1. Prof. S. Sunil, MIT Campus, Anna University, ssunil@mitindia.edu*	*1. Mr. Yokeshwaran S, SRMIST*
2. Mr. E. Joshua Paul, Senior Engineer, L & T Technology services, Joshua.paul@ltts.com	*2. Dr. Ilango M. Assistant Professor, NIT Calicut, ilango@nitc.ac.in*	*2. Mr. Jerome Stanley M, SRMIST*

Course Code	21AUE622J	Course Name	AUTOMOTIVE TESTING AND CERTIFICATION	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	0	2	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*broaden the importance of automotive testing and certification standards & regulation*
CLR-2:	*comprehend various automotive vehicle testing procedure*
CLR-3:	*identify various automotive component testing procedure*
CLR-4:	*recognize the test procedures to test and type approve the engine*
CLR-5:	*form the test approval cycle for the testing of hybrid electric vehicles*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*apprehend the test automotive component/systems requirement as per the SAE standard*	3		2
CO-2:	*apply the test procedure for the system*	3		2
CO-3:	*categorize the component testing of the automotive parts as per the type approval procedures.*	3		2
CO-4:	*methodize the type approval procedures for engines.*	3	3	
CO-5:	*form the test procedure for the hybrid electric powertrain*	3	3	

Module-1 -Homologation	**12 Hour**
Homologation and its types - Regulations overview - Type approval scheme - Type and order of control system - Conformity of production - Homologation for export - Specification of vehicle - Classification of vehicles - Various parameters - Instruments and types of test tracks. *Practice: 1. Weight test of vehicle, 2. Grade-ability test of vehicle*	
Module-2 -Vehicle Testing	**12 Hour**
Photographs - Tire tread depth test - Tell tales - External projection - Foot controls arrangement for M1 vehicle - Angle and dimensions measurement of vehicle - The requirement of temporary cabin for DAC - Weight test - Grade-ability test - Measurement of pass-by noise - Interior noise - TCD and TCCD - Steering effort - Fuel consumption, maximum speed and acceleration - Cooling performance test - Brakes test and Range test - Hood latch test and crash test. *Practice: 3. Vehicle turning circle diameter measurement test, 4. Engine performance measurement test on engine dynamometer*	
Module-3 -Vehicle Component Testing	**12 Hour**
Horn installation and tests - Rear view mirror installation and tests - Safety glasses test and brake hoses test - Metallic and plastic fuel tank test - Hinges and latches test - Tire and wheel rim test - Bumper impact test - Side door intrusion test - Interior fittings test - Steering impact test - Demist Defrost test - Accelerator control system test - Driver field of vision test - Testing of safety belt assemblies - Safety belt anchorages – Airbag - Seat anchorages and head restraints – Photometry *Practice: 5. Emission measurement test in engine test cell, 6. Battery Test as per standard*	

Module-4 -Engine Testing	**12 Hour**
Standards and norms for engine testing instruments - Dynamometers and different types of dynamometers - Engine testing on dynamometers - Measurement of basic engine parameters BHP, IHP - Heat balance sheet - FIP calibrating and testing Engine analyzers- for petrol and diesel engines - Emission test for measurement of CO - Emission test for measurement of HC - Emission test for measurement of NOx - Orsat apparatus - Infrared gas analyzers - Smoke meter. *Practice: 7. Emission test for measurement of CO2 and PM*	
Module-5 -Hybrid Electric Vehicles Test	**12 Hour**
Certification of below 250W-EV - E-rickshaw / E-Cart - CMVR type approval requirements of Electric vehicle - Safety requirements of traction batteries - Requirements for construction and functional safety - Measurement of electrical energy consumption - Method of measuring the range - Measurement of net power & maximum - 30-minute power - Type approval of hybrid electric vehicle - CMVR procedures for approval of retro fitment kits - EV charging coupler - Functional safety standards - EMI Test - EMC Test. *Practice: 8. Electric vehicle range test, 9. EMI/EMC test of vehicle*	

Learning Resources	1. *Michael Plint& Anthony Martyr, Engine Testing & Practice, Butterworth Heinmenn, 3rd ed, 2007* 2. *Vehicle Inspection Handbook, American Association of Motor Vehicle Administrators* 3. *Bureau of Indian Standards (BIS) / IS* 4. *Automotive Industry Standards (AIS)* 5. *ECE & EEC Regulations/Standards* 6. *Motor Vehicle Manual / CMVR Book*	7. *Proficiency Improvement Programme (PIP) proceedings on "Automotive Testing & Certification"* 8. *Proficiency Improvement Programme (PIP) proceedings on "Regulation Driven Global Automotive Crashworthiness and Occupant Safety".* 9. *Global Online Proficiency Improvement Programme (oPIP) on Electric Vehicles (including Charging Infrastructure)* 10. *10. Global Automotive Safety Regulations in Nutshell 2015, Wissen Baum Engineering Solution LLP in association with ARAI*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr. E. Joshua Paul, Senior Engineer, L & T Technology services, Joshua.paul@ltts.com*	1. *Dr.P.Sathish Kumar, Asst. Professor, NIT Puducheryy, Karaikkal, Sathish.p@nitpy.ac.in*	1. *Dr.Sanjay A. Patil, ARAI*
2. *Mr. Thanigai Arasu G, Deputy Manager, RNTBCI, Thanigai.arasu@rntbci.com*	2. *Dr. Ilango M. Assistant Professor, NIT Calicut, ilango@nitc.ac.in*	2. *Mr. Yokeshwaran S, SRMIST*

Course Code	21AUE623T	Course Name	AUTONOMOUS AND CONNECTED VEHICLES	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	1	0	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*enable the students to understand autonomous vehicle concept.*
CLR-2:	*introduce the students to the functional standards relevant to Autonomous vehicles.*
CLR-3:	*introduce the topics of sensors for autonomous and connected vehicles*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Programme Outcomes (PO)		
		1	**2**	**3**
CO-1:	*establish knowledge and principles of autonomous vehicle.*	*3*		*3*
CO-2:	*apply knowledge and principles of computer vision / image processing.*	*3*	*2*	
CO-3:	*apply the knowledge and principles of intelligent vehicle.*	*3*	*2*	
CO-4:	*assess the societal impact of intelligent transport systems.*	*3*		*3*

Module-1 -Introduction of Autonomous Vehicles	***9 Hour***
Brief history of autonomous vehicles -operational design domain (ODD) - object and event detection and response (OEDR) - Pipeline of autonomous vehicle development -performance requirement of autonomous vehicle - Autonomous Driving in political -social and historical contexts.	
Module-2 -Functionalities and Standards	***9 Hour***
Safety frameworks-ISO 26262 - Levels of Autonomous driving-SAE J3016 - research related to autonomous vehicles - national & international legislative development - political development of autonomous vehicle.	
Module-3 -Perception and Planning	***9 Hour***
Sensors used for autonomous vehicle - Proprioceptive and exteroceptive sensor's introduction - Radar, Sonar – Lidar – IMU – Camera - sensor integration architecture - Data acquisition - Sensor data fusion - Localization & Mapping System - Decision Making in Autonomous systems - Autonomous vehicles control systems - Driving behaviors - Parameter Optimization, Examples - mission, objective function and hierarchical motion planning - vehicle dynamic modelling in CARLA.	
Module-4 -Computer Vision	***9 Hour***
Basics of computer vision - Hough transformation - image transformation and scaling - Canny edge detection - Harris corner - Region of interest marking - Image filtering - Feature matching - Semantic segmentation – Tensor Flow - Object tracking - Road sign detection - Lane line detection Object detection using YOLOV4 - Real-time camera calibration and application using Raspberry Pi using - tensor flow lite	
Module-5 -Recent trends in Autonomous and Connected Vehicles	***9 Hour***
Prognostics and diagnostics of moving vehicle - vehicle health monitoring - last mile mobility solutions - V2X for connected mobility - future of automotive intelligence-dialog system.	

Learning Resources	1. Luca Delgrossi, Tao Zhang, "Vehicle Safety Communications- Protocols, Security, and Privacy", John Wiley & Sons, Inc., 2012. 2. Syed Faraz Hasan, Nazmul Siddique and Shyam Chakraborty, "Intelligent Transportation Systems-802.11- based Vehicular Communications" Springer International Publishing AG, 2018. 3. Gilbert Held, "Inter- and Intra-Vehicle Communications", Auerbach Publications, 2008.	4. Hong Cheng, "Autonomous Intelligent Vehicles Theory, Algorithms, and Implementation", Springer London Dordrecht Heidelberg New York, 2011. 5. Markus Maurer, J. Christian Gerdes, Barbara Lenz, Hermann Winner, "Autonomous Driving Technical, Legal and Social Aspects", Springer-Verlag GmbH Berlin Heidelberg, 2015.

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. E. Joshua Paul, Senior Engineer, L & T Technology services, Joshua.paul@ltts.com	1. Dr.P.Sathish Kumar, Asst. Professor, NIT Puducherry, Karaikkal, Sathish.p@nitpy.ac.in	1. Dr.Sanjay A. Patil, ARAI
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