VIT®

Vellore Institute of Technology

(Deemed to be University under section 3 of UGC Act, 1956)

SCHOOL OF MECHANICAL ENGINEERING

M.Tech Smart Mobility

Curriculum & Syllabi

(2024 batch onwards)

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VISION STATEMENT OF VELLORE INSTITUTE OF TECHNOLOGY

- Transforming life through excellence in education and research.

MISSION STATEMENT OF VELLORE INSTITUTE OF TECHNOLOGY

- **World class Education:** Excellence in education, grounded in ethics and critical thinking, for improvement of life.
- **Cutting edge Research:** An innovation ecosystem to extend knowledge and solve critical problems.
- **Impactful People:** Happy, accountable, caring and effective workforce and students.
- **Rewarding Co-creations:** Active collaboration with national & international industries & universities for productivity and economic development.
- **Service to Society:** Service to the region and world through knowledge and compassion.

VISION STATEMENT OF THE SCHOOL OF MECHANICAL ENGINEERING

- To be a leader in imparting world class education in Mechanical Engineering, leading to nurturing of scientists and technologists of highest caliber who would engage in sustainable development of the globe.

MISSION STATEMENT OF THE SCHOOL OF MECHANICAL ENGINEERING

- To create and maintain an environment fostering excellence in instruction & learning, Research and Innovation in Mechanical Engineering and Allied Disciplines.

- To equip students with the required knowledge and skills to engage seamlessly in higher educational and employment sectors ensuring that societal demands are met.

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M. Tech Smart Mobility

PROGRAMME OUTCOMES (POs)

PO_1: Having an ability to apply mathematics and science in engineering applications.

PO_2: Having an ability to design a component or a product applying all the relevant standards and with realistic constraints, including public health, safety, culture, society and environment.

PO_3: Having an ability to design and conduct experiments, as well as to analyse and interpret data, and synthesis of information.

PO_4: Having an ability to use techniques, skills, resources and modern engineering and IT tools necessary for engineering practice.

PO_5: Having problem solving ability- to assess social issues (societal, health, safety, legal and cultural) and engineering problems.

PO_6: Having adaptive thinking and adaptability in relation to environmental context and sustainable development.

PO_7: Having a clear understanding of professional and ethical responsibility.

PO_8: Having a good cognitive load management skills related to project management and finance.

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M. Tech Smart Mobility

PROGRAMME SPECIFIC OUTCOMES (PSOs)

On completion of M. Tech. (Smart Mobility) programme, graduates will be able to

PSO1: Compute, Design, Simulate & analyse various Automotive engineering systems taken into account the social, economic and environmental implications for the current and future mobility.

PSO2: Practice a multidisciplinary approach to solve real-world automotive problems.

PSO3: Independently carry out research / investigation to solve practical problems and write / present a substantial technical report/document.

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M. Tech Smart Mobility

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

1. Graduates will be engineering practitioners and leaders, who would help solve industry's technological problems.

2. Graduates will be engineering professionals, innovators or entrepreneurs engaged in technology development, technology deployment, or engineering system implementation in industry.

3. Graduates will function in their profession with social awareness and responsibility.

4. Graduates will interact with their peers in other disciplines in industry and society and contribute to the economic growth of the country.

5. Graduates will be successful in pursuing higher studies in engineering or management.

6. Graduates will pursue career paths in teaching or research.

Master of Technology in Smart Mobility

School of Mechanical Engineering

Programme Credit Structure	Credits
Discipline Core Courses	24
Skill Enhancement Courses	05
Discipline Elective Courses	12
Open Elective Courses	03
Project/ Internship	26
Total Graded Credit Requirement	70

Discipline Core Courses **24**

		L	T	P	C
MSMO501L	Vehicle Systems Engineering	3	0	0	3
MSMO502L	Automotive Control System	3	0	0	3
MSMO503L	Artificial Intelligence for Mobility	2	0	0	2
MSMO504L	Electric Vehicle Powertrain	3	0	0	3
MSMO504P	Electric Vehicle Powertrain Lab	0	0	2	1
MSMO505E	Model Based Mobility System Design	2	0	2	3
MSMO506L	Autonomous And Connected Vehicles	2	0	0	2
MSMO506P	Autonomous And Connected Vehicles Lab	0	0	2	1
MSMO507L	Battery and Fuel Cells for Smart Mobility	3	0	0	3
MSMO508L	Advanced Drivetrain Systems	3	0	0	3

Skill Enhancement Courses **05**

MENG501P	Technical Report Writing	0	0	4	2
MSTS501P	Qualitative Skills Practice	0	0	3	1.5
MSTS502P	Quantitative Skills Practice	0	0	3	1.5

Discipline Elective Courses **12**

MSMO601L	Embedded System for Mobility	3	0	0	3
MSMO602L	Vehicle Testing and Certification	3	0	0	3
MSMO603L	Vehicle Dynamics	3	0	0	3
MSMO604L	Vehicle Diagnostics System	3	0	0	3
MSMO605L	Power Electronics and Charging Systems for Electric Vehicles	3	0	0	3
MSMO606L	Vehicle Safety Engineering	3	0	0	3
MSMO607L	Intelligent Transportation Systems	3	0	0	3
MSMO608L	Noise, Vibration and Harshness	3	0	0	3
MSMO608P	Noise, Vibration and Harshness Lab	0	0	2	1
MSMO609L	Hydrogen Energy for Smart Mobility	3	0	0	3
MSMO610L	Automotive Transmission System	3	0	0	3
MSMO611L	Thermal Management System for Electric Vehicles	3	0	0	3
MSMO612L	Networks & Communications for Smart Mobility	3	0	0	3
MSMO613L	Smart Convergent Technologies	3	0	0	3
MSMO614L	Cybersecurity For Mobility Systems	3	0	0	3
MSMO615L	Autonomous Systems and Predictive Modelling	3	0	0	3
MSMO616L	Automotive Product Design and Life Cycle management	3	0	0	3
MSMO617L	Computational Fluid Flow and Heat Transfer	3	0	0	3
MSMO617P	Computational Fluid Flow and Heat Transfer Lab	0	0	2	1
MSMO618L	Finite Element Methods	3	0	0	3
MSMO618P	Finite Element Methods Lab	0	0	2	1
MSMO619L	Lightweight Materials for Smart Mobility	3	0	0	3

Open Elective Courses **03**

Engineering Disciplines | Social Sciences

Project and Internship **26**

MSMO696J	Study Oriented Project	02
MSMO697J	Design Project	02
MSMO698J	Internship I/ Dissertation I	10
MSMO699J	Internship II/ Dissertation II	12

Discipline Core Courses

Course Code	Course Title	L	T	P	C
MSMO501L	Vehicle Systems Engineering	3	0	0	3
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

1. To broaden the understanding of students in the vehicle chassis structure, layouts, body engineering and aerodynamics.
2. To introduce students to steering, suspension, braking systems.
3. To make students familiar with heating, ventilation and air-conditioning, lighting systems and other comfort & convenience accessories.
4. To teach students the latest trends in the field of smart vehicles.

Course Outcomes

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

1. Choose and suggest a suitable engine chassis layout for different applications.
2. Discuss the different aspects of vehicle body engineering and aerodynamics.
3. Analyze various types of steering systems.
4. Discuss various types of braking and suspension systems.
5. Troubleshoot the electrical and instrumentation system in the automobiles.
6. Propose advance technologies to improve vehicle performance.

Module:1	Chassis Layouts	6 hours

Vehicle classification (2W, 3W & 4W) - Types of chassis layout with reference to engine location and drive - Automotive frames - material selection and constructional details - various types - different loads acting on frame - testing of automotive frames - vehicle nomenclature.

Module:2	Vehicle Body Engineering	6 hours

Body styling for cars - buses and commercial vehicles - different parts of the vehicle body structure (passenger car and commercial vehicles) - vehicle body design engineering (types, construction, and design aspects) - body materials and trims - manufacturing and safety aspects - ergonomics of body construction – painting - anti-corrosion, and surface treatment.

Module:3	Vehicle Aerodynamics	6 hours

External and internal flow problems - performance of cars and light vans - resistance to vehicle motion - drag and its types - flow field around car - aerodynamic development of cars - optimization of car and commercial vehicles bodies for low drag.

Module:4	Steering System	6 hours

Types of front axles and stub axles - front wheel geometry - condition for true rolling motion of wheels during steering - steering mechanisms - steering error curve - steering linkages - different types of steering gears - slip angle - over steer and under steer, reversible and irreversible steering - power assisted steering - four-wheel steering.

Module:5	Suspension System	6 hours

Need for suspension system - types of suspension springs - constructional details and characteristics of single leaf, multi leaf, coil, torsion bar, rubber, pneumatic and hydro – elastic suspension systems - independent suspension system, shock absorbers - types and constructional details.

Module:6	**Braking System**	**6 hours**
Stopping distance - braking efficiency - weight transfer during braking - drum brakes - constructional details - leading and trailing shoe - braking torque -disc brake – types and constructional details - relative advantages and disadvantages over drum brakes - hydraulic braking system - pneumatic braking system - power assisted braking system - servo brakes - retarders - types and construction.		
Module:7	**Comfort and Convenience Systems**	**7 hours**
Design and characteristic features- electrical seat adjustment - electrical steering column adjustment - multipurpose actuator – HVAC - Infotainment system - horn - lighting system - wiper system - power-window - power sunroof drives - door mechanism and other chassis related accessories.		
Module:8	**Contemporary Issues**	**2 hours**
Heavy Commercial Vehicles: Recent technological progress in chassis and vehicle body engineering. Design for application for HCV, Industry Regulations for Freight and Loading, Vehicle Truck Aggregates, Introduction to Heavy Commercial Vehicles Regulations		
	Total Lecture hours:	**45 hours**

Textbook(s)	
1.	James D. Halderman, “Automotive Chassis Systems”, United States: Pearson, 2020.
2.	David C Barton, John D Fieldhouse, “Automotive Chassis Engineering”, Springer International Publishing, 2018
3.	Giancarlo Genta, Lorenzo Morello, “The Automotive Chassis Volume 1: Components Design”, Germany: Springer International Publishing, 2019.
Reference Books	
1.	James E Duffy, “Modern Automotive Technology”, Goodheart-Willcox, 9th Edition, 2021.
2.	Jack Erjavec, Rob Thompson, Automotive Technology: A Systems Approach Delmar Cengage Learning, 7th Edition, 2019.
3.	Donald E. Malen, “Fundamentals of Automobile Body Structure Design, 2nd Edition’, SAE International, 2020.
4.	Julian Edgar, “A Century of Car Aerodynamics - the Science and Art of Cars and Airflow’, ISBN:9798506846901, Amazon Digital Services LLC – KDP, 2021

Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test

Recommended by Board of Studies	16-02-2024		
Approved by Academic Council	No. 73	Date	14-03-2024

Course Code	Course Title	L	T	P	C
MSMO502L	Automotive Control Systems	3	0	0	3
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

1. To understand the principles and concepts of control systems.
2. For gaining the practical experience in implementing and tuning different types of controllers.
3. To understand the principles of electric and conventional powertrain control systems architecture.
4. To develop the ability to analyze and design control systems for chassis and vehicle related control system applications.

Course Outcomes

1. Ability to demonstrate a clear understanding of the classification of dynamic systems and their mathematical representations.
2. Analyze the system responses in time and frequency domains, evaluate stability, and incorporate performance specifications in controller design.
3. Acquire practical skills in building and tuning different control modules using Simulink in MATLAB.
4. Understanding the control system architecture of the conventional and electric vehicle powertrain systems.
5. Explore the controls strategy applicable towards the vehicle chassis system control aspects.
6. Understand the principles and functions of stability control systems, suspension control systems, and ADAS features.

Module:1	Control System Modelling	6 hours

Introduction to Control - Classification of Dynamic Systems - Closed Loop Control System with Feedback - Mathematical Preliminaries–Complex Variables, Laplace Transform, transfer functions, electrical analogues of other dynamical systems - State-space modelling of dynamical systems - Z domain, mathematical design - Block diagrams - block diagram reductions - Signal flow graph, Mason's gain formula.

Module:2	Performance and Stability of Control System	6 hours

Time response - First Order Systems - Effect of Zeros - Closed Loop Transfer Function, Dynamic Performance Specification - Second Order Systems -Unit Step Response of Underdamped Second Order Systems - Concepts of Rise Time - Peak Time, Maximum Peak Overshoot and Settling Time - Root locus analysis - Frequency response- frequency domain specification -Bode Plots-Gain and Phase Margins. Stability analysis - Incorporation of Performance Specifications in Controller Design - Analysis of Steady State Errors.

Module:3	Linear and Non-linear Controller Design	6 hours

System identification - **Linear**: P, PI, and PID control actions - PID tuning - Simulink to build 'P', 'PI', and 'PID' controller modules in MATLAB - **Non-linear:** Feedback linearization - gain scheduling - Sliding Mode Controller (SMC) : adaptive controller – its performance - **Design Estimation:** Simulink to build Non-linear controller modules

Module:4	Conventional Powertrain Control System	7 hours

Engine: Electronic Fuel Injection Control System of an engine - Sensors for the engine control - Architecture of an EMS, SI & CI engine software strategy - Torque control system of an engine - Throttle control system (Mechanical and electronic throttle) - Air fuel ratio control system and its types - Ignition control system - idle speed control system, knock control system - **Transmission:** Control system architecture with its internal sub control modules of automatic transmission control system.		
Module:5	**Electric Powertrain Control System**	**6 hours**
Motor Control System: Architecture Overview- Inputs and Outputs – Types of Motor Control System. **Motor controller:** Vector-based control– Field oriented control (FOC) - Field Weaking Control - Sensor less motor control system **Power inverter**- Control System for Motor inverter systems - PWM techniques (Space vector/trapezoidal, sinusoidal). **Battery Management System** (BMS): Control System Architecture Overview - Inputs and Outputs - State Estimation.		
Module:6	**Vehicle Stability Control System**	**6 hours**
Fundamentals of Control System architecture - sub-control modules - I/O: Stability control systems (ABS, EBD, TCS, ESP) - Suspension control systems (Conventional and adaptive) - Steering control systems - X-by wire Control System (Steering and brake).		
Module:7	**Chassis Control System**	**6 hours**
Fundamentals of Control System architecture - sub control modules - I/O: Cruise control system - Airbags and belt tensioners control system architecture-collision avoiding system – Advanced driver assistance control - low tire pressure warning system - Drowsiness alert system - keyless entry control system.		
Module:8	**Contemporary Issues**	**2 hours**
Control system towards the ADAS level and OTA.		
	Total Lecture hours:	**45 hours**

Textbook(s)	
1.	Nise, Norman S. Control systems engineering. John Wiley & Sons, 2020
2.	Hayes, John G., and G. Abas Goodarzi. "Electric powertrain: energy systems, power electronics and drives for hybrid, electric and fuel cell vehicles." (2018).
3.	Uwe Kiencke, Lars Nielsen, “Automotive Control Systems for Engine, Driveline, and Vehicle (2nd addition)”, Springer, 2005.
Reference Books	
1.	Golnaraghi, Farid, and Benjamin C. Kuo. Automatic control systems. McGraw-Hill Education, 2017.
2.	Ogata, Katsuhiko. Modern control engineering fifth edition. 2010.
3.	Ozbay, Hitay. Introduction to feedback control theory. CrC Press, 2019.
4.	Denton, Tom. Electric and hybrid vehicles. Routledge, 2020.

5.	Wang, Gaolin, Guoqiang Zhang, and Dianguo Xu. Position Sensorless Control Techniques for Permanent Magnet Synchronous Machine Drives. Singapore: Springer, 2020.			
Mode of Evaluation: CAT / written assignment / Quiz / FAT / Project / Seminar / group discussion / field work (include only those that are relevant to the course. Use ‘,’ to separate the evaluations. Eg. CAT, Quiz and FAT				
Recommended by Board of Studies	16-02-202			
Approved by Academic Council	No. 73	Date	14-03-2024	

Course Code	Course Title	L	T	P	C
MSMO503L	Artificial Intelligence for Mobility	2	0	0	2
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

1. Comprehensive overview of the methods of artificial intelligence
2. Incorporate Artificial technology in vehicle system.
3. Able to tackle current problems in vehicle technology.
4. Able to understand the concepts of AI for the future emerging applications.

Course Outcomes

1. Understand the fundaments and types of Artificial Intelligence
2. Use appropriate techniques of Artificial Intelligence
3. Artificial Intelligence in automotive applications
4. Artificial Intelligence for Powertrain systems
5. Artificial Intelligence for Electric Vehicle

Module:1	Introduction to Artificial Intelligence	4 hours

Introduction of AI - Importance of AI - Evolution of AI - Applications of AI in mobility – Risks of AI: Trustworthy Artificial Intelligence Framework - Ethical, Regulatory and Social Aspects of AI.

Module:2	Fundamentals of Statistical learning	4 hours

Introduction to statistical learning - Statistics fundamentals: probability, random variables, description statistics and stochastic processes - Statistical inference: estimation and testing - Evaluation metrics.

Module:3	Supervised and Unsupervised Learning	4 hours

Supervised Learning - Classification: Linear, Non-linear, Multi-class and multi-label classification - Decision Trees: ID3, Classification and Regression Trees (CART) - Regression: Linear Regression, Multiple Linear Regression, Logistic Regression - Support Vector Machines - k-nearest Neighbors - Neural network - Unsupervised Learning - Clustering: Decision Trees, k-Means clustering.

Module:4	Logic and Automated Reasoning	4 hours

Introduction to logical representation and reasoning - Logical Agents - Propositional Logic, First-order Logic - Fuzzy Logic Inference Algorithms - Rule based knowledge representation - Expert System-Exercises and case studies.

Module:5	Neural network architectures	4 hours

Artificial Neural Networks (Shallow models) - Backpropagation and Training - Deep learning architectures - Convolutional Neural Networks - Recurrent neural networks - Deep learning applications: object detection, identification, classification, tracking, prediction - Introduction to Reinforcement learning - Tensor Flow practical sessions

Module:6	AI Applications in Autonomous vehicle	4 hours

Technologies of Intelligent Vehicles - Multi-sensor Fusion - Path Planning and Decision-Making - Object Detection - Multi Sensor Fusion (LIDAR, RADAR, IMU, GPS etc.) - Intelligent Transportation System.

Module:7	AI Applications in Electric Vehicle	5 hours

BLDC motor speed control with ANN - Fuzzy logic control of active magnetic bearing - Intelligent battery management system - Auto tuning fuzzy controller for induction motor - Battery optimization techniques using AI.		
Module:8	**Contemporary Issues**	**1 hours**
Recent advancements in AI based technology for the future mobility solutions		
	Total Lecture hours:	**30 hours**

Text Book(s)

1.	S. Russell and P. Norvig, Artificial Intelligence: A Modern Approach, Prentice Hall, Fourth Edition, 2021
2.	Dartmann, Guido, Anke Schmeink, Volker Lücken, Houbing Song, Martina Ziefle, and Giovanni Prestiflippo, eds. Smart transportation: AI enabled mobility and autonomous driving. CRC Press, 2021.
3.	Rahul Kala, On-Road Intelligent Vehicles Motion Planning for Intelligent Transportation Systems, Butterworth-Heinemann 2016

Reference Books

1.	Aras Mirfendreski, Powertrain Development with Artificial Intelligence, Springer Berlin, 2022.
2.	Chitra A. et.al, Artificial Intelligent Techniques for Electric and Hybrid Electric Vehicles, Wiley, 2020
3.	Eiza, Mahmoud Hashem, Yue Cao, and Lexi Xu, eds. Toward sustainable and economic smart mobility: shaping the future of smart cities. World Scientific, 2020.
4.	Chow, Joseph. Informed Urban transport systems: Classic and emerging mobility methods toward smart cities. Elsevier, 2018.

Mode of Evaluation: CAT, written assignment, Quiz, FAT, Project. Seminar

Recommended by Board of Studies	16-02-2024		
Approved by Academic Council	No. 73	Date	14-03-2024

Course Code	Course Title	L	T	P	C
MSMO504L	Electric Vehicle Powertrain	3	0	0	3
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

1. Explain the basics of electric and hybrid electric vehicles, their architecture.
2. Discuss the design and component sizing and the power electronics devices used in electric and hybrid electric vehicles.
3. Analyse various electric drives suitable for electric and hybrid electric vehicles.
4. To help the students for understanding the concept of powertrain sizing and energy management system.
5. Understanding of different energy storage technologies and power electronics system used for electric and hybrid electric vehicles.

Course Outcome

1. Understanding the basics of hybrid electric vehicles, their architecture, technologies, and fundamentals.
2. Interpret working of different types of Energy Management strategies in HEV.
3. Interpret and develop the electric vehicle powertrain architecture and sizing of the system for the vehicle configuration.
4. Analyse the use of different types of electrical motors used in hybrid electric vehicles.
5. Analyse and design the various controller aspects of the electric vehicle powertrain control system.
6. Explain the use of different energy storage and power electronics devices used for electric vehicles, their technologies and control and select appropriate technology.

Module:1	Hybrid Vehicle Architecture	6 hours

Introduction - Concept of Hybrid Electric Drivetrains - Architectures of Hybrid Electric Drivetrains - Series and Parallel Hybrid Electric Drivetrains – Coupling Modes - Operating Modes – Hybridization factor – PHEV – Performance characteristics

Module:2	Powertrain Energy Management System	6 hours

Introduction to energy management strategies - classification of energy management strategies - rule based and optimization strategies - real-time working of energy management system in HEV - model-based design and simulation process - Implementation issues of energy management strategies

Module:3	Electric Vehicle Architecture	6 hours

Introduction- Configurations - Traction Motor Characteristics - Tractive Effort and Transmission Requirement – Power Flow Control in Electric Drivetrain – Positioning of Motors - Vehicle Performance - Tractive Effort in Normal Driving - Energy Consumption – Single and Multi- Motor drives.

Module:4	Sizing of Powertrain systems	6 hours

Fundamentals of Vehicle Propulsion – Vehicle Resistance – Basics - sizing and rating of powertrain components - Introduction to tractive force- torque and power - Basics and factors influenced on tractive force- torque and power (2w, 3w &4w) -

Calculation of battery pack- motor torque and power requirements for EV-Case study – Operating fuel economy – Driving cycles and simulation.		
Module:5	**Electric Motors in EV**	**6 hours**
Traction Motor Types – Configuration and Control - DC Motor- Brushless DC Motor – BLDC Motor Control - Switched Reluctance Motor – AC Induction – Axial Flux Motors – Motor Drives and Introduction to Power electronic components – Electronic Control Unit of Motors – Various Control Modes – Drive system efficiency.		
Module:6	**Controllers in EV Powertrain**	**6 hours**
Need of motor controller- types of the controllers- inputs and outputs in a controller- Sensors in motor control operation- motor control system architecture- Need of Battery Management System – types of BMS- I/O of BMS- sensors in BMS- Internal control system architecture- state estimation module- Thermal management strategy.		
Module:7	**Power Electronics in EV**	**7 hours**
Electric Drive Components – Introduction to Power electronic components – Power Electronic Switches DC Drives – DC Regulation and Voltage Conversion – Motor Drives Performance parameters of DC-DC conversion – Step-up and step-down converters with RL load – Switching mode regulators – Comparison of converters – Inverter's introduction Principle of operation – Three phase inverters – Voltage control of three phase inverter		
Module:8	**Contemporary Issues**	**2 hours**
Guest lectures from Industry and, Research and Development Organisations - Recent trends - Challenges in EV and HEV – Motor and Battery design challenges with respect to performance aspects - Electrification challenges		
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	Denton, T. (2020). Electric and hybrid vehicles. Routledge.
2	Ehsani, M., Gao, Y., Longo, S., & Ebrahimi, K. M. (2018). Modern electric, hybrid electric, and fuel cell vehicles. CRC press.
Reference Books	
1.	Emadi, A. (Ed.). (2014). Advanced electric drive vehicles. CRC Press.
2.	Elkamel, A. (2020). Electric Vehicles in Energy Systems: Modelling, Integration, Analysis, and Optimization. Springer.

Mode of Evaluation: CAT, Written assignment, Quiz, FAT, Seminar			
Recommended by Board of Studies		16-02-2024	
Approved by Academic Council	No. 73	Date	14-03-2024

Course code	Course Title	L	T	P	C
MSMO504P	Electric Vehicle Powertrain Lab	0	0	2	1
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

1. To help the students for understanding the performance and operation aspects of electric vehicle powertrain components.
2. To design and analyse the real time electric powertrain components through various simulation aspects for the overall performance improvement of the electric vehicle operation.

Course Outcome

1. Interpret working of different motors and energy storage system used for electric vehicles.
2. Analyse the various system of the hybrid electric vehicles for its effective operation and operation improvement.

Indicative Experiments	
1.	Performance study of AC Induction electric vehicle motor.
2.	Performance study of BLDC electric vehicle motor.
3.	Performance map development for SI engine to operate in hybrid mode
4.	Development of Energy Management system for SI engine with electric vehicle motor
5.	Performance study of Lithium-ion battery for Electric Vehicle
6	Performance study of Fuel Cells and Supercapacitors for Electric Vehicle
7	Performance study battery and motor cooling system in Electric Vehicle
8	Performance study on power electronics system in Electric Vehicle
9	Performance study on regenerative braking for PMSM motor
10	Fault diagnosis of electric and hybrid vehicle components using Simulink
	Total Laboratory Hours **30 hours**

Text Book(s)	
1.	Denton, T. (2020). Electric and hybrid vehicles. Routledge.
2	Ehsani, M., Gao, Y., Longo, S., & Ebrahimi, K. M. (2018). Modern electric, hybrid electric, and fuel cell vehicles. CRC press.
Reference Books	
1.	Emadi, A. (Ed.). (2014). Advanced electric drive vehicles. CRC Press.

Mode of Evaluation: CAT, Written assignment, Quiz, FAT, Seminar			
Recommended by Board of Studies		16-02-2024	
Approved by Academic Council	No. 73	Date	14-03-2024

Course Code	Course Title	L	T	P	C
MSMO505E	Model Based Mobility System Design	2	0	2	3
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

1. To apply the knowledge of mathematical model in automotive systems
2. To model the powertrain systems
3. To investigate the vehicle behavior models
4. To understand the driving and braking control systems
5. To learn mathematical modelling of suspension and steering systems

Course Outcomes

1. Apply the knowledge of mathematical modelling in automotive systems.
2. Model powertrain systems for their optimized performance.
3. Carry out mathematical investigations on the vehicle behavior models.
4. Model the driving and braking control systems of a vehicle.
5. Model the steering and suspension system for optimal performance.
6. Apply the knowledge of model in vehicle systems for its optimized performance

Module:1	Mathematical Modelling of systems	3 hours

System Analysis - Model, formation of models - static model - system to model - dynamic model - discrete time models - spatially continuous models - stochastic models.

Module:2	Linear and Non-linear models	5 hours

Characteristics: System with one and multi variables - Time discrete models (one system and multi system variables) - Models in time and space - mixing and transformation - steady state transport and transformation variables - time dependent solution - Introduction to Simscape and its toolbox elements of the system.

Module:3	Conventional Powertrain Models	6 hours

Powertrain Model for performance and optimization: Engine, Engine combustion (single zone and multi zone) - Engine Intake, and exhaust system - after treatment systems - Engine thermal modelling - operation of the engine system- Fast running Simulation of engine model for the driving cycle.

Module:4	Electric Powertrain Models	4 hours

Electric motor model (electrical, mechanical aspects of AC, DC motors) - Hybrid Vehicle model with EMS (Parallel, Series, combination) - Battery model design and development - Battery thermal management model - Power converters model - Performance model for the Electric vehicle and hybrid electric vehicle simulation for real time driving cycles (High voltage and low voltage)

Module:5	Vehicle Behavior Models	6 hours

Vehicle simulation model - tractive power model - Aerodynamic and Rolling resistance - vehicle torque and power - Coordinate Systems - Wheel modelling – Tire forces - slip angles - tire characteristics - wheel radius - dynamic wheel models - Longitudinal vehicle models- Basic, One mass system - Two-mass system - HVAC and vehicle thermal model.

Module:6	Driving and Braking system model	2 hours

Driving model - cornering forces - model of longitudinal and side forces - Braking force - Acceleration and Braking behavior (ideal and actual conditions) - Lateral vehicle model - Dynamic one track and two track models of Hydraulic Brake Circuit - Anti-lock Control (ABS) - global model for longitudinal dynamics.		
Module:7	**Suspension and Steering models**	**2 hours**
Quarter car model (single and two degree of freedom) - roll model - semi-active suspensions model - active dampers - Active suspension models - Vertical vehicle behavior - Stationary and Dynamic behavior of Mechanical steering systems - Power assisted steering systems – dynamic models – Hydraulic and Electrical Power steering.		
Module:8	**Contemporary Issues**	**2 hours**
Model based design simulation using various advanced techniques		
	Total Lecture hours:	**30 hours**

Text Book(s)	
1.	Rolf Isermann, "Automotive Control: Modeling and Control of Vehicles", 2021, Springer
Reference Books	
1.	Uwe Kiencke, Lars Nielsen, "Automotive Control Systems: For Engine, Driveline, and Vehicle", 2015, 2nd Edition, Springer
2.	A. Galip Ulsoy, Huei Peng, Melih Çakmakci, "Automotive Control Systems", 2015, Cambridge University Press
3.	Imboden DM, Pfenninger S. Introduction to Systems Analysis: Mathematically Modeling Natural Systems. Springer Science & Business Media; 2012 Dec 14.
4.	Das S. Modeling for Hybrid and Electric Vehicles Using Simscape. Morgan & Claypool Publishers; 2021 May 17.

Mode of Evaluation: CAT / written assignment / Quiz / FAT / Project / Seminar / group discussion / field work (include only those that are relevant to the course. Use to separate the evaluations. Eg. CAT, Quiz and FAT

Recommended by Board of Studies		16-02-2024	
Approved by Academic Council	No. 73	Date	14-03-2024

Indicative Experiments	
1.	Modelling of simple electromechanical systems
2.	Transient response of first order systems
3.	Modelling SDOF vibrating system with damper
4.	Modelling of quarter car model
5.	Modelling of engine and vehicle testbed for the performance simulation study
6.	Modelling of Electric vehicle powertrain for the performance simulation study
7.	Modelling of vehicle testbed for the performance simulation study
8.	Modelling of Hybrid Electric vehicle powertrain testbed for the performance simulation study
9.	Modelling of braking systems for the performance simulation study
10.	Modelling of suspension systems for the performance simulation study

		Total Laboratory Hours		**30 hours**
Text Book(s)				
1.	Rolf Isermann, "Automotive Control: Modeling and Control of Vehicles", 2021, Springer			
Reference Books				
1.	Uwe Kiencke, Lars Nielsen, "Automotive Control Systems: For Engine, Driveline, and Vehicle", 2015, 2nd Edition, Springer			
2.	A. Galip Ulsoy, Huei Peng, Melih Çakmakci, "Automotive Control Systems", 2015, Cambridge University Press			
3.	Priyanka Patankar, Swapnil Kulkarni "MATLAB and Simulink In-Depth", 2022, BPB			
Mode of assessment: Continuous assessment / FAT / Oral examination and others				
Recommended by Board of Studies		16-02-2024		
Approved by Academic Council		No. 73	Date	14-03-2024

Course Code	Course Title	L	T	P	C
MSMO506L	Autonomous and Connected Vehicles	2	0	0	2
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

1. Understand the fundamental principles of autonomous and connected vehicle technologies.
2. Analyze the integration of sensor systems and communication protocols in autonomous and connected vehicles.
3. Develop skills in designing and testing autonomous vehicle algorithms and control systems.
4. Explore the ethical, legal, and societal implications of autonomous and connected vehicles.

Course Outcomes

1. Demonstrate proficiency in the application of sensor technologies for autonomous vehicle perception.
2. Evaluate and implement communication protocols essential for connected vehicle systems.
3. Design and simulate control algorithms for autonomous vehicle navigation and decision-making.
4. Assess the ethical and legal challenges associated with autonomous and connected vehicle deployment.
5. Apply knowledge to address societal impacts and potential risks associated with widespread adoption of autonomous and connected vehicles.

Module:1	Connected and Autonomous Vehicle Technology	5 hours

Introduction to the Concept of Automotive Electronics - Levels of autonomous system and its characteristic features - Advanced Driver Assistance Electronic Systems - Features of ADAS - Inputs and Outputs of ADAS - Basic Cyber-Physical System Theory and Autonomous Vehicles - Role of Surroundings Sensing Systems and Autonomy - Role of Wireless Data Networks and Autonomy

Module:2	Sensor Technology for Advanced Driver Assistance Systems	4 hours

Types of Sensors used in ADAS - Basics of Radar Technology and Systems - Ultrasonic Sonar Systems - Lidar Sensor Technology and Systems - Camera Technology - Night Vision Technology - Other Sensors - Integration of Sensor Data to On-Board Control Systems.

Module:3	ADAS Sensor Data Fusion	4 hours

Introduction to ADAS and Sensor Technologies - Sensor Characteristics and Data Types - Sensor Data Preprocessing - Sensor Fusion Algorithms - Object Detection and Tracking - Machine Learning for Sensor Fusion - Integration with ADAS Systems.

Module:4	Wireless Connectivity for vehicles	4 hours

Wireless System Block Diagram and Overview of Components - Transmission Systems and Receiver System principles - DSRC, C-V2X and its architecture - Basics of Computer Networking – the Internet of Things - Wireless Networking

Fundamentals - Integration of Wireless Networking and On-Board Vehicle Networks - Review of On-Board Networks – Use & Function		
Module:5	**Connected Car Technology**	**4 hours**
Connectivity Fundamentals - Telematics system features - on board and off board cloud communication system - Navigation and Other Applications - Vehicle-to-Vehicle Technology and Applications - Vehicle-to-Roadside and Vehicle-to-Infrastructure Applications - Wireless Security Overview of communication protocols.		
Module:6	**ADAS Testing and tuning**	**4 hours**
Basics of Theory of Operation of ADAS standards - Legacy and Upcoming Applications - Integration of ADAS Technology into Vehicle Electronics - System Examples. ISO 21445 overview - ADAS tuning and integration with vehicle chassis system (braking and steering, etc).		
Module:7	**Autonomous Vehicle associated technologies**	**4 hours**
Driverless Car Technology - Artificial Intelligence and Deep Learning - Technical Issues - Security Issues - Inventions going on in Toyota, Nissan, Renault, Honda, Tesla, Hyundai, Volkswagen, BMW, Daimler, Fiat Chrysler Automobiles, Ford, and General Motors overview.		
Module:8	**Contemporary Issues**	**1 hours**
Expert Industry Lecture and Discussing the case studies and applications of Autonomous Vehicles.		
	Total Lecture hours:	**30 hours**

Text Book(s)

1. Murphey, Yi Lu, Ilya Kolmanovsky, and Paul Watta, eds. AI-enabled Technologies for Autonomous and Connected Vehicles. Springer Nature, 2022.
2. Paret, Dominique, and Hassina Rebaine. Autonomous and Connected Vehicles: Network Architectures from Legacy Networks to Automotive Ethernet. John Wiley & Sons, 2022.
3. Mouftah, Hussein T., Melike Erol-Kantarci, and Sameh Sorour, eds. Connected and Autonomous Vehicles in Smart Cities. CRC Press, 2020.

Reference Books

1. Staron, Miroslaw. Automotive software architecture. Cham, Switzerland: Springer, 2021.
2. Sjafrie, Hanky. Introduction to self-driving vehicle technology. CRC Press, 2019.
3. Herrmann, Andreas, Walter Brenner, and Rupert Stadler. Autonomous driving: how the driverless revolution will change the world. Emerald Publishing Limited, 2018.
   Liu, Shaoshan, Liyun Li, Jie Tang, Shuang Wu, and Jean-Luc Gaudiot. Creating autonomous vehicle systems. San Rafael, California: Morgan & Claypool, 2018.

Mode of Evaluation: CAT, Written assignment , Quiz , FAT, Project, Seminar

Recommended by Board of Studies	16-02-2024		
Approved by Academic Council	No. 73	Date	14-03-2024

Course Code	Course Title	L	T	P	C
MSMO506P	Autonomous and Connected Vehicles Lab	0	0	2	1
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

1. Develop a foundational understanding of autonomous vehicle technologies, including perception, decision-making, and control systems.
2. Acquire practical skills in programming and simulation tools used in the development and testing of autonomous and connected vehicle systems.
3. Learn the integration of various sensors (lidar, radar, cameras) and the principles of data fusion to enhance perception capabilities for autonomous vehicles.
4. Explore the safety and security challenges associated with autonomous and connected vehicles, including risk assessment, fail-safe mechanisms, and cybersecurity considerations.

Course Outcomes

1. Demonstrate the ability to program and implement algorithms for autonomous systems using relevant languages and tools.
2. Gain proficiency in utilizing simulation environments for testing and validating autonomous vehicle algorithms and systems.
3. Develop the skills to integrate and calibrate various sensors and implement data fusion techniques to enhance the accuracy and reliability of perception systems.
4. Understand and apply safety principles in the design and implementation of autonomous and connected vehicle systems, ensuring compliance with industry standards and regulations.
5. Apply critical thinking and problem-solving skills to address challenges related to autonomy, connectivity, and real-world deployment of autonomous vehicles.

Indicative Experiments	
1.	Implementation of vehicle data transfer between two remote embedded systems (for example can be computers) using IP address using different wireless transfer protocols.
2.	Implementation of LIDAR sensor perception for Autonomous vehicle
3.	Implementation of RADAR sensor perception for Autonomous Vehicle
4.	Investigation of Intel Real Sense Depth Camera Perception
5.	Implementation of CAN Communication between ECU’s using Vector CANOE
6.	Implementation of CAN Message Error Detection using Vector CANOE
7.	Implementation of Data Fusion using LIDAR and Camera
8.	Implementation of Path Planning using Deep Learning Server
9.	Implementation of Wireless Network Protocol for ITS using NETSIM

10.	Implementation and Evaluation of Wireless Standards (LTE/5G) for vehicle-to-Vehicle/Vehicle to Infrastructure Communication using SUMO/CARLA and NETSIM			
		Total Laboratory Hours	**30 hours**	
Text Book(s)				
1.	Murphey, Yi Lu, Ilya Kolmanovsky, and Paul Watta, eds. *AI-enabled Technologies for Autonomous and Connected Vehicles*. Springer Nature, 2022.			
2.	Paret, Dominique, and Hassina Rebaine. *Autonomous and Connected Vehicles: Network Architectures from Legacy Networks to Automotive Ethernet*. John Wiley & Sons, 2022.			
3.	Mouftah, Hussein T., Melike Erol-Kantarci, and Sameh Sorour, eds. *Connected and Autonomous Vehicles in Smart Cities*. CRC Press, 2020.			
Reference Books				
1.	Staron, Miroslaw. Automotive software architecture. Cham, Switzerland: Springer, 2021.			
2.	Sjafrie, Hanky. Introduction to self-driving vehicle technology. CRC Press,			
3.	2019.			
	Herrmann, Andreas, Walter Brenner, and Rupert Stadler. Autonomous driving: how the driverless revolution will change the world. Emerald Publishing Limited,			
4.	2018.			
	Liu, Shaoshan, Liyun Li, Jie Tang, Shuang Wu, and Jean-Luc Gaudiot. Creating autonomous vehicle systems. San Rafael, California: Morgan & Claypool, 2018.			
Mode of assessment: Continuous assessment, FAT, Oral examination				
Recommended by Board of Studies		16-02-2024		
Approved by Academic Council		No. 73	Date	14-03-2024

Course Code	Course Title	L	T	P	C
MSMO507L	Battery and Fuel Cells for Smart Mobility	3	0	0	3
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

1. To introduce the basics of Electrochemical Cells
2. To introduce the fundamentals of Lithium Ion Cells and its types
3. To introduce the concepts of Battery Pack designing
4. To introduce the principle and operation of Battery Management System
5. To impart the knowledge of advanced automotive batteries, battery recycling and Fuel cells

Course Outcomes

1. Select and analyse a suitable cell chemistry for electric vehicles.
2. Design a suitable battery pack for Electric vehicles.
3. Understanding of the Battery management system for a battery pack
4. Determine and analyse various types of Fuel Cells
5. Design a layout of the plant to recycle the used cells and battery packs

Module:1	Introduction to Automotive Batteries	6 hours

Introduction to electro chemical cells **-** galvanic and electrolytic cells, differences - Thermodynamics of electrochemical cells - Definition, derivation of Nernst equation -Types of Batteries, Characterization of battery, Battery parameters **-** Lead acid battery – Theory of operation – Cell construction – Battery construction – Discharge performance – Charge methods – Temperature effects and limitations – Service life – Storage characteristics – Maintenance requirements – Failure modes, Battery output performance parameters

Module:2	Lithium-Ion Batteries	7 hours

General Characteristics - Cell construction and manufacturing for automotive applications – battery electrodes, electrolytes, and its types – Conventional Lithium battery chemistry, Cylindrical, Prismatic and Polymer Batteries - Li-Ion Battery Performance - Charge and Discharge Characteristics of Li-Ion Batteries - Safety - Charge and discharge characteristics of the battery - Various Chemistries of Lithium-ion battery and its features.

Module:3	Advanced Batteries for EV	5 hours

General Characteristics - Performance Characteristics of Solid-State Li-Ion Batteries - Lithium / Iron Sulfide Batteries – Li-Polymer and Future Trends of Lithium batteries- Construction, features and working - Metal/Air Batteries - Zinc/Bromine Batteries – Sodium ion batteries – Super capacitors its performance and characteristics features.

Module:4	Electric Vehicle Battery pack design	8 hours

Battery sizing - Selection of Battery for Automotive application - Components of the battery pack - high voltage and low voltage - Battery Cell design - EV battery pack design and development - Mechanical Design and Packaging of Battery Packs for Electric Vehicles - Thermal run-away for battery systems - Battery thermal types of the battery thermal management system - characteristic features and design consideration - Battery Performance Measurements, Factors Affecting Battery Performance - Battery Standardization – Maintenance and Test - Battery Installation, Testing of Batteries packs

Module:5	Battery Management System	5 hours
Battery Management System - Battery Cycling SoC and SoH Estimation, Battery Life estimation, Cell balancing, active and passive balancing, circuits for balancing the battery cell - Fault Detection, Safety aspects design of battery pack, Thermal management of battery systems.		
Module:6	**Fuel cells**	**7 hours**
Introduction and overview of fuel cells - technology: low and high temperature fuel Cells - Fuel cell reaction kinetics: Introduction to electrode kinetics – performance characteristics of fuel cells, efficiency of fuel cell, fuel cell stack, fuel cell power plant: fuel processor - Fuel cell types: alkaline fuel cell, Direct Methanol Operated fuel cells, Scaling and stacking of fuel cells, thermal run away and water flooding aspects.		
Module:7	**Battery recycling aspects**	**5 hours**
Battery recycling - Environmental Aspects of the Recycling of Lithium-Ion Traction Batteries - Circular economy aspects of battery system - Disassembly Planning and Assessment of Automation Potentials for Lithium-Ion Batteries - Crushing of Battery Modules and Cells - Separation of the Electrolyte —Types, Material Separation, Off Gas Cleaning by Adsorption. Battery recycling standards and policy in India and European Union regulations.		
Module:8	**Contemporary Issues**	**2 hours**
Model based design and development of Battery pack - EMI and EMC aspect of battery		
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	David Linden and Thomas B. Reddy — Hand Book of Batteries Third Edition, 2015, McGraw-Hill, NY
2.	John T Warner “The Handbook of Lithium-Ion Battery Pack design – Chemistry, Components, Types and Terminology” 2015, Elsevier Publications, USA

Reference Books	
1.	Detchko Pavlov Lead-Acid Batteries: Science and Technology, Second Edition, 2017, Springer Publications
2.	Kai Peter Birke “Modern Battery Engineering: A Comprehensive Introduction” 2019, World Scientific
3.	Jiuchun Jiang, Caiping Zhang “Fundamentals and Applications of Lithium-ion Batteries in Electric Drive Vehicles” 2015, Wiley Publications
4.	San Ping Jiang , Qingfeng Li, “Introduction to Fuel Cells - Electrochemistry and Materials” 2022, Springer Nature Publications, USA
5.	Xiao Lin, “Recycling of Power Lithium Batteries Technology Equipment and Policies” 2022, Wiley Publications

Mode of Evaluation: CAT / written assignment / Quiz / FAT / Project / Seminar / group discussion / field work (include only those that are relevant to the course. Use ‘,’ to separate the evaluations. Eg. CAT, Quiz and FAT

Recommended by Board of Studies	16-02-2024		
Approved by Academic Council	No. 73	Date	14-03-2024

Course Code	Course Title	L	T	P	C
MSMO508L	Advanced Drivetrain Systems	3	0	0	3
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

1. To broaden the understanding of the engine and its working under advanced combustion techniques.
2. To enhance the understanding of engine emissions and control techniques.
3. To enable understanding of different types of driveline systems.

Course Outcomes

1. Realize the combustion process in SI and CI engines.
2. Understanding the emission formation mechanism and the strategic options available to reduce pollutants from engines.
3. Understand the combustion phenomena of premixed and diffusion combustion.
4. For low temperature combustion engines.
5. Understanding the flex fuel operation in the IC engines.
6. Identify and formulate the gaseous in IC engines and analyze their performance characteristics.
7. Study of a suitable clutch and gear box for any given vehicle.
8. Comprehend driveline systems for any given vehicle.

Module:1	SI and CI Engines	7 hours

SI Engine- Stages of Combustion, Phases of Ignition, Flame Propagation, Flame Structure, and Burning Velocity, Cycle to Cycle Variations – GDI Injection System.
CI Engine- Stages of Combustion, Fuel spray structure, Spray Penetration, Spray angle, Droplet distribution and Evaporation. Knocking and Detonation Concepts- CRDI System.

Module:2	Emissions Formation and Control	6 hours

Carbon monoxide Formation, Flame Quenching and Oxidation, HC emissions in SI Engine, HC emissions Mechanism in Diesel Engines -Controlling Techniques – Catalytic Converters, DOC, DPF. Kinetics of NO formation, NO formation in SI Engines, NOx formation in CI Engines –Controlling Techniques –SCR.

Module:3	Advanced combustion engines	6 hours

Low temperature combustion engines- PPCI, HCCI, PCCI, RCCI, High-efficiency clean combustion (HECC) and Stratified charge compression ignition (SCCI) – Lean burn engine - Engine for hybrid vehicles based on advanced combustion.

Module:4	Flex fuel Engines	5 hours

Methanol and Ethanol fueled engines- methodology, Fuel Injection system, - Controller design- Adoption of engine system for alternate fuels, Aldehyde Emissions, Combustion concepts. Government initiatives.

Module:5	Gaseous fuel engine	5 hours

Hydrogen Combustion- Injection system- CNG- LPG- LNG- Biogas- Di-Methyl Ether – Fuel Injection systems design- architecture- Engine performance, emission, and combustion characteristics.

Module:6	Clutch and Transmission system	7 hours

Necessity of clutch in an automobile, types of clutches, Single plate clutch, multi-plate clutch, centrifugal clutch. Necessity of gearbox, Constructional details of

Sliding-mesh gear box, Constant-mesh gearbox, Synchromesh gear, Desirable ratios of 3 speed & 4 speed gearboxes – Electric Vehicle gear box system (reducer box)- Automatic manual transmission systems, Automatic transmission systems- CVT- ECVT.		
Module:7	**Driveline system**	**7 hours**
Effects of driving thrust and torque reaction - Hotchkiss drive. Torque tube drive, radius rods - Propeller shaft - Universal joints. Final drives – different types, double reaction final drive - Two-speed rear axle - Rear axle construction – full floating, three-quarter floating and semi floating arrangements - Differential – conventional type, non-slip type - Differential locks.		
Module:8	**Contemporary Issues**	**2 hours**
Recent advancements in advanced combustion technology - Recent trends in drivetrain system		
	Total Lecture hours:	**45 hours**

Textbook(s)	
1.	John B Heywood, Internal Combustion Engine Fundamentals, (2018), McGraw Hill Education.
2.	Zhang, Y., & Mi, C., Automotive power transmission systems, (2018), John Wiley & Sons.
3.	Pundir, B. P. Engine emissions: fundamentals and advances in control (No. 8278), (2017), Alpha Science International.
Reference Books	
1.	Singh, A. P., Sharma, Y. C., Mustafi, N. N., & Agarwal, A. K. (Eds.). Alternative Fuels and Their Utilization Strategies in Internal Combustion Engines. (2020), Springer Singapore.
2.	Chen, Y. Automotive transmissions: Design, theory and applications. (2020), Springer Nature.
3.	Maurya, R. K., Maurya, R. K., & Luby., Characteristics and control of low temperature combustion engines (pp. 31-133), (2018), Cham, Switzerland: Springer.
4.	Kasab, J., & Strzelec, A. Automotive emissions regulations and exhaust aftertreatment systems. (2020), SAE International.

Mode of Evaluation: CAT / written assignment / Quiz / FAT / Project / Seminar / group discussion / field work (include only those that are relevant to the course. Use ‘,’ to separate the evaluations. Eg. CAT, Quiz and FAT			
Recommended by Board of Studies	16-02-2024		
Approved by Academic Council	No. 73	Date	14-03-2024

Skill Enhancement Courses

Course code	Course Title	L	T	P	C
MENG501P	Technical Report Writing	0	0	4	2
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

1.To develop writing skills for preparing technical reports.
2. To analyze and evaluate general and complex technical information.
3. To enable proficiency in drafting and presenting reports.

Course Outcome

At the end of the course, the student will be able to
1.Construct error free sentences using appropriate grammar, vocabulary and style.
2. Apply the advanced rules of grammar for proofreading reports.
3. Interpret information and concepts in preparing reports.
4. Demonstrate the structure and function of technical reports.
5. Improve the ability of presenting technical reports.

Indicative Experiments	
1.	**Basics of Technical Communication** General and Technical communication, Process of communication, Levels of communication
2.	**Vocabulary& Editing** Word usage: confusing words, Phrasal verbs Punctuation and Proof reading
3.	**Advanced Grammar** Shifts: Voice, Tense, Person, Number Clarity: Pronoun reference, Misplace and unclear modifiers
4.	**Elements of Technical writing** Developing paragraphs, Eliminating unnecessary words, Avoiding clichés and slang Sentence clarity and combining
5.	**The Art of condensation** Steps to effective precis writing, Paraphrasing and summarizing
6.	**Technical Reports:** Meaning, Objectives, Characteristics and Categories
7.	**Formats of reports and Prewriting**: purpose, audience, sources of information, organizing the material
8.	**Data Visualization** Interpreting Data - Graphs - Tables – Charts - Imagery - Info graphics
9.	**Systematization of Information:** Preparing Questionnaire Techniques to Converge Objective-Oriented data in Diverse Technical Reports
10.	**Research and Analyses:** Writing introduction and literature review, Reference styles, Synchronize Technical Details from Magazines, Articles and e-content
11..	**Structure of Reports** Title – Preface – Acknowledgement - Abstract/Summary – Introduction - Materials and Methods – Results – Discussion - Conclusion - Suggestions/Recommendations
12.	**Writing the Report:** First draft, Revising, Thesis statement, Developing unity and coherence
13.	**Writing scientific abstracts:** Parts of the abstract, Revising the abstract Avoiding Plagiarism, Best practices for writers
14.	**Supplementary Texts** Appendix – Index – Glossary – References – Bibliography - Notes
15	**Presentation**

	Presenting Technical Reports Planning, creating anddigital presentation of reports			
			Total Laboratory hours :	**60 hours**
Text Book(s)				
1.	Raman, Meenakshi and Sangeeta Sharma, (2015).Technical Communication: Principles and Practice, Third edition, Oxford University Press, New Delhi.			
Reference Books				
1.	Aruna, Koneru, (2020). English Language Skills for Engineers. McGraw Hill Education, Noida.			
2.	Rizvi,M. Ashraf (2018)Effective Technical Communication Second Edition. McGraw Hill Education, Chennai.			
3.	Kumar, Sanjay and Pushpalatha, (2018). English Language and Communication Skills for Engineers, Oxford University Press.			
4.	Elizabeth Tebeaux and Sam Dragga, (2020).The Essentials of Technical Communication, Fifth Edition, Oxford University Press.			
Mode of Evaluation **:** Continuous Assessment Tests, Quizzes, Assignment, Final Assessment Test				
Recommended by Board of Studies	19-05-2022			
Approved by Academic Council	No. 66	Date	16-06-2022	

Course Code	Course Title	L	T	P	C
MSTS501P	Qualitative Skills Practice	0	0	3	1.5
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives:

1. To develop the quantitative ability for solving basic level problems.
2. To improve the verbal and professional communication skills.

Course Outcome:

At the end of the course, the student will be able to

1. Execute appropriate analytical skills.
2. Solve problems pertaining to quantitative and reasoning ability.
3. Learn better vocabulary for workplace communication.
4. Demonstrate appropriate behavior in an organized environment.

Module:1	**Business Etiquette: Social and Cultural Etiquette; Writing Company Blogs; Internal Communications and Planning: Writing press release and meeting notes**	**9 hours**

Value, Manners- Netiquette, Customs, Language, Tradition, Building a blog, Developing brand message, FAQs', Assessing Competition, Open and objective Communication, Two way dialogue, Understanding the audience, Identifying, Gathering Information,. Analysis, Determining, Selecting plan, Progress check, Types of planning, Write a short, catchy headline, Get to the Point –summarize your subject in the first paragraph., Body– Make it relevant to your audience.

Module:2	**Time management skills**	**3 hours**

Prioritization, Procrastination, Scheduling, Multitasking, Monitoring, Working under pressure and adhering to deadlines

Module:3	**Presentation skills – Preparing presentation; Organizing materials; Maintaining and preparing visual aids; Dealing with questions**	**7 hours**

10 Tips to prepare PowerPoint presentation, Outlining the content, Passing the Elevator Test, Blue sky thinking, Introduction , body and conclusion, Use of Font, Use of Color, Strategic presentation, Importance and types of visual aids, Animation to captivate your audience, Design of posters, Setting out the ground rules, Dealing with interruptions, Staying in control of the questions, Handling difficult questions.

Module:4	**QuantitativeAbility-L1–Numberproperties; Averages; Progressions; Percentages; Ratios**	**11 hours**

Number of factors, Factorials, Remainder Theorem, Unit digit position, Tens digit position, Averages, Weighted Average, Arithmetic Progression, Geometric Progression, Harmonic Progression, increase and Decrease or Successive increase, Types of ratios and proportions.

Module:5	**Reasoning Ability - L1 – Analytical Reasoning**	**8 hours**

Data Arrangement (Linear and circular & Cross Variable Relationship), Blood Relations, Ordering / ranking / grouping, Puzzle test, Selection Decision table.

Module:6	**Verbal Ability -L1 – Vocabulary Building**	**7 hours**

Synonyms & Antonyms, One word substitutes, Word Pairs, Spellings, Idioms, Sentence completion, Analogies.		
	Total Lecture hours:	**45 hours**
Reference Books		
1.	Kerry Patterson, Joseph Grenny, Ron McMillan and Al Switzler, (2017).2nd Edition, Crucial Conversations: Tools for Talking when Stakesare High .McGraw-Hill Contemporary, Bangalore.	
2.	Dale Carnegie,(2016).How to Win Friends and Influence People. Gallery Books, New York.	
3.	Scott Peck. M, (2003). Road Less Travelled. Bantam Press, New York City.	
4.	SMART, (2018). Place Mentor, 1st edition. Oxford University Press, Chennai.	
5.	FACE, (2016). Aptipedia Aptitude Encyclopedia. Wiley publications, Delhi.	
6.	ETHNUS, (2013). Aptimithra. McGraw – Hill Education Pvt .Ltd, Bangalore.	
Websites:		
1.	**www.chalkstreet.com**	
2.	**www.skillsyouneed.com**	
3.	**www.mindtools.com**	
4.	**www.thebalance.com**	
5.	**www.eguru.ooo**	
Mode of Evaluation: Continuous Assessment Tests, Quizzes, Assignment, Final Assessment Test		
Recommended by Board of Studies	19-05-2022	
Approved by Academic Council	No.66	Date 16-06-2022

Course Code	Course Title	L	T	P	C
MSTS502P	Quantitative Skills Practice	0	0	3	1.5
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives:

1. To develop the students' advanced problem solving skills.
2. To enhance critical thinking and innovative skills.

Course Outcome:

At the end of the course, the student will be able to

1. Create positive impression during official conversations and interviews.
2. Demonstrate comprehending skills of various texts.
3. Improve advanced level thinking ability in general aptitude.
4. Develop emotional stability to tackle difficult circumstances.

Module:1	**Resume skills – Resume Template; Use of power verbs; Types of resume; Customizing resume**	**2 hours**

Structure of a standard resume, Content, color, font, Introduction to Power verbs and Write up, Quiz on types of resume, Frequent mistakes in customizing resume, Layout-Understanding different company's requirement, Digitizing career portfolio.

Module:2	**Interview skills – Types of interview; Techniques to face remote interviews and Mock Interview**	**3 hours**

Structured and unstructured interview orientation, Closed questions and hypothetical questions, Interviewers' perspective, Questions to ask/not ask during an interview, Video interview, Recorded feedback, Phone interview preparation, Tips to customize preparation for personal interview, Practice rounds.

Module:3	**Emotional Intelligence - L1 – Transactional Analysis; Brain storming; Psychometric Analysis; SWOT analysis**	**12 hours**

Introduction, Contracting, ego states, Life positions, Individual Brainstorming, Group Brainstorming, Stepladder Technique, Brain writing, Crawford's Slip writing approach, Reverse brainstorming, Star bursting, Charlette procedure ,Round robin brainstorming, Skill Test, Personality Test, More than one answer, Unique ways, SWOT analysis.

Module:4	**Quantitative Ability - L3–Permutation - Combinations; Probability; Geometry and menstruation; Trigonometry; Logarithms; Functions; Quadratic Equations; Set Theory**	**14 hours**

Counting, Grouping, Linear Arrangement, Circular Arrangements, Conditional Probability, Independent and Dependent Events, Properties of Polygon, 2D & 3D Figures, Area & Volumes, Heights and distances, Simple trigonometric functions, Introduction to logarithms, Basic rules of logarithms, Introduction to functions, Basic rules of functions, Understanding Quadratic Equations, Rules & probabilities of Quadratic Equations, Basic concepts of Venn Diagram.

Module:5	**Reasoning ability - L3 – Logical reasoning; Data Analysis and Interpretation**	**7 hours**

Syllogisms, Binary logic, Sequential output tracing, Crypto arithmetic, Data Sufficiency, Data Interpretation-Advanced, Interpretation tables, pie charts & bar chats.		
Module:6	**Verbal Ability - L3 – Comprehension and Critical reasoning**	**7 hours**
Reading comprehension, Para Jumbles, Critical Reasoning (a) Premise and Conclusion, (b) Assumption & Inference, (c) Strengthening & Weakening an Argument.		
	Total Lecture hours:	**45 hours**

Reference Books

1.	Michael Farra and JIST Editors,(2011).Quick Resume & Cover Letter Book: Write and Use an Effective Resume in Just One Day. Jist Works, Saint Paul, Minnesota.
2.	Flage Daniel E, (2003).The Art of Questioning: An Introduction to Critical Thinking. Pearson, London.
3.	David Allen, (2015).Getting Things done: The Art of Stress-Free productivity. Penguin Books, New York City.
4.	SMART, (2018). Place Mentor 1st edition. Oxford University Press, Chennai.
5.	FACE, (2016).Aptipedia Aptitude Encyclopedia. Wileypublications, Delhi.
6.	ETHNUS, (2013).Aptimithra. McGraw-Hill Education Pvt Ltd, Bangalore.

Websites:

1.	www.chalkstreet.com
2.	www.skillsyouneed.com
3.	www.mindtools.com
4.	www.thebalance.com
5.	www.eguru.ooo

Mode of Evaluation: Continuous Assessment Tests, Quizzes, Assignment, Final Assessment Test			
Recommended by Board of Studies	19-05- 2022		
Approved by Academic Council	No.66	Date	16-06-2022

Discipline Elective Courses

Course Code	Course Title	L	T	P	C
MSMO601L	Embedded Systems for Mobility	3	0	0	3
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

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.
2. Acquire the skills necessary to design, implement, and optimize embedded systems tailored for electric vehicles, including motor control, battery management, power electronics, and communication protocols.
3. Understand the importance of the role of embedded computing for E-Mobility.
4. Analyze the environmental and sustainability aspects of E-Mobility and explore how embedded systems contribute to the development of smart and energy-efficient electric transportation solutions.

Course Outcomes

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.
2. Understand the Application of Sustainable E-Mobility Solutions.
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.
4. Demonstrate a strong knowledge of the advanced technologies related to E-Mobility.
5. Understand various computing algorithms in the development of E-Mobility Solutions.

Module:1	Introduction to 8 bit microcontrollers	6 hours

Introduction to embedded system - Programming in Embedded C [8051/PIC18 - Applications on Body and safety - Hex file flashing into microcontroller.

Module:2	Automotive 32 bit applications	6 hours

Choosing MCU‘s 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.

Module:3	Multicores for E Mobility	6 hours

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 - Introduction to CUDA and Open MP.

Module:4	Embedded systems in automotive	6 hours

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 ECU’s Architecture- Characteristic features - Introduction to AUTOSAR – Types- Characteristic features.

Module:5	Automotive embedded rapid prototyping	6 hours

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.		
Module:6	**Automotive Networking and Protocols**	**6 hours**
Overview of CAN –fundamentals –Message transfer –frame types-Error handling – fault confinement-Bit time requirements - Introduction to LIN and Flexray - MOST-Introduction to Network diagnostic tools (CANalyzer, CANape)		
Module:7	**Introduction to ISO26262 Standard: Basic Concepts**	**7 hours**
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.		
Module:8	**Contemporary Issues**	**2 hours**
Expert Industry Lecture and discussing the case studies and applications related to Embedded System for E-Mobility.		
	Total Lecture hours:	**45 hours**

Text Book(s)

1. Kathiresh, M., G. R. Kanaga chidambaresan, 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. *Automotive embedded systems handbook*. CRC press, 2017.

Reference Books

1. Marwedel, Peter. Embedded system design: embedded systems foundations of cyber-physical systems, and the internet of things. Springer Nature, 2021.
2. Barkalov, Alexander, Larysa Titarenko, and Małgorzata Mazurkiewicz. Foundations of embedded systems. Vol. 195. Cham, Switzerland: Springer International Publishing, 2019.
3. Zurawski, Richard. Embedded Systems Handbook: Embedded systems design and verification. CRC press, 2018.
4. Wang, Jiacun. Real-time embedded systems. John Wiley & Sons, 2017.

Mode of Evaluation: CAT, Written assignment, Quiz, FAT, Project, Seminar

Recommended by Board of Studies	16-02-2024		
Approved by Academic Council	No. 73	Date	14-03-2024

Course Code	Course Title	L	T	P	C
MSMO602L	Vehicle Testing and Certification	3	0	0	3
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

1. To understand vehicle testing and certification.
2. To identify the role of testing engineers in determining the quality, and services life during development stages of a new vehicle.
3. To learn instrumentation using modern testing tools.

Course Outcomes

1. Students gain the knowledge and skill of Homologation & Regulations.
2. Impart knowledge on automotive software testing.
3. Gain knowledge of standards and testing of electrical and electronics parts in HEV & EV.
3. Impart knowledge of component level testing instruments and facilities.
4. Outline static and dynamic vehicle testing techniques.
5. Familiarize with autonomous vehicle testing.

Module:1	CMVR and Homologation	4 hours

Classification of Vehicles - Homologation and its types - Regulations overview (EEC, ECE, FMVSS, AIS, and CMVR) - Type approval Scheme - Homologation for export - Conformity of Production - various Parameters - Instruments and Types of test tracks – Introduction – requirements - country regulations and its overview - European standard and testing - Indian Standards - Certification of vehicles - Testing facilities - CMVR, ARAI, NATRIP, GARC – Standards - Testing procedures - Testing conditions, Preparation of vehicles for certifications - Co-relation of test facilities and standards for international type approval.

Module:2	Static vehicle testing techniques	6 hours

Static Testing - Tire Tread Depth Test - Wheel balancing and alignment - Vehicle Weighment (IS: 11825) - Horn installation (IS:15796) - Rear view mirror installation (AIS:002) - Tell Tales (AIS:126), External Projection - Wheel Guard - Arrangement of Foot Controls for Vehicle (M1, etc.) - Angle & Dimensions, Measurement of Vehicle – Drive away chassis - Vehicle posture measurement (basics parameters - Departure angle, approach angle - vehicle body parameters, etc.), - International standards in-line with static testing aspects.

Module:3	Dynamic vehicle testing techniques	7 hours

Chassis dynamometer testing requirements and features - Dynamics Testing: Ride and handling - Different road surfaces for testing and procedures (ARAI, NGARC, ICAT, NATRAX) - seat comfort - Gradeability (AIS:003) - Pass-by Noise (IS:3028), Interior Noise (AIS:020) - Turning Circle Diameter & Turning Clearance Circle Diameter - Cooling Performance - Speedo-meter Calibration (IS:11827) - Range Test - Maximum Speed - Acceleration Test - Coast-down test (IS:14785) - Brakes Performance ABS Test (IS:14664) - Broad band / Narrow band EMI Test - Vehicle standards related to ADAS - International standards in-line with dynamic testing aspects.

Module:4	Engine Testing	6 hours

Engine Testing and Performance (SI, CI, LPG, ethanol and CNG): Automotive and stationary engine testing and related standards - Engine power and efficiency -

Range Test, Maximum Speed, Acceleration Test, Coast-down test, Engine power test (SI, CI, LPG, ethanol and CNG) - Indian driving cycle and related emission - performance testing process - Real world fuel economy with declared value by manufacturers - Vehicle mass emission - Evaporative emission.		
Module:5	**Electric Vehicle Powertrain Testing**	**7 hours**
Electrical safety requirements - Requirements of a vehicle about its electrical safety (AIS: 38) - Safety requirements with respect to the electric power train of motor vehicles of categories as defined in Rule 2 (u) of CMVR - Safety requirements with respect to the Rechargeable Electrical Energy Storage System (REESS) - Method of Measuring the Range for Electric Vehicles (AIS:040) – Electromagnetic Compatibility of the Motor Vehicle (AIS: 003 – part 3) - CMVR Type approval for Electric Vehicles (AIS:049) - CMVR type approval for HEV - Test for EV kit for Conversion - Electric Vehicle Charging System testing and certification - EMI and EMC related aspects for testing and certification for EV powertrain.		
Module:6	**Electric Vehicle Storage system testing**	**7 hours**
Safety Requirements of Traction Batteries (AIS: 048) - Electrical Tests - Short Circuit Test - Overcharge Test - Mechanical Tests- Vibration Test - Shock Test - Roll-Over Test (Battery Module) - Penetration Test (Cell Level or Battery module) - Battery Parameters – Capacity Test - Charge Retention Test - Conformity of Production (COP) - Rated Capacity – Battery Performance Testing (ISO:12405,18243,15118)		
Module:7	**Lighting and Signaling Devices**	**6 hours**
Vehicle Lighting Testing (AIS:009, AIS:010, AIS:037): Installation requirement for lighting - front and rear - signaling and reflective devices Installation - Conspicuity and Reflective - Marking, Photometry Test: Performance requirement for lighting - signaling and reflective - devices - Head lamp, Front lamp, direction indicator lamp, signaling lamp and Warning triangles - vehicles Glasses testing -Infotainment related testing process and its features.		
Module:8	**Contemporary Issues**	**2 hours**
HCV vehicles Lighting Simulation and Visibility for Road Safety, HCV standards, etc		
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	Joe Glassford, The Hands on Vehicle Testing Reference, 2019, ISBN: 978-0-69266-102-4
2.	K.V. Fadadu, B.H.Kadiya, Vehicle Testing and Homologation, 2016
Reference Books	
1.	Vehicle Homologation Process and Tests. Galindo, Eduardo; Blanco, David; Richard Chassis Dynamometer Testing, 2017.
2	W. H. Crouse and L. Anglin – Motor vehicle inspection, McGraw Hill Book Co. 1978
3.	Ulrich Seiffert and Lothar Wech, “Automotive Safety Handbook”, SAE International, 2007.

Mode of Evaluation: CAT / written assignment / Quiz / FAT / Project / Seminar / group discussion / field work (include only those that are relevant to the course. Use ‘,’ to separate the evaluations. Eg. CAT, Quiz and FAT

Recommended by Board of Studies	16-02-2024		
Approved by Academic Council	No. 73	Date	14-03-2024

Course Code	Course Title	L	T	P	C
MSMO603L	Vehicle Dynamics	3	0	0	3
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

1. To enable students to understand the role of tyre characteristics and its mechanics for vehicle dynamics.
2. To enable the students to understand vehicle performance, handling and ride aspects and the issues involved in it such as braking, traction, road holding, vehicle control and stability.
3. To prepare the students to understand Human response and ride comfort criteria.
4. To demonstrate how to address futuristic vehicle's dynamics requirements and challenges.

Course Outcomes

On completion of this course, the student will be able to

1. Predict the necessary forces and moments during tyre/road interaction through various tyre models for vehicle dynamic simulations.
2. Compute maximum traction, optimum braking force distribution and stability of the vehicles and their control strategies.
3. Demonstrate the application of fundamental governing equations for longitudinal, lateral and vertical dynamics and able to use state space approach.
4. Compute steady state and transient response of vehicle during cornering.
5. Outline the role of suspension and its performance in ride and handling and roll over stability analysis.
6. Use the appropriate mathematical models to study motorcycle dynamics.

Module:1	Tyre Mechanics	6 hours

Introduction - Tyre & Vehicle axes systems - Tyre types and construction -Tyre forces and moments -Tyre-slip & skid phenomenon grip and rolling resistance - Cornering properties of tyres - Tyre models - Julien's tyre model for combined tractive and braking effort - Temple & Von Schippe approach of tyre string model for cornering force - Friction Ellipse concept - Magic Formula tyre model for steady state motion - Tyre performance on wet surfaces - Ride properties of tyres.

Module:2	Longitudinal Dynamics	5 hours

Performance characteristics - Maximum tractive effort - Power plant and Transmission characteristics - Braking Performance-Anti lock brake system and Traction control system.

Module:3	Lateral Dynamics	6 hours

General frame work for governing equations for ground vehicles - Bicycle Model- Low speed turning - High speed cornering-State space approach - Steaty state handling characteristics of two axle vehicle- neutral steer-understeer-oversteer - Steady state gains from Bicycle Model during pure cornering - Vehicle handling tests (Constant radius cornering and fishhook) - Vehicle transient responses and understeer gradient effects due to lateral load transfer - roll steer - camber thrust - lateral force compliance and steering system compliance.

Module:4	**Vehicle Stability**	**6 hours**
Yaw plane stability and steering conditions - characteristic polynomial and stability factor – Handling response of a vehicle - Lateral transient response - Mimuro plot. Effect of suspension on cornering - Roll center and Roll axis - Roll moment distribution - Car tyre relative angles - Caster theory - Role of suspension and nonlinearity of tyres on vehicle roll and its effect on Understeer co-efficient - roll over stability analysis - Control strategies required for vehicle.		
Module:5	**Vertical dynamics**	**7 hours**
Vehicle ride characteristics - Human response to vibration - Vehicle ride models - Quarter car model - pitch and bounce-bounce and roll model -Suspension performance for ride-vibration isolation - suspension travel - Road holding - Active and Semi-active suspensions - Introduction to random vibration - ISO road roughness and road profiles - RMS acceleration of sprung mass of vehicle for random road excitation.		
Module:6	**Motorcycle Dynamics**	**6 hours**
Kinematics of Motorcycle - Rectilinear and steady state turning motion - In plane dynamics - Motorcycle vibration modes and stability.		
Module:7	**Vehicle Dynamics for Electric, Hybrid and Autonomous vehicles**	**7 hours**
Introduction to EVs, HEVs, and AVs and their dynamics requirements - Dynamics behavior of the vehicle based on the battery pack location - Dynamics aspects based on the motor location and power distribution - NVH challenges for the EV and HEV- Experimental techniques - Frequency response functions - Modal analysis - Transfer path analysis - Single reference - Multi reference analysis.		
Module:8	**Contemporary Issues**	**2 hours**
Case studies of application of multi-body dynamics software and application of IoT and ML tools, etc, Introduction to HCV Vehicle Dynamics		
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	J. Y. Wong, Theory of Ground Vehicles, 3rd Edition, Wiley-Interscience, 2008.
2	Thomas D Gillespie, Fundamentals of Vehicle Dynamics, 2nd Revised Edition, SAE International, Warrendale, 2021
3	Vittore Cassalter, “Motorcycle Dynamics”, 2nd English edition, 2006.
Reference Books	
1	1. Reza N Jazar “Vehicle Dynamics: Theory and Application”, 3rd Edition, Springer International Publishing AG, Switzerland, 2017
2	2 Katsuhiko Ogata, “Modern Control Engineering”,5th Edition, Prentice Hall,Pearson,2015.
3	3. C. Sujatha, “Vibration and Acoustics: Measurements and Signal Analysis”, McGraw Hill Education (India) Private limited, 2017
4.	Ellis.J.R - “Vehicle Dynamics”- Business Books Ltd., London- 1991
5.	Giles.J.G.Steering - “Suspension and Tyres”, Illiffe Books Ltd., London- 1998

Mode of Evaluation: CAT / written assignment / Quiz / FAT / Project / Seminar / group discussion / field work (include only those that are relevant to the course). Use to separate the evaluations. Eg. CAT, Quiz and FAT			
Recommended by Board of Studies	16-02-2024		
Approved by Academic Council	No. 73	Date	14-03-2024

Course Code	Course Title	L	T	P	C
MSMO604L	Vehicle Diagnostics System	3	0	0	3
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

1. To broaden the understanding of students in vehicle maintenance, its types and their diagnostic techniques.
2. To equip students with the knowledge of engine, sub-system and electric drive train and vehicle systems maintenance.
3. To make the students acquire in-depth knowledge about on-board diagnostics, chassis and electrical system diagnostics.
4. To teach students the latest trends in the field of vehicle diagnostic systems.

Course Outcomes

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

1. Possess the knowledge of overall vehicle maintenance and its types, on and off-board diagnostics and vehicle, engine, electric drive train and their sub-system maintenance.
2. Demonstrate the application of oscilloscope and on-board diagnostics for automobiles.
3. Provide an in-depth knowledge about the diagnostics of engine and sub-systems like fuel supply, ignition, cooling, and lubrication systems air supply and exhaust systems.
4. Gain the knowledge of chassis system maintenance and various diagnostic procedures related to brakes, steering and suspension systems.
5. Discuss the diagnostics of electric drive train and sub-systems like battery, electrical machines, charging system, regenerative braking system and battery management system.
6. Acquire and analyze the maintenance and diagnostics of electrical systems including HVAC, cruise control diagnostics, airbags diagnostics, advanced fault diagnostics and remote diagnostics.

Module:1	Introduction to Diagnostic System	7 hours

Need for maintenance - types of maintenance: preventive and breakdown maintenance - requirements of maintenance - preparation of check lists - Inspection schedule - maintenance of records - log sheets and other forms - safety precautions in maintenance: General safety - tool safety - Diagnostic Techniques needs - history for traditional vehicle to modern vehicles and necessity - diagnostic process - diagnostics on paper - mechanical diagnostic techniques - electrical diagnostic techniques (internal components and their systems) – Overview of diagnostics system in ECU - Diagnostic control system architecture in vehicles ECU, CAN with respect to the diagnostic system and its features - inter system (Types of CAN) ECU diagnostics - error detection - diagnostic protocols - UDS (Unified diagnostic services) - Diagnostic standards (SAE, ISO, AIS etc.)

Module:2	On-Board Diagnostics	7 hours

On and off-board diagnostics - Origin of OBD – K-line, Serial communication protocols - OBD port - SAE J1979 - fault codes - Anatomy of DTC - fault analysis based on DTC - Types of the faults codes and its characteristics features - Data sources – Components of OBD- SI/CI engine OBD monitors – OBD types - OBD II modes – MIL - freeze frame data and fault memory-future development in diagnostic

system - Data identification - Error snapshot - Limp home mode operation and its features		
Module:3	**Diagnostic Devices and Practical Diagnostics System**	**6 hours**
Scanning tools PC based - IOT and others - Basic equipment - Oscilloscopes – Scanners - ECU hardware tester - Gateway tester, ETAS, HIL for diagnostic system, Scan tool interface - ECU Programming and the ODX standard, Initial and reprogramming of ECU - End of Line (EOL) features - Flash programming in vehicle line production - Diagnostic programming process of ECU supplier - Diagnostic updates (OTA)for the vehicle software - Workshop tester and Vehicle application for the diagnostic system testing with case studies examples (Renault, Nissan, Volvo etc.)		
Module:4	**Conventional Powertrain System Diagnostics**	**6 hours**
Diagnostics of Engine operation – Engine management system diagnostic system architecture (CI and SI engine, Gaseous fuels) – Engine fault diagnostic table - Fuel system - Misfire detection - Ignition and Oxygen sensors - After treatment related fault- Emission - Fuel Injection - Diesel injection - Engine management - Fault finding information - air supply and exhaust systems - cooling - lubrication - batteries - starting system - charging system		
Module:5	**Advanced Vehicle Systems Related Diagnostics**	**6 hours**
Diagnostic architecture of the Electric vehicle motor control – Maintenance - Fault diagnosis and repair/replacement - Power electronic related diagnostic system faults and remedies - Electric Vehicle Drive Train diagnostic standards and scan tool - BMS related faults - Battery pack and Charging system diagnostic characteristics and architecture of working - types of faults in EV powertrain - Certification and standards for EV powertrain diagnostics process - HEV related EMS diagnostics features - ADAS related diagnostic testing standards and protocols - fault codes identifications and rectification process - ADAS scan tools.		
Module:6	**Chassis System Diagnostics**	**6 hours**
Chassis system diagnostic (brake, steering and suspension, TPMS etc.) - fault codes and types of faults in chassis system - Basic equipment - Oscilloscopes - Scanners - Fault code readers - Other components - Diagnostics monitors perspective of ABS, ESP and TCS, Safety related (active and passive safety system) diagnostic protocols and types of fault codes and their remedies. Electronic components and circuits diagnosis - power distribution system faults - multiplexing - lighting - diagnosing auxiliary system faults - in car entertainment security and communication - body electrical system faults - diagnosing instruments cluster faults - HVAC diagnostics, steering control, wiper system diagnostics, Vehicle key system and immobilizer related diagnostics.		
Module:7	**Vehicle maintenance and service**	**6 hours**
Servicing and maintenance of engine: Dismantling of engine components: Conventional and gaseous fuel engines - cylinder head - valve train - cylinder block - connecting rod – piston and crankshaft assembly; cleaning and inspection of engine components - reconditioning of components - Servicing and maintenance of fuel system - Engine tune-up, cooling system: water pump, radiator, thermostat. Lubrication system maintenance, Anticorrosion and anti-freeze additives.		

Servicing and maintenance of Drive train system: clutch - gear box - transfer case - universal joints - CV joints - propeller shaft - final reduction -differential system, and rear axles. **Servicing and maintenance of chassis system:** Service and maintenance of brake – disc and drum brakes - front axle - steering systems - wheel alignment and suspension systems - Vehicle body maintenance - Steering system.		
Module:8	**Contemporary Issues**	**1 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	Tom Denton, “Advanced Automotive Fault Diagnosis: Automotive Technology: Vehicle Maintenance and Repair”, 5th Edition; September 2020, Routledge
2.	Asoro Osasumwen, “Automotive Computerized and Electrical Diagnostics Technology: The Use of Automotive Diagnostic Tools, Independently Published, ISBN:9798650645801, 2020
3.	Greg Banish, “OBD-I & OBD-II A Complete Guide to Diagnosis, Repair & Emissions Compliance, CarTech Incorporated Publishers, ISBN:9781613257524, 2023
Reference Books	
1.	Peter Subke, “Diagnostic Communication with Road-Vehicles and Non-Road Mobile Machinery”, ISBN:9780768002980, SAE International, 2019
2.	Marscholik C, Subke P. Road Vehicles: Diagnostic Communication: Technology and Applications. Laxmi Publications, Ltd.; 2009.
3.	James Halderman, “Automotive Technology: Principles, Diagnosis, and Service”, Pearson Automotive Series, 2019
4.	Bosch Automotive Handbook, 10th Edition, 2018.

Mode of Evaluation: Continuous Assessment Test, Digital Assignment, Quiz and Final Assessment Test

Recommended by Board of Studies	16-02-2024		
Approved by Academic Council	No. 73	Date	14-03-2024

Course Code	Curse Title	L	T	P	C
MSMO605L	Power Electronics and charging systems for Electric Vehicles	3	0	0	3

Pre-requisite	Nil	Syllabus version
		1.0

Course Objectives

1. To make the student understand the characteristics of power electronic devices.
2. To understand the working and applications of various converters in power electronics.
3. To understand the automotive application in power drives and its control.
4. To understand the various charging technologies in smart mobility.

Course Outcomes

1. Comprehensive knowledge on power electronic devices and their application.
2. Operation and performance analysis of different types of converters.
3. Apply the control concepts on electric drives.
4. Applications of EMI and EMC in power electronics devices.
5. Understand the charging technologies for electric vehicle batteries.
6. Advance charging concepts and energy management systems.

Module:1	Introduction to Power Electronic Devices	6 hours

Overview and Introduction to power electronic devices: PN diodes - BJTs – MOSFETs – IGBTs – SCRs - DIAC/TRIACs and GTOs - Forward and reverse characteristics – Switching characteristics and their applications - Failure mode and mitigation of power electronic devices for automotive applications.

Module:2	AC-DC Controlled Converters	6 hours

Single phase half and fully controlled converters: Performance analysis with R and RL load under continuous conduction mode - inverter mode operation - THD, input power factor - Concepts of PWM and phase-angle control - Effect of source impedance - Three-phase half and fully controlled converter - Performance analysis – THD - input power factor - Dual converters - Recent trends in Electric Powertrain for AC-DC converters.

Module:3	DC-DC Converters	6 hours

Buck - Boost and Buck-Boost DC-DC converters - design equations - TRC and CLC control strategies - multi-quadrant operation - Cuk, forward and fly-back converters - EMI/EMC issues - Soft-switching - zero-voltage switching (ZVS) and zero-current switching (ZCS) concepts - Quasi-resonant converters.

Module:4	Control of Electric Drives	8 hours

Introduction to electric drives - four quadrant operation of drives - single phase and three phase converter fed DC drives - Chopper fed DC drives -Braking and speed reversal – Closed-loop control of DC Drives - Induction motor drives - Synchronous motor drives – Stepper - and servo motor drives.

Module:5	EMI and EMC aspects of Power electronic devices	5 hours

Introduction and features of EMI and EMC in power electronic devices – Standards - and legislation application to power electronic devices in smart mobility - conducted emission - radiated emission and immunity for power electronic devices.		
Module:6	**Charging Technologies for electric vehicle batteries**	**6 hours**
Overview of electric vehicles and their charging requirements - Types of charging stations: AC charging - DC fast charging (Off board and on-board chargers) - Charging Infrastructure and charging connectors - Regulatory Framework and Standards (Global and Indian perspectives)		
Module:7	**Smart Charging and Energy Management**	**6 hours**
Wireless Charging Systems - Inductive and resonant wireless charging technologies - Benefits, challenges, and applications of wireless charging - High-Power Charging and Ultra-Fast Charging - Battery Swapping features and requirements - Battery Management system.		
Module:8	**Contemporary Issues**	**2 hours**
Analysis of HVDC Converter - Regenerative Braking Characteristics - Hub/In-wheel motors for EVs		
	Total Lecture hours:	**45 hours**

Text Book(s)

1.	Trzynadlowski, Andrzej M. Introduction to modern power electronics. John Wiley & Sons, 2015.
2.	Manias, Stefanos. Power electronics and motor drive systems. Academic Press, 2016.
3.	Kassakian, John G., David J. Perreault, George C. Verghese, and Martin F. Schlecht. Principles of power electronics. Cambridge University Press, 2023.

Reference Books

1.	Kazimierczuk, Marian K. Pulse-width modulated DC-DC power converters. John Wiley & Sons, 2015.
2.	Docherty, Iain, Greg Marsden, and Jillian Anable. "The governance of smart mobility." Transportation Research Part A: Policy and Practice 115 (2018): 114-125.
3.	Ali Emadi “Handbook of Automotive Power Electronics and Motor Drives” CRC Press 2017.

Mode of Evaluation: CAT / written assignment / Quiz / FAT / Project / Seminar / group discussion / field work (include only those that are relevant to the course. Use ‘,’ to separate the evaluations. Eg. CAT, Quiz and FAT

Recommended by Board of Studies	16-02-2024		
Approved by Academic Council	No. 73	Date	14-03-2024

Course Code	Course Title	L	T	P	C
MSMO606L	Vehicle Safety Engineering	3	0	0	3
Pre - requisite	Nil	Syllabus version			
		1.0			

Course Objectives

1. To broaden the understanding of crash testing regulations and legislations
2. To introduce different vehicle body design towards safety
3. To provide knowledge about active and passive safety systems
4. To enable the understanding of driver and occupant biomechanics
5. To acquire experience by carrying out virtual collision model simulation.

Course Outcomes

Upon Successful Completion of this course students will be able to

1. Develop a modern vehicle safety system to comply with testing and regulations.
2. Demonstrate the knowledge about safety and vehicle structural crashworthiness.
3. Understand the importance of human bio - mechanics in vehicle safety design.
4. Analyze the performance of active and passive safety systems.
5. Analyze and suggest suitable collision models for vehicle safety.
6. Solve the barriers for autonomous vehicle

Module:1	Safety Testing and Legislation	5 hours

Need of the safety aspects in vehicle design and development - Necessity behind the safety testing and legislation (FMVSS, etc.) - Types of safety systems - New Car Assessment Program – Procedure - rules and regulations - rating methods; Crash test – frontal impact - rear impact - side impact - and Impact with rebound - movable barrier tests; Roll over crash tests - Behavior of specific body structures in crash testing - Photographic analysis of impact tests - Pedestrian Impact - Crash test dummies

Module:2	Vehicle body design towards safety	6 hours

Design of the body for safety - energy equation - powertrain component's location (engine - motor - battery pack - etc.) - deceleration of vehicle inside passenger compartment - deceleration on impact with stationary and movable obstacle - Exterior safety - interior safety - deformation behavior of vehicle body - Balance of stiffness and toughness characteristics and energy absorption characteristics of vehicle structures - concept of crumple zone - safety sandwich construction - Optimization of vehicle structures for crash worthiness.

Module:3	Biomechanics and Occupant safety	5 hours

Biomechanics - Human impact tolerance - Injury tolerance limits - Severity Index - Study of comparative tolerance - - Application of Trauma for analysis of crash injuries - External injuries - Internal injuries – Concussion - Spinal and Chest injuries - Occupant protection – Head - Chest Neck - Pelvic - Leg and Knee - Pedestrian protection - Criteria for Injury in safety aspects - Importance of Ergonomics in Automotive safety - Locations of controls – Driver seat design.

Module:4	Passive Safety System	7 hours

Survival space requirements - restraints systems - Seat belts – retractor - pre - tensioner - load limiter; Head restraints; Air bags – types - working sequence - activation sensors; Impact protection from steering controls - Design of seats for

safety - types of seats used in automobiles. Bumpers - Use of energy absorbing systems - crash box - damageability criteria in bumper designs - Hinges - latches - central locking - etc.		
Module:5	**Active Safety System**	**8 hours**
Advanced driver assistance systems – Anti - lock braking system - Traction control system - electronic stability program - electronic brake force distribution - Adaptive cruise control - Lane change warning system - Collision warning/ Avoidance system - Tire pressure warning system; Object detection – Challenges - types and requirements - Safety glass - Types and their requirements - Types of rear - view mirrors and their assessment – rearview and side mirror - visibility - Safety assist technology (Seat belt - tire pressure - etc.).		
Module:6	**Vehicle Collision Models**	**6 hours**
Impulsive models - Perfect plastic impact - Perfect elastic impact - Co - efficient of restitution - Central Collision - central head on collision - oblique collision - collision against fixed obstacle - Non central Collision - non - central head on offset collision - Kelvin's theorem - Application of relative motion - Change in vehicle speeds - Total crush energy - Vehicle individual crush energies - Crash severity assessment. Problems involving vehicle collisions.		
Module:7	**Computer support for development of Safety systems**	**6 hours**
Numerical tools – Basics - Component level testing and analysis; Total vehicle crash computation – Dynamic vehicle simulation tests – Frontal collision - Lateral collision - Rear end collision and Roll over - Occupant and restraint system simulation – Seats - seat belt - air bag - head restraint - ADAS system performance improvement through simulation.		
Module:8	**Contemporary Issues**	**2 hours**
Autonomous vehicle and its safety challenges, Industry Expert Lecture on HCV Crash and Traffic Safety		
	Total Lecture hours:	**45 hours**

Text Book(s)

1. Mark Gonter - Ulrich W. Seiffert - "Integrated Automotive Safety Handbook" - SAE International - ISBN of 978 - 0 - 7680 - 6437 - 7 - 2013
2. Ulrich Seiffert - Lothar Wech - "Automotive Safety Handbook" - SAE ISBN 978 - 0 - 7680 - 1798 - 4 - SAE International - 2007
3. Narauan Yoganandan - Alan M. Nahum - John W. Melvin - "Accidental Injury Biomechanics and Prevention - Third Edition - Springer - 2015.

Reference Books

1. Johnson - W. - Mamalis - A.G. - "Crashworthiness of Vehicles" - MEP - London - 1995
2. Paul Du Bois - Clifford C. Chou - Bahig B. Fileta - Tawfik B. Khalil - Albert I. King - Hikmat F. Mahmood - Harold J. Mertz and Jac Wismans - "Vehicle crashworthiness and occupant protection" - American iron and steel institute - 2004.
3. Jorge A.C.Ambrosio - "Crashworthiness Energy Management and Occupant Protection" - International Centre for Mechanical Sciences - Springer Wien

	- 2001 George A. Peters - Barbara J. Peters - “Automotive vehicle safety” - Taylor and francis - London - ISBN 0–415–26333–6 - 2003

Mode of Evaluation: CAT / written assignment / Quiz / FAT / Project / Seminar			
Recommended by Board of Studies	16-02-2024		
Approved by Academic Council	No. 73	Date	14-03-2024

Course Code	Course Title	L	T	P	C
MSMO607L	Intelligent Transportation Systems	3	0	0	3
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

1. Understand ITS Fundamentals
2. Explore ITS Applications and Solutions
3. Analyze ITS Challenges and Future Trends
4. Understand the future technologies related to ITS

Course Outcomes

1. Demonstrate a strong understanding of core ITS concepts and principles.
2. Apply ITS knowledge to address real-world transportation challenges effectively.
3. Stay informed about emerging trends and innovations in the field of Intelligent Transportation Systems.
4. Demonstrate a strong foundation in the wireless communication standards related to ITS technology.
5. Demonstrate a strong knowledge in the sensor and AI technologies supporting ITS and the application of autonomous vehicles.

Module:1	Basics of ITS	6 hours

Introduction to Intelligent Transportation Systems (ITS) -Definition – Role and Responsibilities - Historical development and Evolution of ITS - Component and Technologies in ITS - ITS stakeholders and their roles and Key ITS terminologies.

Module:2	Challenges and opportunities in ITS	6 hours

Traffic congestion and environmental issues - Safety and security concerns - Economic and societal benefits of ITS - Emerging trends and prospects - Case studies on successful ITS implementations

Module:3	Systems engineering in ITS and ITS architecture	6 hours

ITS Standards and Architecture - ITS Communication Systems - ITS System Integration - ITS and Security - ITS Policy Issues - ITS project development life cycle - Architectural frameworks (e.g. - C2C-CC - C-ITS) - Case studies on ITS architecture design.

Module:4	ITS applications	6 hours

Integration of ITS with autonomous vehicles - Autonomous vehicle technologies and levels of automation - ITS applications for autonomous vehicle navigation - Advanced Traveler Information System - Fleet Oriented ITS Services - Electronic Toll Collection - Automatic Vehicle Location (AVL) - Automatic Vehicle - Identification (AVI) - Case studies on autonomous vehicle-ITS integration.

Module:5	Connected and autonomous vehicles (C&AV)	6 hours

Introduction to Cooperative Vehicle Communications - Introduction to DSRC - Introduction to Cellular based Vehicle to Everything (C-V2X) Communications - Communication Standards - Different types of C-V2X – V2V - V2I - V2N - V2P. General Architecture of connected V2X system as per cellular standards - Applications of C-V2X - Introduction and importance of QoS - Automotive surrounding sensing with GHz and THz signals. Introduction to Adaptive Traffic Control Systems and their technologies.

Module:6	**Supporting ITS Technologies**	**6 hours**
Sensor technologies (LiDAR - RADAR - cameras) - Communication protocols (DSRC - 5G - Wi-Fi) - Data analytics and machine learning in ITS - Integration of supporting technologies with ITS.		
Module:7	**ITS standards and specifications**	**7 hours**
Overview of international ITS standards (e.g. - 3GPP - ETSI - C2C - IEEE - SAE - ISO) - C-V2X architectural frameworks with regards to 3GPP and ETSI - IT'S in regulatory frameworks.		
Module:8	**Contemporary Issues**	**2 hours**
Expert Industry Lecture / Case Study		
	Total Lecture hours:	**45 hours**

Text Book(s)

1. Shanzhi Chen - Jinling Hu - Li Zhao - Rui Zhao - Jiayi Fang and Yan Shi and Hui Xu - " Cellular Vehicle to everything Communications (C-V2X)" - Springer Nature - Singapore - 2023.
2. Yu - Huafeng - Xin Li - Richard M. Murray - S. Ramesh - and Claire J. Tomlin - eds. Safe - autonomous and intelligent vehicles. Springer - 2018.
3. Dimitrakopoulos - George J. - Lorna Uden - and Iraklis Varlamis. The future of intelligent transport systems. Elsevier - 2020.

Reference Book

1. Garg - Sahil - Gagangeet Singh Aujla - Kuljeet Kaur - and Syed Hassan Ahmed Shah - eds. Intelligent cyber-physical systems for autonomous transportation. Springer - 2022.
2. Bazzan - Ana LC - and Franziska Klügl. Introduction to intelligent systems in traffic and transportation. Springer Nature - 2022.
3. Mouftah - Hussein T. - Melike Erol-Kantarci - and Sameh Sorour - eds. Connected and Autonomous Vehicles in Smart Cities. CRC Press - 2020.
4. Robert Gordon - "Intelligent Transportation Systems" - Springer International Publishing - 2016.

Mode of Evaluation: CAT - Written assignment - Quiz - FAT - Project - Seminar

Recommended by Board of Studies	16-02-2024		
Approved by Academic Council	No. 73	Date	14-03-2024

Course Code	Course Title	L	T	P	C
MSMO608L	Noise, Vibration and Harshness	3	0	0	3
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

1. To help the students to understand the different sources of vibration & noise from ICV, HEV, ReEV, PHEV, and EV automobiles, including power train, driveline, HEV engine start/stop behavior, and influence of electric machines.
2. To enable the students to identify the role of NVH engineers in determining the quality of noise and vibration in development stages of a new vehicle.
3. To impart knowledge on advance NVH control technologies.

Course Outcomes

1. Understand the fundamentals of vibration and sound.
2. Identify sources of sound and vibration during transient and steady state conditions.
3. Familiarize with various sound and vibration measurement techniques.
4. Compute sampling, statistical, and frequency analysis of various data obtained from sound and vibration measurements.
5. Outline the role of different instrumentations for analyzing the automotive NVH.
6. Possess the knowledge of NVH engineers in a new vehicle development program.

Module:1	Fundamental of Automotive NVH	6 hours

Basics of NVH study- Regulation and terminologies- Narrow band and octave band types- difference between dBA and dB- Basics of order of vibration- frequency domain function- FFT features- Basics of natural frequency and resonance- Automobiles Noise pollution - Engine Noise- Basics of Engine balancing based on vibration source (inertia- combustion- unbalanced force)- Engine mounts and its types- dampers- Transmission Noise- Vehicle structural Noise- Aerodynamics noise- Exhaust Noise- NVH of HEV and EV- Harshness effect- measurement- and solutions - Measure of Vehicle Ride Comfort- Noise sources- Pass-by noise limits- Interior noise of vehicles- Sound quality.

Module:2	Sound sources Identification in HEV and EV	7 hours

Noise quality- Acoustic parameters and its features- Pass-by noise requirements and regulations- contribution from various sources- Target vehicles and objective targets- Component-specific noise- motor/generator whine- Accessory noise- gear rattle/reducer- and noise pattern Changes- Noise induced asynchronous or synchronous motor- gear- and inverter- Vehicle Interior power train noise- wind noise- and road noise in the vehicle's interior.

Module:3	Identification of vibration sources in HEV & EV	7 hours

Sources of vibration in automotive- Transient- and steady-state response of one degree of freedom system applied to vehicle systems- Introduction to PSD- Transmissibility- Magnification factor- Powertrain vibration (BLDC- SRM- Induction and PMSM)- driveline vibration- HEV engine start/stop behavior- influence of electric

machines on power plant integration issues- Performance of accessories- NVH problems from steering pump- vacuum pump- and AC compressor		
Module:4	**Human Scale and Weighting factors**	**6 hours**
ISO standards- Whole-Body Vibration analysis- Human sensitivity and weighting factors related to NVH		
Module:5	**Test Facilities and Instrumentation**	**7 hours**
NVH simulations- noise and vibration measurement on rolling roads- road simulators- semi-anechoic rooms- wind tunnels- etc- Transducers- signal conditioning and recording systems- Binaural head recordings- Sound Intensity technique- Acoustic Holography- Statistical Energy Analysis- near and far fields measurement		
Module:6	**Signal Processing and analysis**	**5hours**
Sampling- aliasing and resolution. Statistical analysis. Frequency analysis. Campbell's plots- cascade diagrams- coherence and correlation functions		
Module:7	**Advance NVH control technologies**	**5 hours**
Combining sound sources- Acoustical resonances- Properties of acoustic materials- Semi-active and active mount - Source ranking- Noise path analysis- Noise reduction in Automobiles- Vibration control methods- Design of Experiments- Optimization of Dynamic characteristics- Passive and Active control techniques- Vehicle noise refinement techniques		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)

1.	Automotive NVH Technology, springer Publisher, 2016. Editors: Anton Fuchs, EugeniusNijman, Hans-HerwigPriebsch.
2.	James E. Duffy, Modern Automotive Technology, Goodheart-Willcox Pub, 2013

Reference Books

1.	M. L. Munjal, 2014, Noise and Vibration Control, World Scientific Press: Singapore.
2.	TrelleborgVibracoustics, Automotive Vibration Control Technology Fundamentals, Materials, Construction, Simulation, and Applications. Vogel Communications Group GmbH & Company KG, 2015.

Mode of Evaluation: CAT / written assignment / Quiz / FAT / Project / Seminar / group discussion / field work (include only those that are relevant to the course. Use ‘,’ to separate the evaluations. Eg. CAT, Quiz and FAT

Recommended by Board of Studies	16-02-2024		
Approved by Academic Council	No. 73	Date	14-03-2024

Course Code	Course Title	L	T	P	C
MSMO608P	Noise Vibration and Harshness Lab	0	0	2	1
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

1. To introduce the computational and instrumentation to measure NVH.
2. To assist the students to learn instrumentation for acquiring vibration and sound.

Course Outcomes

1. Simulate the condition and analyze using MATLAB and related tools.
2. Compute sampling, frequency analysis of various data obtained from sound and vibration measurements.
3. Able to estimate the interior and exterior vehicle noises.
4. Familiarize with various sound and vibration measurement techniques.

Indicative Experiments

1.	EV/HEV NVH Simple simulations (Ex: Simcenter 3D / MATLAB).	**3 hours**
2.	Electric vehicle sound quality measurement.	**3 hours**
3.	Drive train vibration response analysis.	**4 hours**
4.	Interior noise measurement.	**4 hours**
5.	Radiated noise measurement.	**4 hours**
6.	Structural vibration measurement.	**4 hours**
7.	Automotive EV/HEV chassis vibration measurement.	**4 hours**
8.	Whole vehicle NVH performance analysis.	**4 hours**
	Total Laboratory Hours	**30 hours**

Text Book(s)

1. Automotive NVH Technology, springer Publisher, 2016. Editors: Anton Fuchs, Eugenius Nijman, Hans-Herwig Priebsch.

Reference Books

1. Trelleborg Vibracoustics, Automotive Vibration Control Technology Fundamentals, Materials, Construction, Simulation, and Applications. Vogel Communications Group GmbH & Company KG, 2015.

Mode of assessment: Continuous assessment / FAT / Oral examination and others

Recommended by Board of Studies	16-02-2024		
Approved by Academic Council	No. 73	Date	14-03-2024

Course Code	Course Title	L	T	P	C
MSMO609L	Hydrogen Energy for Smart Mobility	3	0	0	3
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

1. To familiarize with the fundamentals of hydrogen as an energy source for smart mobility applications
2. To study in detail on the hydrogen production methodologies
3. To understand the working principle of a hydrogen storage, its types and to elaborate on its thermodynamics.
4. To know the essential material for the hydrogen economy and safety aspects in hydrogen handling

Course Outcomes

1. Analyze the details of hydrogen energy sources for mobility and hydrogen production technology.
2. Understand the various aspects of the hydrogen storage system and its features.
3. Identify the hydrogen safety and supply system for eco-friendliness of hydrogen usage.
4. Understand the characteristic features of electrochemical energy conversion techniques.
5. Recognize the different specific developments on hydrogen in integrated transport systems.
6. Ability to understand the life cycle assessment of hydrogen energy in smart mobility applications.

Module:1	Introduction and Overview	6 hours

Fundamentals - terminology - history of hydrogen technology -General overview: Advantages - current situation of technology and challenges - Hydrogen – physical and chemical properties - salient characteristics - Hydrogen Energy as Future of Sustainable and Smart Mobility

Module:2	Hydrogen production methods	6 hours

Production of hydrogen– steam reforming – water electrolysis– gasification and woody biomass conversion – biological hydrogen production – photodissociation– direct thermal or catalytic splitting of water - Green Hydrogen - and types of electrolyzer - status - advantages and challenges

Module:3	Hydrogen Storage	6 hours

Fundamentals and thermodynamics of hydrogen storage - Hydrogen storage options – compressed gas – liquid hydrogen – hydrides metal hydrides - types of metal hydrides – chemical Storage – comparisons. Hydrogen liquefaction - liquid state hydrogen storage tanks - fundamentals of hydrogen storage in adsorption-based materials

Module:4	Hydrogen Safety and Supply System	6 hours

Hydrogen dispensing and supply system - Hydrogen supply chain network design and hydrogen fueling station - Classification of hydrogen hazards - regulation - codes - and standards - Hydrogen Sensors - and Flame arrestors

Module:5	Electrochemical Energy Conversion	7 hours

History–principle-working-thermodynamics and kinetics of fuel cell process–performance evaluation of fuel cell - electrochemical energy transformation - comparison on battery vs. fuel cell - Types of fuel cells–relative merits and demerits		
Module:6	**Hydrogen in integrated transport system**	**7 hours**
Design of integrated hydrogen energy systems - Hydrogen for smart mobility applications & vehicle fitments (Case studies) - Engineering aspects of the development of hybrid systems (batteries, supercapacitors, and fuel cells).		
Module:7	**Life-cycle assessment of hydrogen**	**6 hours**
Life cycle analysis - Sustainable applications - global status - Future and present functions in the energy system in the transport sector.		
Module:8	**Contemporary Issues**	**1 hours**
Hydrogen economy & Global market opportunities (current market and future targets)		
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	I Dincer - C Zamfirescu - Sustainable Hydrogen Production - Elsevier - 2017.
2.	I Dincer - H Ishaq - Renewable Hydrogen Production - Elsevier - 2021.
Reference Books	
1.	Rebecca L. and Busby - Hydrogen and Fuel Cells: A Comprehensive Guide - Penn Well Corporation - Oklahoma - 2005.
2.	B Sorensen - G Spazzafumo - Hydrogen and Fuel Cells: Emerging Technologies and Applications - 3rd Edition - Academic Press - 2018.

Mode of Evaluation: CAT - written assignment - Quiz - FAT - Seminar			
Recommended by Board of Studies	16-02-2024		
Approved by Academic Council	No. 73	Date	14-03-2024

Course Code	Course Title	L	T	P	C
MSMO610L	Automotive Transmission System	3	0	0	3
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

1. To help students gain knowledge about different vehicle transmission systems.
2. To enable the students to understand different energy conversions techniques.
3. To develop skills in design, Control, and maintenance of transmission components

Course Outcomes

Students will be able to

1. Describe the working of manual, automatic and semi-automatic transmission systems.
2. Estimate the transmission system efficiency and arrive at power saving opportunities.
3. Assess the transmission systems required for the any given vehicle.
4. Identify and select a suitable clutch and design of the gearbox for any given vehicle.
5. Possess the knowledge of various special purpose vehicle transmission systems.
6. Understand the latest technology in transmission systems, including hybrid electric vehicles

Module:1	Overview of Vehicle Transmission Systems	5 hours

Introduction vehicle transmission system (according to different types of vehicles - driving conditions - etc) - Various Resistances to Motion of the Automobile- Rolling - Air and Gradient resistance - Traction - tractive effort - Performance curves - acceleration grade ability - drawbar pull.

Module:2	Clutches and Conventional Gear box	8 hours

Requirements and design aspects of clutch design - Clutch – Need and types – Dry and Wet - Pendulum mass - types clutch engagement mechanism - Fluid coupling – Necessity of gear box - Manual transmission for light and heavy-duty vehicles - (3-speed & 4-speed gear boxes - multi speed gearbox - etc) - Constructional details of Manual gear box - Clutch master cylinder (CMC) and CSC (slave and Master) - Types of gear shifting - overdrive - Reducer and its requirements - Thermal Management and lubrication of Gear Box.

Module:3	Automatic and Semi-automatic transmission systems	6 hours

Relative merits and demerits when compared to conventional transmission – epicyclic and its characteristic feature – continuously variable transmission (CVT) - Semi-automatic transmission - dual clutch transmission (DCT) and DSG – automated manual transmission (AMT) - Transmission with automatic park lock - Automatic transmission system control units and its internal control system architecture - Principal of torque conversion - single - multistage and polyphase torque converters - performance characteristics - constructional and operational details of typical hydraulic transmission drives - Vibration isolation in the aspects of the transmission systems in vehicles.

Module:4	Driveline systems	6 hours

Introduction to final driveline system for conventional powertrain vehicles - Effects of driving thrust and torque reaction - Hotchkiss drive - Torque tube drive - radius rods - Propeller shaft - Universal joints - Transfer case and four-wheel drive

transmission system - Final drives – different types - double reaction final drive - Two speed rear axle - Rear axle construction – full floating - three quarter floating and semi-floating arrangements - Differential – conventional type - non-slip type - Differential locks -		
Module:5	**Electric vehicle transmission**	**6 hours**
Electric propulsion systems; block diagram of EV propulsion system; single motor and multi-motor configurations; Reducer types (single - twin speed with seamless gear shifting - etc) and its features - Effect of multi speed transmission system in EV motors and its advancements - In wheel motor configuration; EV motors types and the transmission requirements for the types in vehicle categories - fixed & variable geared transmission; Motor speed ratio and transmission matching - Torque- speed characteristics of EV motors -		
Module:6	**Hybrid vehicle transmission**	**7 hours**
Hybrid Electric vehicles - Design requirement of transmission system in HEV - Different schemes of power transfer in HEV (single - two motors - etc) and its features - Methods for power distribution to wheels in HEV (series - parallel - combined - and complex hybrid) and their design features - Propulsion systems and components - Regenerative Braking requirements in the aspects of transmission system - Hybrid Electric Vehicles System – Torque-Power analysis and its controls - Torque-Power splitter - Hybrid vehicle transmission control system architecture and working -		
Module:7	**Special transmission systems**	**5 hours**
Janney Hydrostatic drive - Hydromatic transmission — Paddle shift gear box - Intelligent variable transmission (IVT) – Tip-tronic transmission- Ward leonard control system for electric drive - principles of Ward Leonard system of control Modern electric drive for buses and performance characteristics - Janney Hydrostatic drive - Electrical drives: advantages and limitations - Modern transmission fluids -		
Module:8	**Contemporary Issues**	**2 hours**
Transmission failure and its impact on vehicle performance and handling - Diagnostic methods for transmission system		
	Total Lecture hours:	**45 hours**

Text Book(s)	
1 -	Harald Naunheimer - Bernd Bertsche - Joachim Ryborz - Wolfgang Novak - Automotive transmission - Fundamentals - Selection - Design and Application - 2011- Springer - ISBN 978-3-642-16213-8 -
Reference Books	
1 -	Robert Fischer - Ferit Küçükay - Gunter Jürgens - Rolf Najork - Burkhard Pollak - The Automotive Transmission Book - 2015 - Springer - ISBN : 978-3-319-05262-5 -
2 -	Yong chen - Automotive Transmissions - Design - Theory and Applications - 2021 - Springer - ISBN: 978-981-15-6702-5 -

Mode of Evaluation: CAT - written assignment - Quiz - FAT - Project - Seminar			
Recommended by Board of Studies	16-02-2024		
Approved by Academic Council	No. 73	Date	14-03-2024

Course Code	Course Title	L	T	P	C
MSMO611L	Thermal Management System for Electric Vehicles	3	0	0	3

Pre-requisite	Nil	Syllabus version
		1.0

Course Objectives

1. To broaden the understanding of students in the system requirements and design aspects of thermal management systems in electric vehicles.
2. To introduce students to the thermal management of electric motors, power electronics, interior space, and batteries.
3. To introduce students to the different sensors adopted in thermal management.
4. To make the students explore the different modelling approaches of thermal management in electric vehicles.

Course Outcomes

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

1. Understand the basic requirements and design aspects of thermal management systems in electric vehicles.
2. Analyze the performance of different thermal management systems.
3. Discuss the different thermal management systems for electric motors, power electronics and internal space.
4. Select a suitable battery thermal management system for an intended application.
5. Identify suitable sensors for implementation at different locations of an electric vehicle.
6. Get familiar with different modelling approaches of thermal management in electric vehicles.

Module:1	System Requirements and Design Aspects	7 hours

Introduction to thermal management- motivation and need in EVs- heat sources-sinks and thermal balance- design aspects of thermal management systems- exemplary design calculations- technologies in comparison- operational aspects- convective heat transfer- flow and pressure drop calculations through various channels and pipes- different cooling circuits and their architecture for electric vehicles.

Module:2	Thermal Management of Electric Motor	7 hours

Impact of temperature on motor performance (AC and DC) - heat generation in electric motor and associated components- passive thermal design- active convective cooling- stator cooling- different types of cooling systems for motors: direct- indirect- air- liquid- oil-jet cooling- winding cooling: slot wind cooling- end wind cooling- desirable coolants for electric motors with hierarchical properties- case study on a CFD based motor thermal management.

Module:3	Thermal Management of Power Electronics	5 hours

Need and requirements of thermal management in power electronic components- Impact of thermal aspects on the performance of power electronics - cooling

techniques for on-board charger- converters and power inverter- different fin configurations adopted in power electronics and their characteristics- heat pipe- cold plate- heat spreaders for electronic cards- card to chassis interface- thermal interface materials		
Module:4	**Thermal Management of Interior Space In EV**	**6 hours**
Importance of cabin climatic control- HVAC - circuits- components- architecture- performance assessment with different refrigerants- future prospects- thermal comfort- cabin cooling- air conditioning types- refrigerants- energy efficiency comparison- alternative cooling systems- need and performance of heat pumps in EV- types and architecture of cabin heating- standards applicable towards cabin thermal management in EV- energy consumption during heating mode- energy consumption during cooling mode- cabin preconditioning- state of art technologies in cabin thermal management.		
Module:5	**Battery Thermal Management Systems**	**7 hours**
Need of battery thermal management- battery heat generation and its estimation- flow calculations for heat removal with different fluids- pressure drop calculation in cooling circuit- types of heat transfer in battery pack- battery cooling and heating- battery thermal runaway and its impact of vehicle driving range- thermal derating- sizing of cooling system- battery cooling during fast charging process and its impact- benchmarking of the different BTMS in the market (specification- parameters- range- etc.)- battery thermal standards and its features- Primary considerations in battery cooling for different Lithium battery chemistries- case study on CFD based BTMS.		
Module:6	**Types of Battery Cooling in EV**	**7 hours**
Types of Battery Cooling: Constructional details of air based thermal management- liquid-based thermal management- PCM based thermal management system- refrigerant cooling- immersive cooling- hybrid (combinational) thermal management system- relative merits and demerits- role of electronic controller in battery thermal management- battery cooling plates and their configuration- types of heaters in BTMS- types of cooling circuits for BTMS based on vehicle and battery types- battery cooling components - working and architecture- e-water pumps- radiators- chillers- blowers- solenoid valves.		
Module:7	**Modeling of Thermal Management Systems**	**4 hours**
Numerical model development for cell and submodules- electro thermal coupling modeling of Li-ion batteries- modeling and optimization of air cooling- modeling and optimization of liquid cooling- modeling of external and internal heating technologies for Li-ion batteries based on sinusoidal alternating current- Types of BTMS for the different classes of vehicles- cabin thermal management and powertrain management for different types of the vehicles.		
Module:8	**Contemporary Issues**	**2 hours**
Recent technological progress in battery thermal management of electric vehicles		
	Total Lecture hours:	**45 hours**
Text Book(s)		
1.	Ibrahim Dinçer- Halil S. Hamut- Nader Javani- “Thermal Management of Electric Vehicle Battery Systems”- Wiley Publishers- 2017	

2.	Marc A Rosen- Aida Farsi- “Battery Technology: From Fundamentals to Thermal Behavior and Management”- ISBN:9780443188633- Elsevier Science- 2023
3.	Shichun Yang- Xinhua Liu- Shen Li- Cheng Zhang- “Advanced Battery Management System for Electric Vehicles”- Springer Nature Publishers- 2023
Reference Books	
1.	Junqiu Li- “Modeling and Simulation of Lithium-ion Power Battery Thermal Management”- Springer Nature Singapore- 2022
2.	Ehsani- M.- Gao- Y.- Longo- S.- & Ebrahimi- K. M. “Modern electric- hybrid electric- and fuel cell vehicles”- CRC press- 2018
3.	Fethi Aloui- Ankit Sonthalia- Edwin Geo Varuvel- “Handbook of Thermal Management Systems: E-Mobility and Other Energy Applications”- Elsevier Science- 2023
4.	Jing Liu- “Advanced Liquid Metal Cooling For Chip- Device and System”- World Scientific Publishing Company- 2022
Mode of Evaluation: Continuous Assessment Test- Digital Assignment- Quiz and Final Assessment Test	

Recommended by Board of Studies	16-02-2024		
Approved by Academic Council	No. 73	Date	14-03-2024

Course Code	Course Title	L	T	P	C
MSMO612L	Networks and Communications for Smart Mobility	3	0	0	3

Pre-requisite	Nil	Syllabus version
		1.0

Course Objectives

1. To attain comprehensive overview of connected vehicles.
2. To understand intra and inter vehicle communication.
3. Acquiring knowledge on Vanet.
4. Able to tackle current problems in connected vehicle technology

Course Outcomes

1. Understand the fundaments of connected vehicles.
2. Comprehend intra and inter vehicle network.
3. Network architecture for connected vehicles.
4. Understand VANET networking.
5. Application of V2V and V2I.
1. 6. Security and privacy of vehicle network.

Module:1	**Introduction to Connected Vehicles**	**4 hours**
Basics of cyber physical system- Architecture of connected cars. Vehicle sensor with on-board platform.		
Module:2	**Intra and Inter vehicle network**	**7 hours**
Topology of LIN- CAN- Flex ray- WIFI and GPS- Automotive Ethernet- GPRS and 5G application for automotive systems communications- SOME-IP and DO-IP		
Module:3	**Network architectures**	**6 hours**
Overview of the Architecture- channel models- properties of vehicle to vehicle and vehicle to infrastructure communication- performance of 802.11 in V2X.		
Module:4	**VANET**	**6 hours**
Vehicular AD hoc network operations- single-hop broadcasting and multi-hop broadcasting- mobile IP solution in VANET.		
Module:5	**V2V application**	**7 hours**
Emergency vehicle approach, Blind spot lane change warning, Rear end collision warning, Emergency brake light and Intersection movement assist.		
Module:6	**V2I application**	**7 hours**
Traffic information system- Curve speed warning system- work zone warning system- weather impact warning system and Platoon detection.		
Module:7	**Cyber security Risk management and Standards**	**6 hours**
Secure Vehicular Communication Architecture- Secure and Privacy-enhancing Vehicular Communication- Data Trustworthiness- Future challenges. SECOC for CAN protocol- MACSEC and TLS for Ethernet.		
Module:8	**Contemporary Issues**	**2 hours**
Multi-Radio interfaces – Software Re-configurability for hardware update.		
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	Christoph Sommer, Falko Dressler, Vehicular Networking, Cambridge University Press, 2015.
2.	Markus Meuck, Ingolf Karls, Networking Vehicles to Everything ,DE Gruyter press, 2018
3.	Dominique Paret, Hassina Rebaine “Autonomous and Connected Vehicles Network Architectures from Legacy Networks to Automotive Ethernet” 2022 Wiley

Reference Books	
1.	Peter Han Joo Chong “Vehicular Networks Applications, Performance Analysis and Challenges”, 2019, Nova Science Publishers.
2.	Guojun Wang, Md Tabrez Nafis, Muhammad Arif, Mazin Abed Mohammed “Vehicular Ad Hoc Networks Futuristic Technologies for Interactive Modelling, Dimensioning, and Optimization” 2022, CRC Press
3.	Jiajia Liu, Abderrahim Benslimane ·”Intelligent and Connected Vehicle Security”, 2022 River Publishers.

Mode of Evaluation: CAT / written assignment / Quiz / FAT / Project / Seminar / group discussion / field work (include only those that are relevant to the course. Use ‘,’ to separate the evaluations. Eg. CAT, Quiz and FAT			
Recommended by Board of Studies	16-02-2024		
Approved by Academic Council	No. 73	Date	14-03-2024

Course Code	Course Title	L	T	P	C
MSMO613L	Smart Convergent Technologies	3	0	0	3
Pre-requisite	Nil	Syllabus Version			
		1.0			

Course Objectives

1. Develop a comprehensive understanding of the Internet of Things (IoT) ecosystem, including its components, communication protocols, and data management, to enable the design and implementation of IoT solutions.
2. Explore wireless communication protocols and technologies crucial for IoT connectivity, such as Wi-Fi, Bluetooth, and cellular networks, and learn how to select and optimize them for specific IoT applications.
3. Explore the advanced and emerging technologies in the avenue of Smart Convergent Technologies
4. Gain proficiency in integrating cloud computing services into IoT solutions, enabling data storage, processing, and analysis for scalable and efficient smart convergence technologies.

Course Outcomes

1. Demonstrate the ability to design, implement, and manage IoT solutions, including sensor integration, data transmission, and remote monitoring, for various applications.
2. Showcase the capability to select and configure wireless communication protocols effectively, ensuring reliable connectivity and data transfer in diverse IoT scenarios.
3. Successfully apply cloud computing techniques to create and manage smart convergence technologies, allowing for scalable and data-driven solutions that leverage the power of cloud resources.
4. Strong understanding of the embedded algorithms for the applications of IoT.
5. Demonstrate a good understanding of the Edge and Cloud based computing technologies.

Module:1	Introduction towards IoT Universe for Smart Mobility	7 hours

Introduction to IoT – IoT definition – Characteristics – IoT Complete Architectural Stack – IoT enabling Technologies – IoT Challenges. Sensors and Hardware for IoT – Hardware Platforms – Arduino, Raspberry Pi, and Node MCU - A Case study with any one of the boards and data acquisition from sensors, Data visualization and its features.

Module:2	IoT Architecture	6 hours

IoT reference model and architecture -Node Structure - Sensing, Processing, Communication, Powering, Networking - Topologies, Layer/Stack architecture**,** IoT standards, Cloud computing for IoT, Bluetooth, Bluetooth Low Energy beacons.

Module:3	Protocols for IoT used in Smart Mobility	6 hours

NFC- Matter and RFID- Zigbee MIPI- M-PHY- UniPro- SPMI- SPI- M-PCIe GSM-CDMA- LTE- GPRS- small cell- **Wireless technologies for IoT:** WiFi (IEEE 802-11)- Bluetooth/Bluetooth Smart- ZigBee/ZigBee Smart- UWB (IEEE 802-15-4)- 6LoWPAN- Proprietary Systems-Recent trends

Module:4	Introduction to Industrial IoT (IIoT) towards Smart Mobility	6 hours

Key IIoT Technologies- SCADA- OPC and OPCUA- IIoT Applications- IP Mobility- Network Virtualization- SDN (Software Defined Networks)- Introduction towards

Cloud and Fog Computing- Introduction towards Edge Computing- Architectures of Cloud- Fog- and Edge Computing- Industry 4.0 and future prospects.		
Module:5	**Cloud Computing Introduction**	**6 hours**
Introduction to Cloud Computing - Service Model – Deployment Model- Virtualization Concepts – Cloud Platforms – Amazon AWS, Green Grass – Microsoft Azure – Google APIs.		
Module:6	**Cloud Computing application in Smart Mobility**	**6 hours**
IoT and the Cloud - Role of Cloud Computing in IoT - AWS Components - S3 – Lambda - AWS IoT Core -Connecting a web application to AWS IoT using MQTT- AWS IoT Examples. Security Concerns, Risk Issues, and Legal Aspects of Cloud Computing- Cloud Data Security		
Module:7	**Vehicle Application of IoT and Cloud Computing**	**7 hours**
Smart mobile apps for vehicle control- Fundamental concepts of 5G and Next Generation networks- Vehicle-to-Infrastructure (V2I) and Vehicle-to-Vehicle (V2V) communications- home automation- Fleet management- Telematics- On-board diagnostics- predictive maintenance.		
Module:8	**Contemporary Issues**	**1 hours**
Expert Industry Lecture on recent advancements		
	Total Lecture hours:	**45 hours**

Text Book(s)

1.	Mahmood- Md Rashid- Rohit Raja- Harpreet Kaur- Sandeep Kumar- and Kapil Kumar Nagwanshi- eds. Ambient Intelligence and Internet of Things: Convergent Technologies. John Wiley & Sons- 2022.
2.	Mahalle- Parikshit N.- Gitanjali Rahul Shinde- and Arvind Vinayak Deshpande. The convergence of internet of things and cloud for smart computing. CRC Press- 2021.
3.	Kirwan- Christopher Grant- and Fu Zhiyong. Smart cities and artificial intelligence: convergent systems for planning- design- and operations. Elsevier- 2020.

Reference Books

1.	Dong- Jian- and Long Zhang- eds. Proceedings of the International Conference on Internet of Things- Communication and Intelligent Technology. Vol. 1015. Springer Nature- 2023.
2.	Diamandis- Peter H.- and Steven Kotler. The future is faster than you think: How converging technologies are transforming business- industries- and our lives. Simon & Schuster- 2020.
3.	Jeschke- Sabina- Christian Brecher- Tobias Meisen- Denis Özdemir- and Tim Eschert. Industrial internet of things and cyber manufacturing systems. Springer International Publishing- 2017.
4.	The Internet of Things: Enabling Technologies- Platforms- and Use Cases"- by Pethuru Raj and Anupama C. Raman- CRC Press- 2017

Mode of Evaluation: CAT- Written assignment- Quiz- FAT- Project- Seminar

Recommended by Board of Studies	16-02-2024		
Approved by Academic Council	No. 73	Date	14-03-2024

Course Code	Course Title	L	T	P	C
MSMO614L	Cybersecurity for Mobility Systems	3	0	0	3
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

1. To understand the basics of cyber security in automotive systems.
2. Acquiring knowledge on securities in vehicle communication systems
3. To understand the AUTOSAR embedded security concepts.
4. To understand the trends and standards for cyber security

Course Outcomes

1. Understand potential cyber security for automotive systems.
2. Understand the hacking surface of vehicle.
3. Identify the security for intelligent vehicles.
4. Need of cyber security for IN and Intra vehicle communication
5. Applying embedded security for vehicle
6. Automotive standards for securities.

Module:1	Introduction to Automotive cyber security	6 hours

Introduction to cybersecurity - Network and Security Concepts- Symmetric and Asymmetric Encryption –Domain Name System (DNS)- firewall- attack value chain- holistic cybersecurity solution, Introduction to features of AIS Standards (189, 190), ISO 27001, 21434 -SAE J2534

Module:2	Hacking and automotive attack surfaces	6 hours

Hacking- Antiforensics - Tunneling Techniques - Fraud Techniques Threat Infrastructure-Automotive attack surface- Intrusion detection and preventions- Phishing – Password cracking – Keyloggers and Spywares – Industrial CSMS (cyber security management system), DoS and DDoS attacks, – SQL Injection.

Module:3	Security and privacy	7 hours

Cryptography-confidentiality-data integrity- authentication, Cryptography primitives, -Elliptic Curve cryptography – Key distribution and Key exchange protocols- Autonomous vehicle cybersecurity, connected vehicle security, Privacy of digital personal data protection act, Europe (EU) GDPR act characteristic features and its importance, Comparison of India and EU act.

Module:4	Cyber security for In-vehicle communication	6 hours

In-vehicle networks, threat analysis and vulnerabilities, security mechanisms and architectures - In-Vehicle cybersecurity issues, - cybersecurity protection layers- cybersecurity for ECU. AIS Standard 190 regarding communication aspects, Over the Air (OTA) updates and its features.

Module:5	Cyber security for Intra-vehicle communication	7 hours

V2X communication -VANET Technology-Homomorphic Encryption in VANET- Security and privacy in V2X communication- IEEE 1609 & Wireless Access in Vehicular Environments (WAVE)- Attacking Wireless Systems- Potential attacks and Remote attacking in V2X.

Module:6	AUTOSAR embedded security	4 hours

Introduction to Autosar architecture - Autosar COM Stack - Autosar Diagnostic Stack - Autosar Crypto Stack - Layered Automotive Security Approach- Automotive

Security Controls- Gateway ECU- Automotive Network Topology- Diagnostics CAN Security.		
Module:7	**Cyber security Risk management and Standards**	**7 hours**
Applied standards and cyber risk management, ISO standards towards risk - Seven Principles of Network Security Analysis Strategy, Network Traffic Monitoring and Analysis standards - cyber security of SAE level 2, 3, and 4 autonomous driving systems-Cyber-attacks in future autonomous vehicle.		
Module:8	**Contemporary Issues**	**2 hours**
Working with OWASP - Honeypots, passworx guessing and cracking.		
	Total Lecture hours:	**45 hours**

Text Book(s)

1.	Shiho Kim , Rakesh Shrestha, "Automotive Cyber Security Introduction, Challenges, and Standardization", 2020, 1,Springer Singapore.
2.	Dietmar P.F. Möller, Roland E. Haas, "Guide to Automotive Connectivity and Cybersecurity", 2019, Springer Cham.
3.	Ahmad Mk Nasser, "Automotive Cybersecurity Engineering Handbook", 2023, 1, Pack. Publishing limited,

Reference Books

1.	Craig Gibbs "Automotive Cybersecurity: Issues and Vulnerabilities" 2016 Nova Science Publishers.
2.	Gloria D'Anna "Cybersecurity for Commercial Vehicles" 2018 SAE International.
3.	Jiajia Liu, Abderrahim Benslimane ·"Intelligent and Connected Vehicle Security", 2022 River Publishers.

Mode of Evaluation: CAT / written assignment / Quiz / FAT / Project / Seminar / group discussion / field work (include only those that are relevant to the course. Use ',' to separate the evaluations. Eg. CAT, Quiz and FAT

Recommended by Board of Studies	16-02-2024		
Approved by Academic Council	No. 73	Date	14-03-2024

Course Code	Course Title	L	T	P	C
MSMO615L	Autonomous Systems and Predictive Modelling	3	0	0	3

Pre-requisite	Nil	Syllabus version
		1.0

Course Objectives

1. Master the predictive models for the application of AV.
2. Exploration of functional architecture and applications of Autonomous Systems
3. To understand how to integrate and utilize the predictive modeling for Autonomous Systems.

Course Outcomes

1. Demonstrate the ability to effectively apply predictive modeling techniques to solve real-world problems and make data-driven decisions.
2. Showcase the capability to design, implement, and evaluate autonomous systems using relevant technologies and methodologies.
3. Successfully combine predictive modeling skills with autonomous system development to create intelligent, adaptive agents capable of making informed predictions and decisions in dynamic environments.

Module:1	Introduction and Functional Architecture of Autonomous Vehicles	6 hours

Functional architecture - Major functions in an autonomous vehicle system, Motion Modelling - Coordinate frames and transforms, point mass model, Vehicle modelling (kinematic and dynamic bicycle model - two-track models), Sensor Modelling - encoders, inertial sensors, GPS.

Module:2	Perception for Autonomous Systems	6 hours

SLAM - Localization and mapping fundamentals, LIDAR and visual SLAM, Navigation – Global path planning, Local path planning, Vehicle control - Control structures, PID control, Linear quadratic regulator, Sample controllers.

Module:3	Foundation and Integration of ML/DL to Autonomous Vehicles Applications	6 hours

Introduction, ML use cases for autonomous vehicles, driving monitoring, Driving assistance, Engine monitoring, Cybersecurity, Data privacy protection, Current and future trends for ML usage in AV development projects, Imaging radar, LiDAR, Fully integrated microcontrollers.

Module:4	Introduction for Predictive modeling and Predictive Modelling Algorithms	6 hours

Supervised and unsupervised learning - Classification vs. Prediction - Association Rules-Clustering Models –Decision Trees- Ruleset Models- KNearest Neighbors – Naive Bayes - Neural Network Model – Regression Models – Regression Trees – Classification & Regression Trees (CART) – Logistic Regression – Multiple Linear Regression Scorecards – Support Vector Machines – Time Series Models

Module:5	Probabilistic methods for Learnings	6 hours

Introduction -Naïve Bayes Algorithm -Maximum Likelihood -Maximum Apriority - Bayesian Belief Networks -Probabilistic Modelling of Problems -Inference in Bayesian Belief Networks – Probability Density Estimation - Sequence Models – Markov Models – Hidden Markov Models

Module:6	Neural Network and Deep Learning	6 hours
Neural Networks – Biological Motivation- Perceptron – Multi-layer Perceptron – Feed Forward Network – Back Propagation-Activation and Loss Functions-Limitations of Machine Learning – Deep Learning– Convolution Neural Networks – Recurrent Neural Networks – Use cases		
Module:7	**Predictive modelling essentials for AV**	**7 hours**
Generative models: Linear Discriminative Analysis, Naive Bayes classifier, Decision trees, Ensemble models – Bagging and Boosting. Unsupervised Learning Algorithms: Dimensionality Reduction Principal Component Analysis (PCA), Singular Value Decomposition (SVD). Clustering – Hierarchical, Partitioned clustering: K-means, PAM, explainable AI (XAI), Approaching an ML problem.		
Module:8	**Contemporary Issues**	**2 hours**
Expert Industry Lecture		
	Total Lecture hours:	**45 hours**

Text Book(s)

1. Stephen Marsland, “Machine Learning: An Algorithmic Perspective”, Chapman & Hall/CRC, 2nd Edition, 2014.
2. Kevin Murphy, “Machine Learning: A Probabilistic Perspective”, MIT Press, 2012
3. Ethem Alpaydin, “Introduction to Machine Learning”, Third Edition, Adaptive Computation and Machine Learning Series, MIT Press, 2014
4. Tom M Mitchell, “Machine Learning”, McGraw Hill Education, 2013.
5. Peter Flach, “Machine Learning: The Art and Science of Algorithms that Make Sense of Data”, First Edition, Cambridge University Press, 2012.
6. Shai Shalev-Shwartz and Shai Ben-David, “Understanding Machine Learning: From Theory to Algorithms”, Cambridge University Press, 2015
7. Christopher Bishop, “Pattern Recognition and Machine Learning”, Springer, 2007.
8. Hal Daumé III, “A Course in Machine Learning”, 2017 (freely available online)
9. Trevor Hastie, Robert Tibshirani, Jerome Friedman, “The Elements of Statistical Learning”, Springer, 2009 (freely available online)
10. Daniel Watzenig and Martin Horn (Eds.), Automated Driving: Safer and More Efficient Future Driving, Springer, 2017

Mode of Evaluation: CAT / written assignment / Quiz / FAT / Project / Seminar

Recommended by Board of Studies	16-02-2024		
Approved by Academic Council	No. 73	Date	14-03-2024

Course Code	Course Title	L	T	P	C
MSMO616L	Automotive Product Design and Life Cycle Management	3	0	0	3

Pre-requisite	Nil	Syllabus version
		1.0

Course Objectives

The objectives of this course are to

1. Competence with a set of tools and methods for product design.
2. Expose students to product life cycle management and its impact on organization.
3. Teach students the material design concepts from the concept to recovery or disposal.
4. Enable students to apply analytic methods during all stages of product planning, development, launch, and control.

Course Outcomes

Upon completion the course, student will be able to

1. Demonstrate product design and development practices.
2. Evaluate the product planning and product life cycle.
3. Identify the customer needs in product development.
4. Design and analyze the material concept and Product Architecture
5. Apply design concepts from the conception to recovery or disposal.
6. Apply innovation in stages of product planning, development, analysis, and control

Module:1	Introduction to Automotive product design and development	5 hours

Introduction – complex automotive products – processes and phases in product design – Design methodology – types – models, Product development – Characteristics – organizations – generic development – concept development – process flows – Product life cycle strategies. Design to cost – Design to Life cycle cost – Design for warranties – Design for Quality – Design for Reliability – Approach to Robust Design – Design for Optimization – challenges.

Module:2	Tools in automotive design process	6 hours

Tools in vehicle development phases – Spread sheets – Design standards and guidelines–Product Planning tools – Benchmarking – pugh diagram – quality function deployment – failure modes and effect analysis – decision making tools – CAD and engineering tools – ergonomics tools – safety and measurement tools – financial, management and market analysis.

Module:3	Steps and Iterations in automotive design process	6 hours

Customer and business needs – Raw data collection – Interpret raw data – System engineering process – ‘V’ Model – design and engineering, verification – manufacturing – assembly – Vehicle attributes – requirements – Vehicle target setting – vehicle decomposition – decomposition tree – evaluation – verification – validation test.

Module:4	Concept Generations and Product design Architecture	6 hours

Clarify the problem – Search externally – search internally – Systematic exploration. Concept Selection – Concept Screening – Concept Scoring. Concept Testing – Purpose – Survey population – Survey Format – Communicate – Response – Types of Modularity – Product change – product variety – component standardization-product performance- Industrial Design for people - process-managing- Quality – Ergonomics.		
Module:5	**Environmental and safety design**	**6 hours**
Introduction-Life cycle analysis - Emission control-recycling- ELV considerations-Hygiene - BIW design - frontal impact test - car-to-car side impact test - Side-impact pole test - pedestrian protection tests- safety performance improvement – material influence.		
Module:6	**Automotive materials in product design**	**8 hours**
Type of automotive materials-sustainable materials-Carbon neutral materials – selection criteria – classifications - Steel-Aluminium-Nickel-Titanium-Polymers-composites -properties-production and processing techniques-Applications-Cost and market analysis- sustainable batteries – materials- design terminology-recycling-Carbon neutrality strategies and development.		
Module:7	**Future trends in automotive product material and Intellectual property**	**6 hours**
Geographic aspects - Current material utilization and vehicle demographics - Quantitative assessment-Factors influencing material change - Actual BIW material effects - Effects of future design - Advances in manufacturing technology - Improvements in materials specification, trends and requirements - Recycling and ELV legislation - Patent- trademark- trade secret- copyright- preparing a disclosure. Product development economics- Elements of economic analysis- economic analysis process.		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	Karl T. Ulrich, Steven D. Eppinger (2015), Product Design and Development, McGraw-Hill.
2.	Batteries for Sustainability, Selected Entries from the Encyclopedia of Sustainability Science and Technology, Ralph J. Brodd, 2012, Springer New York (ISBN:9781461457916, 1461457912)
3.	Materials for, Automobile Bodies, Geoffrey Davies, first edition, 2012, Elsevier, ISBN: 978-0-08-096979-4.
4.	Automotive Product Development: A Systems Engineering Implementation, Vivek D. Bhise, 2017, CRC press, ISBN:9781498706841, 1498706843.
Reference Books	
1.	Robert G. Cooper (2017), Winning at New Products: Creating Value Through Innovation, Hachette Book Group, New York.
2	John Stark (2015), Product Lifecycle Management (Decision Engineering), Springer Publications.

Mode of Evaluation: CAT ,Written Assignment, Quiz and FAT			
Recommended by Board of Studies	16-02-2024		
Approved by Academic Council	No. 73	Date	14-03-2024

Course Code	Course Title	L	T	P	C
MSMO617L	Computational Fluid Flow and Heat Transfer	3	0	0	3
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

1. To provide sufficient background to understand the mathematical representation of the governing equations of fluid flow and heat transfer.
2. To enable the students to understand the fundamental concepts of different discretization techniques.
3. To introduce various turbulence models for solving engineering problems.
4. To gain knowledge about finite difference method and finite volume method.

Course Outcomes

At the end of the course- the student will be able to:

1. Apply mathematics and engineering fundamentals to identify the nature of complex fluid flow and heat transfer problems and to formulate governing equations to represent them.
2. Identify and formulate the appropriate discretization techniques based on the mathematical nature of the governing equations.
3. Solve fluid flow and heat transfer problems (diffusion) using finite difference method.
4. Solve fluid flow and heat transfer problems (convection – diffusion) using finite volume method.
5. Possess the knowledge of algorithm for pressure-velocity coupling for incompressible flow using SIMPLE- SIMPLER- SIMPLEC- and PISO.
6. Analyze and suggest the type of turbulence models to be chosen for IC engine subsystems.

Module:1	Governing Equations of Fluid flow and Heat Transfer	4 hours

Impact of CFD on engineering application Merits of CFD- Vector calculus- Integral transform theorems- Reynolds transport theorem- substantial derivative- Conservation of mass- momentum and energy equations in conservation and non-conservation forms- Physical boundary conditions.

Module:2	Mathematical Nature of the Governing Equations and discretization methods	6 hours

Characteristics of PDE - elliptic- parabolic and hyperbolic types of PDE- well-posed Problems - Basic aspects of discretization- Different discretization techniques – Introduction to finite difference- finite volume- finite element and spectral methods.

Module:3	Finite difference method	8 hours

Finite difference discretization (FDM) - Taylor series method- difference operator method- Forward- backward and central differences- Explicit- Implicit and semi-implicit approaches- Finite difference solution to steady and unsteady 1-D and 2-D diffusion problems- Different types of errors - consistency- accuracy- and stability.

Module:4	Finite volume method	8 hours

Central difference- upwind- quick- exponential- hybrid and power law schemes- False diffusion- Finite volume solution to 1-D and 2-D convection-diffusion problems.

Module:5	Solution Algorithm for Pressure-velocity Coupling	6 hours

Staggered grid- The pressure velocity corrections- The pressure correction equation-

SIMPLE- SIMPLER- SIMPLEC- PISO algorithms.		
Module:6	**Turbulence Modelling**	**7 hours**
Nature- Description and Characterization of turbulent flow- Reynolds averaging- Reynolds averaged N-S equations- Eddy viscosity hypothesis- Reynolds Stress Transport Equations- First order closures: k-ε two equation models- SST k-ω model- Large Eddy Simulations.		
Module:7	**Application of CFD in IC engines**	**4 hours**
Flow through manifolds- valves and ports- Elements of air motion in engines- Outline of fluid dynamic models- application of available commercial codes to engine processes with and without chemical reactions.		
Module:8	**Contemporary Issues**	**2 hours**
Moving grids- simulation of turbulence- computation of free-surface flows- multigrid methods and parallel computing. Industry Case Studies on CFD using STAR CCM / Ansys Fluent		
	Total Lecture hours:	**45 hours**

Text Book(s)

1-	John D- Anderson- JR-- "Computational Fluid Dynamics the Basics with Applications"- McGraw Hill Education- Fifth reprint- Indian Edition- 2017
2-	Joel H- Ferziger- Milovan Perić- and Robert L- Street-- "Computational Methods for Fluid Dynamics"- Springer- 4th edition- 2020
3-	K- Muralidhar- and T- Sundarajan- "Computational Fluid Flow and Heat Transfer"- second edition (reprint)- Narosa Publishing House- New Delhi- 2014

Reference Books

1-	H-K Versteeg and W Malalasekera- Introduction to Computational Fluid Dynamics-The Finite Volume Method- second edition- Prentice Hall India- 201-
2-	S C Gupta- "Applied Computational Fluid Dynamics"- Wiley publication- ISBN-13-978-8126577538- 2019
3-	F - Moukalled-- L-Mangani- M-Darwish- "The Finite Volume Method in Computational Fluid Dynamics: An Advanced Introduction with Open FOAM® and Matlab" ISBN 13 978-3319168739- Springer publication
4-	T J Chung- "Computational fluid dynamics"- ISBN 13 978-1107425255- Cambridge university press- Second edition- 2014

Mode of Evaluation: CAT- written assignment- Quiz- FAT- Project- Seminar

Recommended by Board of Studies	16-02-2024		
Approved by Academic Council	No. 73	Date	14-03-2024

Course Code	Course Title	L	T	P	C
MSMO617P	Computational Fluid Flow and Heat Transfer Lab	0	0	2	1

Pre-requisite	Nil	Syllabus version
		1.0

Course Objectives

The main objectives of this course are to:

1. Introduce student to the applied computational fluid dynamics and to teach them how to solve a fluid flow problem using commercially available CFD software.
2. Enable the student formulate the design problems into CFD.
3. Enable the students to understand the fundamental concepts of different discretization techniques.
4. Teach students the characteristics of various elements in structural and thermal analysis and selection of suitable elements for the problems being solved.

Course Outcomes

At the end of the course the students are able to:

1. Have a working knowledge of a variety of computational techniques that can be used for solving engineering problems.
2. Develop an understanding for the major theories, approaches and methodologies used in CFD.
3. Build up the skills in the actual implementation of CFD methods (e.g. boundary conditions, turbulence modelling etc.) in using commercial CFD codes.
4. Gain experience in the application of CFD analysis to real engineering designs.

Indicative Experiments

1	Creation of 2d/3d geometry and practice on design modeler	**3 hours**
2	Creation of 2d/3d mesh with different techniques, mesh control parameters	**3 hours**
3	Computational analysis of laminar flow and turbulent flow through a pipe	**3 hours**
4	Computational analysis of parallel flow and counter flow concentric tube heat exchanger	**3 hours**
5	Computational analysis of steady compressible flow in a convergent - divergent nozzle	**3 hours**
6	Computational analysis of steady flow over an aero foil	**3 hours**
7	Computational analysis of one-dimensional steady-state methane combustion using species transport modeling	**3 hours**
8	Hexa mesh generation for a 2d pipe junction	**3 hours**
9	Computational analysis of flow over a ahmed body	**3 hours**
10	Natural convection on a cylinder	**3 hours**
	Total Laboratory Hours	**30 hours**

Text Book(s)

1. Joel H. Ferziger, Milovan Perić, and Robert L. Street., “Computational Methods for Fluid Dynamics”, Springer, 4th edition, 2020.

2.	K. Muralidhar, and T. Sundarajan, “Computational Fluid Flow and Heat Transfer”, second edition (reprint), Narosa Publishing House, New Delhi, 2014.
Reference Books	
1. 2.	F, Moukalled, L.Mangani, M.Darwish, “The Finite Volume Method in Computational Fluid Dynamics: An Advanced Introduction with Open FOAM® and Matlab” ISBN 13 978-3319168739, Springer publication.(Year) John D. Anderson, JR., “Computational Fluid Dynamics the Basics with Applications”, McGraw Hill Education, Fifth reprint, Indian Edition, 2017
Mode of assessment: Continuous assessment, FAT, Oral examination	

Recommended by Board of Studies	16-02-2024		
Approved by Academic Council	No. 73	Date	14-03-2024

Course Code	Course Title	L	T	P	C
MSMO618L	Finite Element Methods	3	0	0	3
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

The main objectives of this course are to:

1. Enable the students understand the mathematical and physical principles underlying the Finite Element Method (FEM) as applied to solid mechanics and thermal analysis.
2. Introduce students to the theory of elasticity.
3. Teach students the characteristics of various elements in structural and thermal analysis and selection of suitable elements for the problems being solved.
4. Introduce students to various field problems and the discretization of the problem.
5. Make the students derive finite element equations for simple and complex elements

Course Outcomes

At the end of the course, the student will be able to:

1. Apply the knowledge of mathematics and engineering to solve problems in structural and thermal engineering by approximate and numerical methods
2. Employ various formulation methods in FEM.
3. Apply suitable boundary conditions to a global equation for bars, trusses to solve displacements, stress and strains induced.
4. Apply suitable boundary conditions to a global equation for beams and frames to solve displacements, stress and strains induced.
5. Analyze linear 2D and 3D structural problems using CST element and analyze the Axi-symmetric problems with triangular elements. Evaluate heat transfer problems for bar, stepped bar and fin like structures.
6. Analyze the Vector Variable problems using Plane stress, Plane Strain and Axi-symmetric conditions.
7. Demonstrate the use of Finite element analysis in Production Processes

Module:1	Fundamental concepts	6 hours

Physical problems - Finite Element Analysis as Integral part of Computer Aided Design - Stresses and Equilibrium - Boundary Conditions - Strain-Displacement Relations - Stress –strain relations - Linear and nonlinear material laws - Temperature Effects - Definition of Tensors and indicial notations - Deformation gradients - Classification of different types of deformations - Degree of Freedom - Field Problem and their degree of freedom. Solid Mechanics Problems and Fluid Mechanics Problems. Deformations and stresses in bars - thin beams - thick beams - plane strain- plane stress hypothesis - thin plate - thick plate - axisymmetric bodies - Approximate nature of most of these deformation hypotheses - General 3D deformation (linear small deformation) - Large deformation (nonlinear).

Module:2	General Techniques and Tools of Displacement Based Finite Element Analysis	6 hours

Mathematical models - Approximate solutions - Minimization procedure - Variational

procedure - Interpolation polynomial method - Nodal approximation method and Finite Element Solutions. Strong or classical form of the problem and weak or Variational form of the problem - Galerkin's and Weighted residual approaches - Shape and interpolation functions for 1D - 2D & 3D applications - Use of shape (interpolation) functions to represent general displacement functions and in establishment of coordinate and geometrical transformations - Hermite - Lagrange and other interpolation functions.		
Module:3	**One Dimensional Problems: Bars & Trusses**	**6 hours**
Introduction- Local and global coordinate systems - Transformation of vectors in two- and three-dimensional spaces - Finite Element stiffness matrix and load vector of a basic element in local coordinate system using energy approach. Assembly of Global Stiffness Matrix and Load vector - Treatment of boundary conditions - Solution algorithms of linear system matrices - Example problems in trusses - Formulation of dynamics analysis - global mass matrix - Extraction of modal frequencies and mode shape.		
Module:4	**One Dimensional Problems – Beams and Frames**	**7 hours**
Finite Element Modeling of a basic beam element in local coordinate system using energy approach. Formulation of element matrices - Assembly of the Global Stiffness Matrix - Mass matrix and Load vector - Treatment of boundary Conditions. Euler Bernoulli (thin) beam element and Timoshenko (thick) beam element - Beam element arbitrarily oriented in plane (2D) as Plane frames and in space as space frame analysis (3D) - Solution algorithms of linear systems. - Extraction of modal frequencies and mode shape.		
Module:5	**Two-Dimensional Analysis – Scalar Variable Problems**	**6 hours**
Formulation of 2D problems using Partial Differential Equations - Solution algorithm using Energy principle - Constant Strain Triangles (CST) - Bilinear Quadrilateral Q4 - Formulating the element matrices - Modelling boundary conditions - Solving the field problems such as heat transfer in automotive cooling fin - engine cover - Torsion of a non-circular shaft etc. - Introduction to Nonlinear system.		
Module:6	**Vector Variable problems - Plane stress - Plane Strain and Axi-symmetric Analysis**	**6 hours**
Equilibrium equation formulation – Energy principle and formulating the element matrices - Plane stress - plane strain and axi-symmetric elements - Orthotropic materials - Isoperimetric Elements - Natural co-ordinate system - Higher Order Elements - Four-node Quadrilateral for Axisymmetric Problems - Hexahedral and tetrahedral solid elements - Linear - Quadratic and cubic elements in 1D - 2D and 3D - Numerical integration of functions - Gauss and other integration schemes. C0 and C1 continuity elements - FEA process and convergence.		
Module:7	**Analysis of Production Processes**	**6 hours**
FE Analysis of metal casting – Special considerations - latent heat incorporation - gap element – time stepping procedures – Crank – Nicholson algorithm – Prediction of grain structure - Basic concepts of plasticity – Solid and flow formulation – small incremental deformation formulation – FE Analysis of metal cutting - chip separation criteria - incorporation of strain rate dependency.		
Module:8	**Contemporary Issues**	**2 hours**

Applications of FEM in nonlinear and coupled problems - Nonlinear FEM for magneto electric composite , Industry Case Study from Automotive Product development on Static and transient FEA applications		
	Total Lecture hours:	**45 hours**
Text Book(s)		
1.	J.N Reddy , An introduction to the Finite Element Method , 2017 , Mcgraw Hill	
2.	Saeed Moaveni ,Finite Element Analysis , Theory and Application with ANSYS , Pearson , Fifth Edition , 2021	
3.	Tirupathi R. Chandrapatla , Ashok D. Belegundu , Introduction to Finite Element in Engineering Pearson 4th Edition , 2011	
Reference Books		
1.	Seshu.P , Finite Element Analysis , Prentice Hall of India , 2013	
2.	Robert D. Cook , David S. Malkus , Michael E. Plesha , Robert J. Witt ,Concepts and Applications of Finite Element Analysis , John Wiley & Sons , Incl.2002	
3.	S.S.Rao , Finite element method in Engineering , 2011 , Butterworth Heinemann	
Mode of Evaluation: CAT - Written assignment - Quiz - FAT - Project - Seminar		
Recommended by Board of Studies	16-02-2024	
Approved by Academic Council	No. 73	Date 14-03-2024

Course Code	Course Title	L	T	P	C
MSMO618P	Finite Element Methods Lab	0	0	2	1
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

The main objectives of this course are to:

1. Acquire basic understanding of Modeling and Analysis software.
2. Understand the different kinds of analysis and apply the basic principles to find out the stress and other related parameters of bars, beams loaded with loading conditions.
3. Teach students the characteristics of various elements in structural and thermal analysis and selection of suitable elements for the problems being solved.
4. Learn to apply the basic principles to carry out dynamic analysis to know the natural frequency of different kind of beams.

Course Outcomes

At the end of the course the students are able to:

1. To develop an understanding for the major theories, approaches and methodologies used in FEA.
2. Use modern tools to formulate the problem, and able to create geometry, discretize, apply boundary condition to solve problems of bars, truss, beams, and plate to find stress with different loading conditions.
3. Analyze linear 2D and 3D structural problems using CST element and analyze the axi-symmetric problems with triangular elements.
4. Apply suitable boundary conditions to a global equation for beams and frames to solve displacements, stress and strains induced.
5. Demonstrate the use of Finite element analysis in various applications.

Indicative Experiments

1.	Stress analysis of a bar without considering self-weight	**3 hours**
2.	Effect of self-weight on stress of a vertical hanging bar	**3 hours**
3.	Stress analysis of the tapered rod	**4 hours**
4.	Two-dimensional truss problem	**4 hours**
5.	Bending moment and shear force diagram of various beams	**4 hours**
6.	Plane stress and plane strain analysis	**4 hours**
7.	Modal, harmonic and transient analysis on bar, beam and plates	**4 hours**
8.	Axi-symmetric analysis	**4 hours**
	Total Laboratory Hours	**30 hours**

Text Book(s)

1. Mats G. Larson , Fredrik Bengzon, ‘The Finite Element Method: Theory, Implementation, and Applications’, Springer, 2013
2. Zhu Bofang, ‘The Finite Element Method’, John Wiley & Sons Singapore Pvt. Ltd ISBN:9781119107316, 2018

Reference Books				
1.	Tirupathi R. Chandrapatla, Ashok D. Belegundu, Introduction to Finite Element in Engineering Pearson 4th Edition, 2011			
2.	Saeed Moaveni, Finite Element Analysis, Theory and Application with ANSYS, Pearson, Fifth Edition, 2021			
Mode of assessment: Continuous assessment, FAT , Oral examination				
Recommended by Board of Studies		16-02-2024		
Approved by Academic Council		No. 73	Date	14-03-2024

Course Code	Course Title	L	T	P	C
MSMO619L	Lightweight Materials for Smart Mobility	3	0	0	3
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives:

The main objective of this course are to

1. Make an understand the importance and need for lightweight materials in automotive industries.
2. Understand the application of various steel, aluminum and magnesium alloys in automotive industries.
3. Understand the importance of polymer and manufacturing process in automotive applications.
4. Identify the different production processes for manufacturing lightweight structures and explain their functions.
5. Understand the importance of joining and Crashworthiness design issues for lightweight vehicles

Expected Course Outcome:

1. At the end of the course, students will be able to:
2. Remember the various lightweight alloys used in automotive industries.
3. Demonstrate the tailor welded blanks for automotive application.
4. Identify different types of lightweight materials, such as metals, aluminum, and polymers, and their applications in automotive industries.
5. Apply advanced techniques of composite materials and manufacturing processes.
6. Apply the knowledge on the materials and design the automotive structures.
7. Analyses the key issues of structural crashworthiness.

Module: 1	Lightweight material in automotive sector	6 hours

Introduction to need and requirements for lightweight materials (Conventional powertrain, electric powertrain), - History, - legislative requirements for light weighting (powertrain system, vehicle body, etc.) - techniques for achieving the light weighting – certification and homologation requirement towards the light weighting system – Sustainability and circular economy point of view in material selection for automotive applications.

Module: 2	Advanced steels for lightweight automotive structures	7 hours

History of steel in automobiles - Types of high strength steels - Third generation advanced high strength steels- Manufacturing and forming high strength steels - Designing with steels for lightweight automotive Structures - Introduction to tailor welded blanks and Historical perspective of tailor welded blanks (TWBs) – Advantages and Disadvantages of TWBs -Application of TWBs - efforts for TWBs - TWB forming methods - Welding processes for TWBs - Materials used to produce TWBs.

Module: 3	Aluminum alloys for lightweight automotive structures	6 hours

International designation systems for aluminium alloys - International temper designations for aluminium alloys-Aluminium alloys used in lightweight automotive vehicles - Substituting aluminium alloys for competitive materials, Novel techniques

for Aluminium casting and its features - Introduction to Aluminium casting and sheet metal processing.		
Module: 4	**Magnesium alloys for lightweight powertrains and automotive structures**	**6 hours**
Magnesium alloys, properties, and processes overview – Cast Magnesium – Casting and sheet metal process – Automotive applications of cast and sheet magnesium		
Module: 5	**Thermoplastics and composites for lightweight automotive structures**	**7 hours**
Introduction- Thermoplastics used in automobiles - Design considerations for thermoplastic polymers- Thermoplastic matrix composites for automobiles – Introduction and manufacturing process of FRP, GFRP, CFRP, Joining of thermoplastic matrix composites		
Module: 6	**Manufacturing and Design of lightweight automotive structures**	**6 hours**
Vehicle architecture design for lightweight materials - Forming of structural components - Cast structural components - Enablers - Promising metal forming processes for automotive applications, Meta materials and their application automotive structures, Introduction to Giga factor features. Additive manufacturing technique for automotive structures. Material modelling features using artificial intelligence techniques		
Module: 7	**Crashworthiness design for lightweight vehicles**	**6 hours**
Introduction - Background of vehicle crash safety-Designing for crashworthiness with lightweight materials -Crash safety design using computer-aided engineering (CAE) – Miscellaneous lightweight countermeasures.		
Module 8	Contemporary Issues – Aluminium alloys – Magnesium alloys	**1 hours**
Total Lecture hours		**45 hours**

Text Book(s)	
1.	P.K. Mallick. Materials, Design and Manufacturing for Lightweight Vehicles, 1st Edition - March 1, 2010
Reference Books	
1.	Brad L. Kinsey and Xin Wu, Tailor welded blanks for advanced manufacturing. Woodhead Publishing Limited, 2011
2.	Erik L. Persson, Aluminum Alloys: Preparation, Properties, and Applications, , Nova Science, 2011
3.	Charles Moosbrugger, Engineering Properties of Magnesium Alloys, ASM International, 2017
4.	William F. Hosford & Ann Arbor Robert M. Caddell, Metal Forming : Mechanics and Metallurgy, Cambridge University Press, 2011

Mode of evaluation: Continuous Assessment Test, Quizzes, Assignments, Final Assessment Test			
Recommended by Board of Studies		16-02-2024	
Approved by Academic Council	No. 73	Date	14-03-2024

Course Code	Course Title	L	T	P	C
MSMO620L	Hydrogen Engines	3	0	0	3
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

1. To impart the essential characteristics and safety aspects of using hydrogen as the fuel for engines.
2. To acquire the knowledge in production and storage methods of hydrogen.
3. To know the fundamentals of advanced engine systems and combustion process.
4. To understand the combustion attributes of hydrogen powered engines.

Course Outcomes

1. Comprehend the characteristics and safety systems of hydrogen fuel.
2. Understand the advanced technologies used in internal combustion engines.
3. Acquire knowledge in properties, production, and storage of hydrogen.
4. Apply the knowledge to real-world applications of hydrogen powered engines.
5. Analyze the combustion, performance, and emissions attributes of hydrogen powered engines under various combustion modes.

Module:1	Hydrogen applications for engine	5 hours

Essential requirement of hydrogen used as an engine fuel- properties of hydrogen-engine emissions caused by conventional fuels- fuel supply system for hydrogen engines- safety aspects and devices for hydrogen engines.

Module:2	Production and storage methods for hydrogen engines	5 hours

Production methods - electrolysis, steam reformation, and renewable energy - hydrogen from biomass, hydrogen storage requirements and challenges - gaseous, liquid, and metal hydrides for engine applications.

Module:3	Engine systems modifications	5 hours

Modification requirements in engine for hydrogen application – Factors needs to be considered for the engine systems modification – Hydrogen Fuel tank, Fuel line and Injection requirements and characteristic features – Electronic control and its function in hydrogen application towards engine - combustion, performance and emissions indices, combustion stoichiometry.

Module:4	Hydrogen in spark ignition engines	7 hours

Engine modifications needed for hydrogen utilization in SI engine- neat hydrogen powered SI mode - combustion- performance- and emissions attributes- direct injection of hydrogen in SI engine – Ammonia Combustion characteristics in SI engine - Modes of engines operation for hydrogen - Comparison of Gasoline fuel operation with Hydrogen in SI engine.

Module:5	Hydrogen in compression ignition engines	7 hours

Engine modifications needed for hydrogen utilization in CI engine- hydrogen dual fuel mode - combustion- performance- and emissions attributes- direct injection of hydrogen in CI engine- hydrogen enrichment to enhance the combustion process - Modes of engines operation for hydrogen - Ammonia Combustion characteristics in CI engine -Comparison of Diesel fuel operation with Hydrogen in CI engine.

Module:6	Hydrogen low temperature combustion strategies	8 hours

Benefits- characteristics- and challenges of low temperature combustion (LTC) strategies - HCCI- PCCI- and RCCI modes- utilization of hydrogen in LTC strategies-

combustion- performance- and emissions attributes of hydrogen powered LTC engine.				
Module:7	**Emerging technologies in automotive applications**			**7 hours**
Hybrid electric vehicle technology- on-board generation and storage of hydrogen- ammonia as effective hydrogen storage- application of fuel cell in automotive industry- use of hydrogen in heavy commercial vehicles and off-road vehicle applications- Modelling and simulation of Hydrogen in vehicle applications				
Module:8	**Contemporary Issues**			**1 hours**
Hydrogen fuel for next-generation truck transportation.				
	Total Lecture hours:			**45 hours**
Text Book(s)				
1.	Efstathios-Al. Tingas, Hydrogen for Future Thermal Engines, 2023, Green Energy and Technology.			
Reference Books				
1.	Keith Owen and Trevor Eoley, Automotive Fuels Handbook, SAE Publications,1990.			
2.	Osamu Hirao and Richard K. Pefley, Present and Future Automotive Fuels, John Wiley and Sons, 1988.			
3.	Hua Zhao. HCCI and CAI engines for the automotive industry. Woodhead Publishing Limited, Abington Hall, Abington, Cambridge CB21 6AH, England.			
4.	John B. Heywood. Internal combustion engines fundamentals, 2018, McGraw-Hill international editions.			
Mode of Evaluation: CAT / written assignment / Quiz / FAT				
Recommended by Board of Studies	16-02-2024			
Approved by Academic Council	No. 73	Date	14-03-2024	

Course Code	Course Title	L	T	P	C
MSMO621L	Special Purpose Vehicle Technology	3	0	0	3
Pre-requisite	Nil	Syllabus version			
		1.0			

Course Objectives

1. To help the students to understand the different construction, agriculture & special purpose vehicle.
2. To enable the students to identify the role of automotive engineers in special purpose vehicle design.
3. To impart knowledge on advance construction and agricultural vehicle technologies.

Course Outcomes

1. Understand the fundamentals of construction, agricultural and other earth moving vehicles
2. Identify the way to design implements to enhance the productivity.
3. Familiarize with various crane design and agricultural attachments
4. Compute power requirement of agricultural, constructional and mobile cranes.
5. Outline the role of automotive engines in special purpose machine design
6. Possess the knowledge of testing of agricultural implements.

Module:1	Construction Vehicle – Dozers & Scrapers	6 hours

Earthwork Vehicles - types - tractors- motor graders- scrapers- front end waders- Dozers - types- crawler bulldozer- wheel bulldozer- mini bulldozer (Straight (s-blade)- universal (u-blade)- s-u (semi-u) blade- angle blades)- single bucket- multi bucket and rotary types – bulldozers. scrapers types- single-engine wheeled- dual-engine wheeled- elevating- and pull-type scrapers.

Module:2	Earth Moving - Dumpers And Hauling Equipment	7 hours

Dumpers - design aspects on dumper body- articulated dumpers. Safety features- safe warning system for dumper. loaders -- loader and bulldozers with operational linkages- excavators- backhoe loaders- motor graders- Earth work steering system & articulated steering assembly Brake system and actuation- Body hoist and bucket operational hydraulics- hydro pneumatic suspension cylinders- -power and capacity of earth moving machines.

Module:3	Mobile Crane And Hoist Vehicle Technology	7hours

Mobile crane and hoist types- Design aspects- Hydraulic fluids- types- pneumatics actuators constructional details of air compressors- types- Air motors- control valves- actuators- and regulator. hydraulic systems -Cylinder-Pumps Gear - vane - piston type and motors - types- characteristics.- construction details. Valves for control of direction- flow and pressure – types and construction details. Types of Sensor and its Technology

Module:4	Agriculture Vehicle And Attachments	6 hours

Introduction of traction devices- tyres-types- function & size- their selection; mechanics of traction devices. Deflection between traction devices and soil- slippage and sinkage of wheels- evaluation and prediction of traction performance- design of traction and transport devices. Soil compaction by agricultural vehicles and machines. Reaper machine- Power shawl- Bush cutters- stumpers- rippers– transporters

Module:5	Agriculture Vehicle Implements	7 hours

Modern trends- principles- procedures- fundamentals and economic considerations for design and development of farm machineries- Design considerations- procedure and their applications in agricultural tractors & typical machines- Power requirement and other design aspects of farm equipment's: – tillage- seeding- planting- interculture- plant protection- harvesting and threshing- Rotary- vibrating and oscillating machines- Safety devices for tractors & farm implements- Soil working tools: shares- discs- shovels- sweeps and blades- rota-tillers and puddlers- Metering of seeds and granular fertilizers with various mechanism		
Module:6	**Testing And Evaluation Of Tractors And Farm Equipment**	**5hours**
Types of tests; test procedure- national and international codes- Test equipment; usage and limitations- Tractor performance testing power requirement of various components of field machines Power losses in dynamometers and hydraulic test equipment- Laboratory and field testing of farm equipment- Nondestructive testing techniques- NVH analysis Case studies		
Module:7	**Special Purpose Vehicles Road Vehicles**	**5 hours**
Types of off-the-road tires- transport for earthmoving machines- Combine harvester machines- Road roller machines- slow moving earthmoving machines- and load and carry for transporting- digging- off-highway tires have six categories of service compactor- earthmover- grader- loader- log-skidder and mining and logging		
Module:8	**Contemporary Issues**	**2 hours**
Introduction to special purpose commercial vehicle, trucks, trailers, etc their features and design aspects		
	Total Lecture hours:	**45 hours**

Text Book(s)

1-	Harris Pearson Smith- Farm Machinery and Equipment- 2011-
2-	Gianpiero Mastinu- Manfred Ploechl Road and Off-Road Vehicle System Dynamics Handbook- 2017-

Reference Books

1-	Y Pokras; M- Tushnyakov- Construction equipment - Operation and maintenance- Mir Publishers- Moscow- 1971
2-	David A- Day- Neal B- H- Benjamin- "Construction Equipment Guide"- Wiley-
3-	J-Y Wong - Theory of Ground vehicles - John Wiley and Sons-
4-	Kepner R-A- Principles Of Farm Machinery- CBS Publishers 2017-
5-	Robert L- Peurifoy--Clifford J- Schexnayder- Robert L- Schmitt- Aviad Shapira- Construction Planning- Equipment- and Methods- McGraw-Hill Education- 2018-

Mode of Evaluation: CAT / written assignment / Quiz / FAT / Project / Seminar / group discussion / field work (include only those that are relevant to the course- Use '-' to separate the evaluations- Eg- CAT- Quiz and FAT

Recommended by Board of Studies	16-02-2024		
Approved by Academic Council	No. 73	Date	14-03-2024

Course Code	Course Title	L	T	P	C
MSMO622L	Advanced Mobility Solutions	2	1	0	3
Pre-requisite	MSMO501L	Syllabus version			
		1.0			

Course Objectives

1. Recognize and address mobility challenges for differently abled individuals through inclusive design principles.
2. Grasp the concept and principles of Mobility as a Service (MaaS) and Autonomous Farming Mobility (AFM), including successful case studies and future trends.
3. Define, design, and understand the applications of military mobility solutions, half-road vehicles, industrial mobility solutions, and the integration of robotics and automation.

Course Outcomes

1. Apply inclusive design principles to create transportation solutions addressing mobility challenges for differently abled individuals.
2. Evaluate and integrate various transportation modes within the MaaS and AFM framework using real-world case studies.
3. Design personalized mobility solutions, military mobility solutions half-road vehicles and industrial mobility, considering user-centric principles, ethical considerations, and adaptive systems.

Module:1	**Introduction to Advanced Mobility**	**5 hours**

Overview of evolving mobility trends- Impact of technology on transportation- Global case studies in advanced mobility.

Module:2	**Differently Abled Mobility**	**8 hours**

Introduction to Assistive Mobility- Understanding mobility challenges for differently abled individuals- Types of Mobility Challenges and Disabilities. Inclusive design principles in transportation- Assistive technologies- and their applications- Social and Psychological Aspects of Differently Abled Mobility- Accessibility and Universal Design Principles

Module:3	**Mobility as a Service (MaaS)**	**6 hours**

Concept and principles of Mobility as a Service- Integration of different transportation modes- Case studies of successful MaaS implementations- Challenges- and future trends in MaaS.

Module:4	**Autonomous Farming Mobility**	**5 hours**

Introduction to Autonomous Farming Mobility- Technology behind autonomous systems for agriculture- Applications in agriculture processes

Module:5	**Military Mobility Solutions**	**5 hours**

Military-grade transportation and logistics- Tactical mobility and strategic deployment- Case studies on military mobility in diverse terrains, Unmanned aerial Vehicles.

Module:6	**Personalized Mobility**	**9 hours**

Introduction to personalized mobility and its significance- Technological underpinnings: IoT- AI- and data analytics- User-centric design principles and

human factors- Overview of mobility apps- platforms- and user interfaces- Data-driven personalization: collection- analysis- and ethical considerations- Adaptive transportation systems: dynamic routing and smart traffic management- Inclusive design and accessibility in personalized mobility		
Module:7	**Half-road Vehicles and Industrial Mobility**	**5 hours**
Definition- design- and applications of half-road vehicles- Industrial mobility solutions for manufacturing and logistics- Integration of robotics and automation in industrial mobility		
Module:8	**Contemporary Issues**	**2 hours**
	Total Lecture hours:	**45 hours**

Text Book(s)	
1.	Mobility and Transport for Elderly and Handicapped Persons. (2021). United Kingdom: Taylor & Francis.
2	Hensher, D. A., Mulley, C., Ho, C., Wong, Y., Smith, G., Nelson, J. D. (2020). Understanding Mobility as a Service (MaaS): Past, Present and Future. Netherlands: Elsevier Science
Reference Books	
1.	Smart Automotive Mobility: Reliable Technology for the Mobile Human. (2020). Germany: Springer International Publishing.
2	Allen, J., Weber, J. (2021). The Four-Wheeler's Bible: The Complete Guide to Off-Road and Overland Adventure Driving, Revised & Updated. United States: Motor books.

Mode of Evaluation: CAT / written assignment / Quiz / FAT / Project / Seminar / group discussion / field work (include only those that are relevant to the course. Use ‘,’ to separate the evaluations. Eg. CAT, Quiz and FAT			
Recommended by Board of Studies	16-02-2024		
Approved by Academic Council	No. 73	Date	14-03-2024