M.Tech in Electrical Engineering

with specialisation in Electric Vehicle Technology

Course Structure and Contents

Semester-I

Course Structure—Semester I

S. No	Course Title	Course Code	L	T	P	Credits
1.	Fundamentals & Dynamics of EVs	MEC511C	4	0	0	4
2.	Electrical Engineering Essentials for Electric Mobility	ELE510C	3	0	2	4
3.	Power Converters for EVs	ELE507C	4	0	0	4
4.	EV Charging Infrastructure	ELE402S	3	0	0	3
5.	Research Methodology: Methods and Techniques	ELE502C	3	0	0	3
6.	Modelling and Simulation of EVs	ELE508C	2	0	2	3
			Total Credits			**21**

MEC511C - Fundamentals and Dynamics of EVs

Type of Course: Core **Semester:** I

L	T	P	Contact Hrs/Week	Credits
4	0	0	4	4

Course Objectives: Understand the dynamics of vehicle ride under different riding conditions. Present a problem-oriented in-depth knowledge of vehicle dynamics and the underlying concepts and methods. Calculate and refer to the loads and forces associated with vehicles and analyze their behavior under acceleration, ride, and braking.

Course Outcomes:

1. Analyze the dynamics of vehicles under various riding conditions.
2. Evaluate acceleration and braking performance in electric vehicles.
3. Articulate road loads and tyre dynamics in EVs.
4. Interpret comfort, vibrations, cornering, and rollover behaviors.
5. Infer suspension kinematics and controllable suspension systems in EVs.

Module I: Basics of Vehicle Dynamics

History, vehicle classifications, fundamental approaches to vehicle dynamics, vehicle axis systems, forces and moments acting on a vehicle, earth-fixed coordinate system, dynamic axle loads, equations of motion, transmission characteristics, vehicle performance, brake proportioning, and braking efficiency.

Module II: Acceleration and Braking Performance

Powertrain components, power and traction-limited acceleration, transverse weight shift, drive configurations (FWD, RWD, AWD), braking force analysis, brake design, federal regulations, ABS, tire/road friction, safety, and maintenance.

Module III: Road Loads and Tire Dynamics

Wind drag and car body design, rolling resistance, total road loads, gas mileage and driving style analysis, aerodynamics, tire specifications and constructions, tire force and motion analysis, vibration and contact stress analysis, and tire modeling.

Module IV: Ride and Cornering/Steering

Ride comfort and vibration perception, sources and transmission of vibration, low/high-speed cornering, bicycle model, rollover analysis: quasi-static rigid and suspended vehicles, transient rollover.

Module V: Chassis and Suspension Systems

Suspension kinematics and types, solid axles, independent suspension, anti-squat, anti-pitch, and anti-dive geometries, roll center analysis, suspension dynamics, body/wheel hop, controllable suspension (active/semi-active), spring rate selection, and calculation.

Books Recommended

Textbooks:

1. Thomas Gillespie, *Fundamentals of Vehicle Dynamics*, SAE Publications.
2. Mike Blundell and Damian Harty, *The Multibody Systems Approach to Vehicle Dynamics*, Elsevier, 2004.
3. Iqbal Hussein, *Electric and Hybrid Vehicles: Design Fundamentals*, CRC Press, 2003.

Reference Books:

1. Reimpell, Stoll, and Betzler, *The Automotive Chassis: Engineering Principles.*
2. Hans Pacejka, *Tire and Vehicle Dynamics*, Elsevier, 2012.
3. R.V. Dukkipati, *Vehicle Dynamics*, Narsova Publications.

ELE510C - Electrical Engineering Essentials for Electric Mobility

Type of Course: Core **Semester:** I

L	T	P	Contact Hrs/Week	Credits
3	0	2	5	4

Course Objectives: This course enables students to apply principles of electrical engineering to electric vehicle systems, design and simulate EV power electronics and motor drives, and develop effective control strategies. Through hands-on labs and case studies, students will implement theoretical concepts while building a strong foundation for research and development in electric vehicle technologies.

Course Outcomes:

1. Analyze and solve power circuits using network theorems, phasor analysis, and three-phase power calculations for EV electrical systems.
2. Evaluate and select appropriate electric motors (BLDC, PMSM, Induction) by understanding electromechanical energy conversion principles.
3. Design and tune control strategies (PID, root locus, frequency response) using modeling and stability analysis.
4. Simulate and implement power electronic converters (DC-DC, inverters) with PWM techniques for efficient EV power management.
5. Integrate theoretical knowledge through hands-on labs (MATLAB/Simulink, V/f control) to address real-world EV challenges.

Module I: Review of Power Circuits

Network theorems, mesh and nodal analysis, transient response analysis, AC circuit fundamentals, phasors, real, reactive, and apparent power, power factor, three-phase configurations, and power calculations.

Module II: Electromechanical Energy Conversion

Magnetic materials, BH characteristics, transformers, electromechanical energy conversion principles, DC motors, induction motors, synchronous motors, BLDC motors, and PMSM.

Module III: Control Systems for EV Propulsion

Mathematical modeling of electrical and mechanical systems, transfer functions, and response analysis; stability (Routh-Hurwitz, root locus); frequency response (Bode, Nyquist); PID controller design for EV motor control; sensors in EV systems.

Module IV: Power Semiconductor Devices for EV Applications

Converter topologies (rectifiers, inverters), DC-DC converters (buck, boost, buck-boost), voltage and current source inverters, PWM techniques (SPWM, SVPWM), multilevel inverters, and bidirectional converters.

List of Experiments:

1. Design and implementation of various control algorithms using MATLAB/Simulink.
2. Circuit-level simulation of power electronic converters.
3. Implementation of different control techniques for motor drives.

Books Recommended

Textbooks:

1. C.K. Alexander, M.N.O. Sadiku, *Fundamentals of Electric Circuits*, McGraw-Hill.
2. M.H. Rashid, *Power Electronics: Circuits, Devices, and Applications*, Prentice Hall.
3. K. Ogata, *Modern Control Engineering*, Prentice Hall.

Reference Books:

1. T. Wildi, *Electrical Machines, Drives and Power Systems*, Pearson Education, 2006.
2. C.C. Chan and K.T. Chau, *Modern Electric Vehicle Technology*, Oxford University Press.

ELE507C - Power Converters for EVs

Type of Course: Core **Semester:** I

L	T	P	Contact Hrs/Week	Credits
4	0	0	4	4

Course Objectives: Analysis of the theoretical aspects of different converters and inverters. To understand the design aspects and component selection of converters and the control aspects of converters for electric vehicles.

Course Outcomes:

1. Analyze the operation of different power converters.
2. Design of nonisolated and isolated converters used in electric vehicles.
3. Design thermal and magnetic components for power converters.
4. Analyze the operation of practical inverters.
5. Evaluate the topologies of the bidirectional converters used in electric vehicles.

Module I: Power Semiconductor Devices and Drive Circuit Design

Ideal and typical power switching waveforms, device characteristics, turn-on/off behavior, drive circuits for different power semiconductor switches, snubber circuit design, and intelligent power modules (IPM).

Module II: DC to DC Switch Mode Power Converters and Their Design

Steady-state analysis of non-isolated and isolated DC-DC converters in continuous/discontinuous modes, component selection, filter design, and PWM techniques.

Module III: Design of Switch Mode DC-AC Inverters

Single-phase inverters with pulse control, unipolar PWM, three-phase inverters using PWM and space vector modulation, principles and applications, and component selection for inverter design.

Module IV: Design of Thermal and Magnetic Components

Heat transfer modes, thermal modeling of power devices, heatsink selection, magnetic materials, hysteresis/eddy losses, magnetic component design for power electronics, and inductor design.

Module V: Bidirectional Converter Topologies for Plug-In EVs

Overview and literature survey of bidirectional converters, bidirectional AC/DC converters with reduced conduction losses, buck/boost operations, and regenerative braking integration.

Books Recommended

Textbooks:

1. L. Ashok Kumar, S. Albert Alexander, *Power Converters for Electric Vehicles*, CRC Press, Taylor & Francis Group, 2021.
2. Mohan N., Undeland T., Robbins, *Power Electronics: Converters, Applications, and Design*, Wiley, 3rd ed., 2002.
3. Iqbal Hussein, *Electric and Hybrid Vehicles: Design Fundamentals*, CRC Press, 2003.

Reference Books:

1. Christophe Basso, *Switch Mode Power Supplies: SPICE Simulations and Practical Designs*, McGraw-Hill, 2008.
2. Daniel M. Mitchell, *DC-DC Switching Regulator Analysis.*
3. B. Jayant Baliga, *Power Semiconductor Devices*, International Thompson Computer Press, 1995.

ELE402S - EV Charging Infrastructure

Type of Course: Core **Semester:** I

L	T	P	Contact Hrs/Week	Credits
3	0	0	3	3

Course Objectives: To understand electric vehicle operation and battery fundamentals, EV battery charging methods, fast charging behavior, renewable energy-based charging station design, and charger specifications.

Course Outcomes:

1. Analyze the impact of EV charging on the power grid.
2. Design and analyze various charging infrastructures, their selection, and their sizing.
3. Design renewable energy-based electric vehicle charging stations.
4. Evaluate charging methodologies and analyze their performance.
5. Design charger specifications and select communication protocols.

Module I: Introduction to EV Charging System

EV charging options and infrastructure, energy, economic and environmental considerations, impact on power grid and distribution systems, effect on generation and load profile, smart charging, demand identification, and EV penetration scenarios.

Module II: Electric Vehicle Battery Fast Charging

On-board and off-board charging, fast charging processes and strategies, charger configurations, equalizing/leveling chargers, inductive and wireless charging, and EV range testing under fast charging.

Module III: Charging Stations and Infrastructure

Battery swapping stations, move-and-charge zones, AC and DC charging, onboard/offboard charger specs, EVSE technical specifications, charging time estimation, fast and slow charger selection, and sizing.

Module IV: Renewable Energy-Based EV Charging Stations

Design and calculation for renewable-powered charging stations, components, earth protection, fire and safety aspects, and case studies on different charging approaches.

Module V: Advancements in Charging

V2G and G2V technologies, EV charging case studies, charging station reliability, predictive analysis for maintenance-free operation, bathtub curve, and reliability prediction based on usage.

Books Recommended

Textbooks:

1. Sandeep Dhameja, *Electric Vehicle Battery Systems*, Newnes Publishing, 2002.
2. Emadi, A. (Ed.), Miller, J., Ehsani, M., *Vehicular Electric Power Systems*, CRC Press, 2003.
3. Sheldon S. Williamson, *Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles*, Springer, 2013.
4. M. S. Alam, R. K. Pillai, and N. Murugesan (Eds.), *Developing Charging Infrastructure and Technologies for Electric Vehicles*, IGI Global, 2022.

Reference Books:

1. Jerry Sergent and Al Krum, *Thermal Management Handbook: For Electronic Assemblies*, McGraw-Hill, 1998.
2. I. Husain, *Electric and Hybrid Vehicles*, CRC Press, 2010.
3. James Larminie and John Lowry, *Electric Vehicle Technology Explained*, Wiley, 2012.
4. Tariq Muneer and Irene Illescas García, *The Automobile, in Electric Vehicles: Prospects and Challenges*, Elsevier, 2017.

ELE502C - Research Methodology: Methods and Techniques

Type of Course: Core **Semester:** I

L	T	P	Contact Hrs/Week	Credits
3	0	0	3	3

Course Objectives: To provide foundational knowledge in scientific research and methodology, introduce statistical and computational tools for data analysis, and develop technical writing and documentation skills using LaTeX and related tools.

Course Outcomes:

1. Understand the epistemological foundations and evolution of scientific inquiry.
2. Apply statistical methods for hypothesis testing and do data analysis and visualisation using tools like Excel, MATLAB, Python etc.
3. Understand how to write structured and impactful scientific reports, theses, and research papers.
4. Prepare technical documents and presentations using LaTeX and Overleaf.
5. Perform basic modeling, simulation, and visualization using scientific computing tools.

Module I: Foundations of Scientific Research

Knowledge and the epistemology of knowledge, deductive and inductive inference, history of scientific ideas, major thinkers and advancements, principles of effective research, aspects of research, self-development and creativity, finding and solving research problems.

Module II: Statistical Analysis and Experimental Design

Central tendency and data visualization, hypothesis testing (t-test, F-test, ANOVA), parametric and non-parametric tests, correlation (simple, partial, multiple), statistical computation using tools (Excel, MATLAB, etc.), and introduction to Python for statistics using numpy, pandas, scipy, matplotlib, seaborn, and Jupyter Notebooks.

Module III: Scientific Writing and Communication

Research reports, steps in report writing, report structure, writing references and bibliography, the importance of effective presentations, planning scientific presentations, the paper writing process, and storytelling models.

Module IV: Documentation Using LaTeX

LaTeX essentials: formatting, equations, references, BibTeX for bibliography management, Beamer for presentations, introduction to Overleaf, and hands-on LaTeX practice.

Module V: Modeling, Simulation and Data Visualization

Data structures (arrays, matrices), 2D/3D plotting, subplots, complex data handling, visualization using MATLAB and Python (using numpy, Matplotlib, and other libraries in Jupyter Notebooks.)

Books Recommended

Textbooks:

1. R.C. Kothari, *Research Methodology: Methods and Techniques*, 2nd ed., New Age International, 2009.
2. David V. Thiel, *Research Methods for Engineers*, Cambridge University Press.
3. Ranjit Kumar, *Research Methodology: A Step-by-Step Guide for Beginners*, 2nd ed., SAGE, 2005.

Reference Books:

1. Stephen J. Chapman, *MATLAB Programming for Engineers*, Cengage Learning.
2. William M. Trochim, *The Research Methods Knowledge Base*, 2nd ed.
3. Thomas Hill, Paul Lewicki, *Statistical Methods and Applications*, StatSoft Inc., 2013.
4. Jake VanderPlas, *Python Data Science Handbook*, O'Reilly.
5. Leslie Lamport, *LaTeX: A Document Preparation System*, Addison-Wesley.

Additional Resources:

1. `https://michaelnielsen.org/blog/principles-of-effective-research/`
2. `https://www2.isical.ac.in/~palash/research-methodology.html`
3. `https://goelsan.wordpress.com/2013/04/10/research-method-for-engineering-research-students-iv-an-incomplete-course-for-phd-scholars/`

ELE508C - Modelling and Simulation of EVs

Type of Course: Core **Semester:** I

L	T	P	Contact Hrs/Week	Credits
2	0	2	4	3

Course Objectives: To understand the performance parameters of electric vehicles. This course aims to describe drivetrain characteristics, concepts of energy management systems, and vehicle dynamic control systems.

Course Outcomes:

1. Understand the modelling of vehicle performance parameters.
2. Model battery electric vehicles.
3. Describe the drivetrain characteristics.
4. Apply the concepts of energy management systems.
5. Explain vehicle dynamic control systems.

Module I: Modelling and Performance Parameters

Vehicle acceleration modelling, performance metrics, and case studies on electric scooters and small cars.

Module II: Modelling of Electric Vehicles

EV modelling: tractive effort, rolling resistance, aerodynamic drag, hill climbing, acceleration forces, driving cycles, and range modelling for BEVs, HEVs, and FCEVs under different conditions.

Module III: Drivetrain Characteristics

Modelling and characteristics of EV/HEV powertrain components: ICEs, electric motors, batteries, transmissions, regenerative braking, and representative driving cycles.

Module IV: Energy Management

Handling analysis for EVs and HEVs, power/energy allocation and management strategies, and rule-based and optimization-based controllers.

Module V: Vehicle Dynamic Control

Control of EV/HEV dynamics, fundamentals of vehicle dynamic control (VDC), VDC implementation in EVs/HEVs, and case studies on battery-electric, hybrid, and fuel-cell-powered vehicles.

List of Experiments:

1. Simulation of driving cycles and their analysis.
2. Effect of rolling resistance on vehicle range and performance.
3. Impact of vehicle mass on range and performance.
4. Effect of aerodynamic drag on range and performance.
5. Effect of hill climbing force on range and performance.
6. Series HEV simulation to study parameter variation.
7. Parallel HEV simulation with parameter impact analysis.
8. Complete system-level electric vehicle simulation.

Books Recommended

Textbooks:

1. Amir Khajepour, Saber Fallah, and Avesta Goodarzi, *Electric and Hybrid Vehicles: Technologies, Modelling and Control*, John Wiley & Sons, 2014.
2. James Larminie, John Lowry, *Electric Vehicle Technology Explained*, John Wiley & Sons, 2003.
3. Iqbal Hussein, *Electric and Hybrid Vehicles: Design Fundamentals*, CRC Press, 2003.

Reference Books:

1. Antoni Szumanowski, *Hybrid Electric Powertrain Engineering and Technology: Modelling, Control, and Simulation*, IGI Global, 2013.
2. Mehrdad Ehsani, Yimin Gao, and Ali Emadi, *Modern Electric, Hybrid Electric, and Fuel Cell Vehicles*, 2nd ed., CRC Press, 2010.
3. B. Jayant Baliga, *Power Semiconductor Devices*, 1st ed., International Thompson Computer Press, 1995.