भारतीय सूचना प्रौद्योगिकी संस्थान रांची

INDIAN INSTITUTE OF INFORMATION TECHNOLOGY RANCHI

An Institute of National Importance under
Ministry of Education, Government of India

EXECUTIVE M.TECH. PROGRAMME IN

ECE (Autonomous Connected Electric Vehicles)

COURSE STRUCTURE & SYLLABI

Effective from 2022-23 Admitted Batch

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Course Structure and Syllabi

for

Executive M. Tech. Programme

in

ECE (Autonomous Connected Electric Vehicles)

भारतीय सूचना प्रौद्योगिकी संस्थान राँची

INDIAN INSTITUTE OF INFORMATION TECHNOLOGY, RANCHI

(An Institute of National Importance under act of Parliament)

Ranchi - 834004, Jharkhand

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M. Tech. in Autonomous Connected Electric Vehicles (ACE)
Semester-wise Curriculum

Semester I

S. No.	Course Code	Course Name	L	T	P	C
1	EV5001	Introduction to Automobile Engineering	2	0	0	2
2	EV5003	Hybrid Electric Vehicle	2	0	0	2
3	EV5005	Advance Power Electronics and Control	3	0	0	3
4	HV50XX	Elective -I	2	1	0	3
5	EV5101	Introduction to Automobile Engineering Lab	0	0	3	2
6	EV5103	Hybrid Electric Vehicle Lab	0	0	3	2
7	EV5105	Advance Power Electronics and Control Lab	0	0	3	2
		Total	**9**	**1**	**9**	**16**

Semester II

S. No.	Course Code	Course Name	L	T	P	C
1	EV5002	Electric Vehicle Motor and Controller	3	0	0	3
2	EV5004	Energy Storage Systems	3	0	0	3
3	EV5006	Battery Management Systems	3	0	0	3
4	HV50XX	Elective -II	2	1	0	3
5	EV5102	Electric Vehicle Motor and Controller Lab	0	0	3	2
6	EV5104	Energy Storage Systems and Battery Management System Lab	0	0	3	2
		Total	**11**	**1**	**6**	**16**

Semester III

S. No.	Course Code	Course Name	L	T	P	C
1	EV6001	Charging Infrastructure: Battery Charging, Protection and Sizing	3	0	0	3
2	EV6003	Autonomous, Connected Vehicles	3	0	0	3
3	HV60XX	Elective -III	2	1	0	3
4	EV6101	Charging Infrastructure: Battery Charging, Protection and Sizing Lab	0	0	3	2
5	EV6103	Autonomous, Connected Vehicles Lab	0	0	3	2
		Total	**8**	**1**	**4**	**13**

Semester IV

S. No.	Course Code	Course Name	L	T	P	C
1	PR6102	Research Project (Stage-I)	0	0	24	12
2	PR6104	Comprehensive Viva	0	0	0	02
		Total	**0**	**0**	**24**	**14**

Semester V

S. No.	Course Code	Course Name	L	T	P	C
1	PR7101	Research Project (Stage-II)	0	0	32	16
		Total	**0**	**0**	**32**	**16**

L-T-P-C Notation

L – T – P − C => Lecture – Tutorial – Practical – Credits
Credit structure of each course is given in L – T – P − C form. The numbers corresponding to L, T and P denote the contact hours per week for Lecture, Tutorial and Practical respectively, and that of C denotes the total number of credits for that course in a semester.

Courses for Elective I

S. No.	Course Code	Course Name	L	T	P	C
1	HV5001	Wireless Sensor Networks	2	1	0	3
2	HV5003	Machine Learning	2	1	0	3
3	HV5005	Embedded System Design	2	1	0	3
4	HV5007	Wireless Power Transfer Technologies	2	1	0	3

Courses for Elective II

S. No.	Course Code	Course Name	L	T	P	C
1	HV5002	IoT Sensors & Actuator	2	1	0	3
2	HV5004	Solar Photovoltaic Energy Conversion Systems	2	1	0	3
3	HV5006	Data Analytics and Visualization	2	1	0	3

Courses for Elective III

S. No.	Course Code	Course Name	L	T	P	C
1	HV6001	Intelligent Transportation System	2	1	0	3
2	HV6003	IoT Architecture & Computing	2	1	0	3
3	HV6005	Computer Vision for Automated Electric Vehicles	2	1	0	3

Note:

- Other elective courses to be taken from NPTEL/MOOCs/SWAYAM/COURSERA or any other online platform as determined by the committee. Students should complete the online courses completely and submit assignments, project work, etc., and appear for the final exam conducted by the online instructor. The awarded grade must be submitted for the award of a suitable letter grade in this course. Course codes will be decided later as per the format.
- Elective courses may be added or removed later on the recommendation of a competent authority.
- Students can choose elective courses from any department, but the subject must be offered in that semester.

Distribution of Credit Semester Wise

Semester	I	II	III	IV	V	Total
Credits	16	16	13	14	16	**75**

Format of Course codes

1) Course code AA-XYZZ is explained as
   - AA – Department
   - X – Academic year
   - Y – Theory/ Lab; 0 ==Theory and 1== Lab
   - ZZ – odd/ even semester; odd number == odd semester and even number == even semester
2) For project/seminar/comprehensive viva:
   - AA – PR
   - Y = 1

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DETAIL SYLLABUS

FROM

I - V SEMESTER OF EXECUTIVE M.TECH. DEGREE PROGRAMME

for

AUTONOMOUS CONNECTED ELECTRIC VEHICLES (ACE)

Semester I

S. No.	Course Code	Course Name	L	T	P	C
1	EV5001	Introduction to Automobile Engineering	2	0	0	2
2	EV5003	Hybrid Electric Vehicle	2	0	0	2
3	EV5005	Advance Power Electronics and Control	3	0	0	3
4	HV50XX	Elective -I	2	1	0	3
5	EV5101	Introduction to Automobile Engineering Lab	0	0	3	2
6	EV5103	Hybrid Electric Vehicle Lab	0	0	3	2
7	EV5105	Advance Power Electronics and Control Lab	0	0	3	2
		Total	**9**	**1**	**9**	**16**

EV5001	Introduction to Automobile Engineering	L-T-P-C: 2-0-0-2

Course Objectives:

- To understand the concept on working principles of various systems of automobiles and fuel supply systems.
- To learn the modern technologies used in automobiles.

Course Content:

Unit 1: Introduction to Automotive Industry

Introduction to automobiles, history of automobile, evolution and growth of the industry, major automobile companies and their products, classification of automobiles (commercial, passenger), product segments (criteria for vehicle architecture, classification & specifications of automobile systems and subsystems. introduction to electric vehicle technology, EV terminology, comparison of electric vehicle with IC engine vehicle based on emission, range, fuel type etc.

Unit 2: Introduction to Automotive Systems & Sub-systems

Introduction to various automotive systems and subsystems, powertrain, chassis, BIW, Body engineering (Interiors, Exteriors, Closures, Seating system, Safety, etc.), auto electronics, auto electricals, lighting systems.

Automobile design considerations, vehicle design, and development process, market research, benchmarking, vehicle specifications, vehicle attributes, perceived quality, vehicle integration, ergonomics, layout and packaging studies.

Unit 3: Automotive Materials, Manufacturing Processes & Latest Technologies

Automotive materials (steels, all alloys, magnesium alloys, plastics, composite, hybrid materials etc.). Manufacturing Processes (forming, forging, plastic molding, assembly processes, joining processes, welding etc.). Introduction to design of JIG and fixtures etc. Overview of digital manufacturing, agile manufacturing technologies, and industrial internet of things (IIOT).

Unit 4: Regulatory Requirements, Testing, Certification & Homologation

Regulatory and other safety requirements (AIS, FMVSS, CMVSS, ECE/EEC, JIS, ENCAP, US NCAP IIHA, etc.), certification and homologation. Testing requirements, type of testing. Overview of design considerations for crash, energy management and occupant protection. Overview of vehicle testing (frontal crash, side impact, roof crush, pedestrian safety), on-board diagnostics (OBD), EMS, engine configuration and components updating in BS3, BS4 and BS6 applications, Overview of various loads acting on body. Durability and NVH requirements. Vehicle indoor testing, outdoor testing. Virtual and real-world assessments to ensure it is safe, reliable and complaint with safety.

Course Outcomes:

- Students will gain knowledge about the construction and working of different systems and subsystems of automobile.
- They will be able to disassemble and assemble major aggregates of the automobile.
- Students will be able to do vehicle trouble shooting.

Text Books:

1. D. A. Crolla, "*Automotive Engineering: Powertrain, Chassis System and Vehicle Body*", Butterworth-Heinemann, 1st edition, 2009.

Reference Books:

1. J. K. Ball and R. Stone, "*Automotive Engineering Fundamentals*", SAE International, 1st edition, 2019.

EV5003	Hybrid Electric Vehicle	L-T-P-C: 2-0-0-2

Course Objectives:

- To explain electric, hybrid electric and plug-in hybrid electric vehicle (PHEV), their architecture, technologies and fundamentals.
- To explain the design, component sizing of the power electronics converters and various electric drives suitable for hybrid electric vehicles.
- To discuss different energy storage technologies used for hybrid electric vehicles and their control and energy balancing techniques.
- To demonstrate different configurations of electric vehicles and charging techniques.

Course Content:

Unit 1

History of Electric Vehicles, Development towards 21st Century, Need of Electric vehicle, Types of Electric Vehicles in use today – Battery Electric Vehicle, Hybrid (ICE & others), Fuel Cell EV, Solar Powered Vehicles. Trends and developments in electric vehicle markets.

HEV Fundamentals: Vehicle Basics, vehicle model, Vehicle Resistance: Rolling Resistance, Aerodynamic Drag, Grading Resistance, Dynamic Equation Tire–Ground Adhesion and Maximum Tractive Effort, Power Train Tractive Effort and Vehicle Speed, EV Powertrain Component Sizing.

Hybridization of the Automobile: Basics of the EV, Basics of the HEV, Basics of Plug-In Hybrid Electric Vehicle (PHEV) and vehicle architectures: Series Hybrid Vehicle, Parallel Hybrid Vehicle, Basics of Fuel Cell Vehicles (FCVs).

Unit 2

Power Electronics in HEVs: Power electronics circuits used for control and distribution of electric power in DC-DC, AC-DC, DC-AC converters used for HEV.

Electric Machines and Drives in HEVs: Fundamental of Drives and Control of EV Using DC motor, Induction Motor, Permanent Magnet Motor, Switched Reluctance Motor, BLDC motor, Design and Sizing of Traction Motors.

Unit 3

Batteries, Ultracapacitor, Fuel Cells, and Controls: Introduction, Different batteries for EV, Battery Characterization, Comparison of Different Energy Storage Technologies for HEVs, Battery Charging Control, Charge Management of Storage Devices, Flywheel Energy Storage System, Fuel Cells and Hybrid Fuel Cell Energy Storage System and Battery Management System.

Unit 4

EV Charging Technologies: Classification of different charging technology for EV charging station, introduction to Grid-to-Vehicle, Vehicle to Grid (V2G) or Vehicle to Buildings (V2B) or Vehicle to Home (V2H) operations, bi-directional EV charging systems, energy management strategies used in hybrid and electric vehicle, Wireless power transfer (WPT) technique for EV charging.

Unit 5

Regulations and Certification for Electric Vehicles: Need for Certifications and Standards, Overview of the Main International Standards Related to Electric Mobility: Safety and security, charging connectors, charging topology, EV charging related communications.

Course Outcomes:

- Able to explain the basics of electric and hybrid electric vehicles, their architecture, technologies and fundamentals.
- Able to analyze the use of different power electronics converters and electrical machines in hybrid electric vehicles.
- Able to interpret the working of different configurations of electric vehicles and its components, hybrid vehicle configurations.
- Able to explain the use of different energy storage systems used for hybrid electric vehicles, their control techniques, and select appropriate energy balancing technology.
- Ability to understand the control and configurations of HEV charging stations.

Text Books:

1. M. Ehsani, Y. Gao, and A. Emadi, "*Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design*", 2nd edition, CRC Press, 2009.
2. I. Hussein, "*Electric and Hybrid Vehicles: Design Fundamentals*", CRC Press, 3rd edition, 2021.

Reference Books:

1. J. Larminie and J. Lowry, "*Electric Vehicle Technology Explained*", Wiley, 2nd edition, 2012.
2. C. Mi and M. A. Masrur, "*Hybrid Electric Vehicles: Principles and Applications with Practical Perspectives*", Wiley, 2nd edition, 2017.

EV5005	Advance Power Electronics and Control	L-T-P-C: 3-0-0-3

Course Objectives:

- To understand the modern topics of Power Electronics in terms of switches, topologies and control.
- To provide the applications of Power Electronics in drives, Power Systems and Renewable Energy and other utility.

Course Content:

Unit 1

Basic Concept of Switches and Device Physics

Device Physics, Application and Analysis of Switches and Single-Phase Converter

Unit 2

Single Phase Converter, Three Phase Converter, Multipulse Converter and Effect of Source Inductance and PWM Rectifiers.

PWM Rectifiers and Power Factor Improvement Techniques and non- isolated DC- DC converters.

Unit 3

Non- isolated and isolated DC- DC Converters and Choppers.

Isolated DC- DC Converters IV and VSI & CSI, MLI and ZSI.

Unit 4

SVM, AC to AC Converters, Cycloconverter and Matrix Converter.

Linear Control in Power Electronics, Nonlinear Control in Power Electronics, Applications.

Course Outcomes:

- Ability to design a power converter for required applications.
- Able to design the control circuit and the power circuit for a given power converter.

Text Books:

1. M. H. Rashid, "*Power Electronics: Circuits, Devices and Applications*", Pearson Education, 4th edition, 2017.
2. N. Mohan, T. M. Undeland, and W. P. Robbins, "*Power Electronics*", Wiley, 3rd edition, 2022.

Reference Books:

1. B. Wu and M. Narimani, "*High-Power Converters and AC Drives*", Wiley-IEEE Press, 2nd edition, 2017.

EV5101	Introduction to Automobile Engineering Lab	L-T-P-C: 0-0-3-2

Lab Experiments:

- Prepare a layout of the automobiles, front in line, cross engine, rear engine, two-wheeler and four-wheeler drives.
- Dismantling, measurement, inspection and assembling of different modern engine [like Multipoint fuel injection (MPFI) and Common rail injection (CRI) engines and Digital twin spark ignition (DTSI) etc.] engine for passenger car, commercial vehicle and two-wheeler engines.
- Dismantle, inspect and reassemble of different Steering system and study of driver seat.
- Test a lead acid battery for open voltage and specific gravity measurement.
- Dismantle, inspect and reassemble the Distributor used in Battery Ignition System.
- Prepare a simple electrical circuit for Automobile applications like Batteries/ motors/ Lighting/ Horn/ Wiper/ Flasher/ Indicators etc.
- Study of Interfacing Sensors like RTD, LVDT, Load Cell etc., Interfacing ADC for Data Acquisition, Interfacing DAC for Control Application, Micro controller programming and interfacing, Interfacing Actuators.
- To study and prepare report on the constructional details, working principles and operation of Automotive Emission / Pollution control systems.

The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences.

EV5103	Hybrid Electric Vehicle Lab	L-T-P-C: 0-0-3-2

Lab Experiments:

- Understand working of different configurations of electric vehicles.
- Understand hybrid vehicle configuration and its components, performance analysis.
- Understand the properties of batteries and its types.
- Understand of electric vehicle drive systems.
- Understand of hybrid electric vehicles.
- Understand Auxiliary systems including charging, starter motor, on board power supply, lighting and environmental sensing and conducting repairs.
- Fault diagnosis & replacement of Battery, AC/DC Inverter, DC/DC Converters, and Hybrid Electric Vehicles.
- Case study of Electric Scooter and Electric Car.

The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences

EV5105	Advance Power Electronics and Control Lab	L-T-P-C: 0-0-3-2

List of Experiments:

- Introduction to Power electronics Lab simulation and Hardware setup.
- Single Phase Uncontrolled (Diode) Rectifier.
- Three phase Uncontrolled (Diode) Rectifier.
- Single phase and three phase uncontrolled rectifier with Smoothing Capacitor
- To study the operation of single phase fully controlled converter.
- To study the operation of single-phase half-controlled converter.
- To study the operation of three phase fully controlled converter.
- Study the performance of the Buck converter.
- Study the performance of the Boost converter.
- Study the performance of the Buck-Boost converter.
- Study the performance of the single phase PWM voltage source inverter.
- Study the performance of three phase VSI with PWM control.
- Study the performance of single phase cyclo-converter.
- Study the performance of three phase cyclo-converters.

Semester II

S. No.	Course Code	Course Name	L	T	P	C
1	EV5002	Electric Vehicle Motor and Controller	3	0	0	3
2	EV5004	Energy Storage Systems	3	0	0	3
3	EV5006	Battery Management Systems	3	0	0	3
4	HV50XX	Elective -II	2	1	0	3
5	EV5102	Electric Vehicle Motor and Controller Lab	0	0	3	2
6	EV5104	Energy Storage Systems and Battery Management System Lab	0	0	3	2
		Total	**11**	**1**	**6**	**16**

EV5002	Electric Vehicle Motor and Controller	L-T-P-C: 3-0-0-3

Course Objectives:

- To understand all types of Motors used in Electric Vehicles

Course content:

Unit 1

Classifications of Motors: motors introductions, requirements, challenges, comparisons of EV motors and industrial motors, Motors (DC, Induction, BLDC, PMSM), Types, Principle, Construction, Control, Electric Drive Train and its types.

Unit 2

DC motor operation characteristics: DC motor operation and its types, BLDC Motor and Control, Operation of BLDC Motor, Torque and Rotating Field Production, Torque, Speed Characteristics and Typical Technical Parameters, Sensor less BLDC Motor Control.

Unit 3

AC motor operation characteristics: AC Induction Motor and Control, Basic Principle of AC Induction Motor Operation, Controls of AC Induction Motor, Selection and sizing of Motor, RPM and Torque calculation of motor, Motor Controllers.

Unit 4

Configuration of motors: Configuration and control of DC Motor drives - Configuration and control of Induction Motor drives, configuration and control of Permanent Magnet Motor drives.

Unit 5

Special electrical motors: Switched Reluctance Motor, Basic Magnetic Structure, Torque Production, SRM Drive Converter, Modes of Operation, Generating Mode of Operation (Regenerative Braking), Sensorless Control, Phase Flux Linkage based Method.

Course Outcomes:

- Able to analyze and compare the performance of DC and AC motors in various drive applications.
- Examine the operation and control for addressing the real time problems in the field of electrical machines.

Text Books:

1. I. Hussein, "*Electric and Hybrid Vehicles: Design Fundamentals*", CRC Press, 3rd edition, 2021.
2. M. Ehsani, Y. Gao, S. Longo, and K. Ebrahimi, "*Modern Electric, Hybrid Electric and Fuel Cell Vehicles*", CRC Press, 3rd edition, 2004.

Reference Books:

1. J. Larminie and J. Lowry, "*Electric Vehicle Technology: Explained"*, Wiley", 2nd edition, 2012.
2. K. T. Chau, "*Electric Vehicle Machines and Drives: Design, Analysis and Application*", Wiley-IEEE Press, 1st edition, 2015.

EV5004	Energy Storage Systems	L-T-P-C: 3-0-0-3

Course Objectives:

- To learn about current and upcoming energy storage systems.
- To explore the fundamentals, technologies and applications of energy storage.

Course Content:

Unit 1

Introduction to energy storage for power systems: Role of energy storage systems, applications.
Overview of energy storage technologies: Thermal, Mechanical, Chemical, Electrochemical, Electrical. Efficiency of energy storage systems.

Unit 2

Electrical energy storage: Introduction to Batteries, Dynamic Battery Modeling, Battery Balancing Methods, Battery Safety, Battery types and their properties.
Introduction to lithium-ion battery, Components, functions, advantages and disadvantages of lithium-ion batteries, Growth & development of Li-Ion batteries, charging procedures, Safety of lithium-ion batteries, Lifetime, Types of lithium-ion battery.

Electrical energy storage: Super capacitors, Superconducting Magnetic Energy Storage (SMES), charging methodologies, SOC, SOH estimation techniques. Hydrogen production and storage, fuel cells.

Unit 3

Storage for renewable energy systems: Solar energy, Wind energy, pumped hydro energy, fuel cells. Battery sizing and stand-alone. Energy storage in Micro-grid and Smart grid. Energy Management with storage systems, increase of energy conversion efficiencies by introducing energy storage. Mobile storage system: electric vehicle, G2V, V2G. Hybrid Energy storage systems: configurations and applications.

Unit 4

Battery pack and battery management system: Selection of battery for EVs & HEVs, Traction Battery Pack design, Requirement of Battery Monitoring, Battery State of Charge Estimation methods, Battery Cell equalization problem, thermal control, protection interface, Energy & Power estimation, Battery thermal management system, Battery Management System: Definition, Parts: Power Module, Battery, DC/DC Converter, load, communication channel, Battery Pack Safety, Battery Standards & Tests.

Unit 5

Battery testing, disposal & recycling: Chemical & structure material properties for cell safety and battery design, battery testing, limitations for transport and storage of cells and batteries, Recycling, disposal and second use of batteries. Battery Leakage: gas generation in batteries, leakage path, leakage rates. Ruptures: Mechanical stress and pressure tolerance of cells, safety vents, Explosions: Causes of battery explosions, explosive process, Thermal Runway: High discharge rates, short circuits, charging and discharging. Environment and Human Health impact assessments of batteries, General recycling issues and drivers, methods of recycling of EV batteries.

Course Outcomes:

- The student will be able to cope up with upcoming technologies in the energy storage systems.

Text Books:

1. A. G. T. Gazarian, "*Energy Storage for Power Systems*", IET Press, 3rd edition, 2020.
2. F. D. Gonzailez, A. Sumper, and O. G. Bellmunt, "*Energy Storage in Power Systems*", Wiley, 1st edition, 2016.

Reference Books:

1. R. Korthauer, "*Lithium-Ion Batteries: Basics and Applications*", Springer, 2018.

EV5006	Battery Management Systems	L-T-P-C: 3-0-0-3

Course Objectives:

- Understand and summarize the basic components and functionality of the Battery Management System.
- Design and model battery systems.
- Choose the appropriate model complexity for a given application
- Parameterize equivalent circuit battery models using experimental I, V, T data.
- Discuss the factors that influence battery performance and required protection schemes.
- Apply the state of the art in battery modeling and controls research.

Course Content:

Unit 1

Introduction: Introduction to Battery Management System, Cells & Batteries, Nominal voltage and capacity, C rate, Energy and power, Cells connected in series, Cells connected in parallel, Electrochemical and lithium-ion cells, Rechargeable cell, Charging and Discharging Process, Overcharge and Undercharge, Modes of Charging.

Unit 2

Battery Management System Requirement: Introduction and BMS functionality, Battery pack topology, BMS Functionality, Voltage Sensing, Temperature Sensing, Current Sensing, BMS Functionality, High-voltage contactor control, Isolation sensing, Thermal control, Protection, Communication Interface, Range estimation, State-of-charge estimation, Cell total energy and cell total power.

Unit 3

Battery State of Charge and State of Health Estimation, Cell Balancing: Battery state of charge estimation (SOC), voltage-based methods to estimate SOC, Model-based state estimation, Battery Health Estimation, Lithium-ion
aging: Negative electrode, Lithium-ion aging: Positive electrode, Cell Balancing, Causes of imbalance, Circuits for balancing.

Unit 4

Modelling and Simulation: Equivalent-circuit models (ECMs), Physics-based models (PBMs), Empirical modelling approach, Physics-based modelling approach, Simulating an electric vehicle, Vehicle range calculations, Simulating constant power and voltage, Simulating battery packs.

Unit 5

Design principles of battery BMS, Effect of distance, load, and force on battery life and BMS, energy balancing with multi-battery system.

Course Outcomes:

- Interpret the role of battery management system.
- Identify the requirements of Battery Management System.
- Interpret the concept associated with battery charging / discharging process.
- Calculate the various parameters of battery and battery pack.
- Design the model of battery pack.

Text Books:

1. G. L. Plett, "*Battery Modeling: Battery management systems Volume I*", Artech House, 2015.
2. G. L. Plett, "*Equivalent-Circuit Methods: Battery Management Systems Volume II*", Artech House, 2015.

Reference Books:

1. V. Pop, H. J. Bergveld, D. Danilov, P. P. L. Regtien, and H. L. Notten, "*Battery Management Systems: Accurate State-of-Charge Indication for Battery-Powered Application*", Springer, 2008.
2. D. Andrea, "*Battery Management Systems for Large Lithium-Ion Battery Packs*", Artech House, 1st edition, 2010.

EV5102	Electric Vehicle Motor and Controller Lab	L-T-P-C: 0-0-3-2

Lab Experiments:

- Study of EV motors and its classification
- Study & Demonstration of DC (series, shunt & separately excited) motors, Induction & Synchronous motors.
- Study & Demonstration of BLDC Motor. (Industry visit)
- Study & Demonstration of Switched Reluctance Motor (SRM). (Industry visit)
- Speed control of D.C. shunt motor by (a) Field current control method and plot the curve for speed vs field current. (b) Armature voltage control method and plot the curve for speed vs armature voltage.
- Speed control of BLDC motor.
- To perform the load test on a 3-phase induction motor and determine its performance characteristics (a) Speed vs load curve (b) pf vs load curve (c) Efficiency vs load curve (d) Speed vs torque curve
- To perform no load and blocked rotor test on a 3-phase induction motor and to determine the parameters of it equivalent circuits. Draw the circle diagram and compute the following (i) Max. Torque, (ii) Current, (iii) slip, (iv) pf, (v) Efficiency.
- Experimental view in industry for EVs.

EV5104	Energy Storage Systems and Battery Management Systems Lab	L-T-P-C: 0-0-3-2

Lab Experiments:

- Study of different types of batteries, its design and development.
- Study of different types of batteries with their characteristics & detailed specifications with terminologies.
- Develop a simulation model for Lead-acid and Li-ion Batteries.
- SOC Estimation by Open-Source voltage for Lead-Acid battery, Ni-MH battery and Li-ion battery.
- SOC Estimation by specific gravity for Lead-Acid battery.
- SOC Estimation by Coulomb counting method for Lead-Acid battery and Li-ion battery.
- Design a circuit for Battery monitoring System for Lead acid battery.
- Design a circuit for passive cell balancing for Li-Ion battery.
- Study of Battery Management System and Monitoring.

Semester III

S. No.	Course Code	Course Name	L	T	P	C
1	EV6001	Charging Infrastructure: Battery Charging, Protection and Sizing	3	0	0	3
2	EV6003	Autonomous, Connected Vehicles	3	0	0	3
3	HV60XX	Elective -III	2	1	0	3
4	EV6101	Charging Infrastructure: Battery Charging, Protection and Sizing Lab	0	0	3	2
5	EV6103	Autonomous, Connected Vehicles Lab	0	0	3	2
		Total	**8**	**1**	**4**	**13**

EV6001	Charging Infrastructure: Battery Charging, Protection and Sizing	L-T-P-C: 3-0-0-3

Course Objectives:

This course provides an entry-level overview of EV charging infrastructure nomenclature and fundamental hardware and software components. EV charging infrastructure, often referred to as electric vehicle supply equipment (EVSE), is a core component of a healthy EV ecosystem and requires adequate planning and dedicated electrical infrastructure at various levels of the distribution grid.

Course content:

Unit 1

Energy Storage: Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Battery based energy storage and its analysis. Fuel Cell based energy storage and its analysis, Super Capacitor based energy storage and its analysis, Flywheel based energy storage and its analysis.

Unit 2

Robust mechanical design and battery packaging continuous transmission of mechanical vibrations, exposure to high impact forces and, thermal runaway structural safety and high cooling performance robust and lightweight module frame minimize the deformation of batteries in case of swelling or explosion.

Unit 3

Types of EV Chargers: Electric Vehicle Technology and Charging Equipment’s, Basic charging Block Diagram of Charger, Difference between Slow charger and fast charger, Slow charger design rating, Fast charger design rating, AC charging and DC charging, Inboard and off board charger specification, Type of Mode of charger Mode -2, Mode-3 and Mode-4, EVSE associated charge times calculation.

Unit 4

Selection and sizing of fast and slow charger (AC & DC): AC Pile Charger, DC Pile Charger, EVSE Power Module selection and technical specification, Selection of EVSE Communication Protocol (PLC / Ethernet / Modbus/ CAN Module), Communication gateway, Specification of open charge point protocol (OCCP 1.6/2.0), Bharat DC001 & AC001 Charger specification, Communication Interface between charger and CMS (central management system), Payment apps.

Unit 5

Selection and sizing of Common types of connectors and applications: Selection of AC charger type-1, type -2 and type -3, Communication between AC charger and EV, Selection of DC charger connector GB/T, CHAdeMO, CCS-1 and CSS-2, Communication methodology of DC fast chargers, IS/ IEC/ARAI/ standard of Charging topology, Communication and connectors (IEC 61851-1, IEC 61851-24,62196-2), Selection sizing of Charger connector cable.

Course Outcomes:

- Describe about vehicle electrification and impact of charging strategies.

Text Books:

1. O. Veneri, "*Technologies and Applications for Smart Charging of Electric and Plug-in Hybrid Vehicles*", Springer, 1st edition, 2018.

Reference Books:

1. K. T. Chau, "*Electric Vehicle Machines and Drives: Design, Analysis and Application*", Wiley-IEEE Press, 1st edition, 2015.
2. J. Larminie and J. Lowry, "*Electric Vehicle Technology: Explained"*, Wiley, 2nd edition, 2012.

Research Papers:

1. M. R. Khalid, I. A. Khan, S. Hameed, M. S. J. Asghar and J. S. Ro, "A Comprehensive Review on Structural Topologies, Power Levels, Energy Storage Systems, and Standards for Electric Vehicle Charging Stations and Their Impacts on Grid", *IEEE Access*, vol. 9, pp. 128069-128094, sept. 2021.
2. S. S. Sayed and A. M. Massoud, "Review on State-of-the-Art Unidirectional Non-Isolated Power Factor Correction Converters for Short-/Long-Distance Electric Vehicles", *IEEE Access*, vol. 10, pp. 11308-11340, Jan. 2022.
3. M. A. H. Rafi and J. Bauman, "A Comprehensive Review of DC Fast-Charging Stations with Energy Storage: Architectures, Power Converters, and Analysis", *IEEE Transactions on Transportation Electrification*, vol. 7, no. 2, pp. 345-368, June 2021.
4. H. Tu, H. Feng, S. Srdic and S. Lukic, "Extreme Fast Charging of Electric Vehicles: A Technology Overview", *IEEE Transactions on Transportation Electrification*, vol. 5, no. 4, pp. 861-878, Dec. 2019.

EV6003	Autonomous, Connected Vehicles	L-T-P-C: 3-0-0-3

Course Objectives:

The goal of the course is to introduce students to the various technologies and systems used to implement advanced driver assistance systems. These systems have the overall impact of automating various driving functions, connecting the automobile to sources of information that assist with this task, and allowing the automobile to make autonomous intelligent decisions concerning future actions of the vehicle that potentially impact the safety of the occupants.

Course Content:

Unit 1: Introduction to autonomous and connected vehicle

Introduction of autonomous vehicle, history & evaluation of autonomous vehicle, concept of connected car.

Vehicle system architecture: autonomous & connected vehicle, overview of infotainment/ body/ chassis/ powertrain electronics in vehicle, role of human capabilities and attentional factors in driving, potential advantages and disadvantages of autonomous & connected vehicle.

Unit 2: Vehicle control system and sensor technology

Introduction to automotive control system, function and integration of electronic control unit, surroundings sensing system and autonomy, concept of sensor, actuators and their types, radar technology, ultrasonic sonar technology, lidar sensor technology, mono-vision camera technology, night vision technology.

Unit 3: Networking and connecting technology

Introduction to internet of things (IOT), fundamental of wireless networking, concept of wiring harness, basic principle of networking, classification of automotive multiplex bus, control area network, local interconnect network, FlexRay, automotive ethernet, global positioning system (GPS), satellite-based augmentation system, concept of on-board vehicle system, fundamentals of connectivity.

Vehicle communication system: vehicle to network (V2N), vehicle to infrastructure (V2I), vehicle to vehicle (V2V), vehicle to cloud (V2C), vehicle to pedestrian (V2P), vehicle to device (V2D), vehicle to grid (V2G).

Unit 4: Driver assistant technology

Concept of advanced driver assistance systems (ADAS), applications of ADAS, adaptive cruise control (ACC), lane departure warning (LDW), traffic sign recognition (TSR), intelligent high beam assistants with light ranging (HBA), lane-centering assistants (LCA), glare-free high beam (GFHB), autonomous emergency braking (AEB), pedestrian detection (PD), advanced city assistants (ACA), automatic parking, driver monitoring system, connected car display technology, warning technology, impaired driver technology, vehicle prognostics technology, basic maintenance & end-of-life predictions (EOLP), troubleshooting and maintenance of advanced driver assistance systems.

Unit 5: Path planning, control and vehicle security
Introduction to path planning, motion planning, prediction & trajectory generation, behaviour planning, data sharing methods inside and outside the connected car, concept of data sensitivity and data flow in autonomous and connected vehicle technology, importance control system security, ADAS security requirements, ADAS data protection, telematics vs. infotainment data and their security, radio frequencies and its conflicts.

Unit 6: Autonomous and connected car industry ecosystem
Opportunities for entrepreneurship in future industry ecosystem (live agent assistance, roadside assistance, concierge services, remote monitoring and control, remote vehicle diagnostics, remote software updates, fleet management, location-based services, etc.), technology scenario, commercial market scenario, present companies and their developments, policies and regulations for autonomous and connected vehicle developments, vehicle development case studies on – autonomous and connected car disruptive technology.

Course Outcomes:

- Understand the rational for and evolution of automotive electronics.
- Understand which automotive systems have been replaced by electronic control systems.
- Understand the basics of how automotive ECUs function in conjunction with the vehicle data bus networks and sensors.
- Understand the concept of remote sensing and the types of sensor technology needed to implement remote sensing.
- Understand the fundamentals of on-board vehicle networks.

Text Books:

1. G. J. Mullett, "*Wireless Telecommunications Systems and Networks*", Cengage, 1st edition, 2013.
2. D. Paret, H. Rebaine, and B. A. Engel, "*Autonomous and Connected Vehicles: Network Architectures from Legacy Networks to Automotive Ethernet*", Wiley, 2022.
3. P. Coppola and D. E. Kiss, "*Autonomous Vehicles and Future Mobility*", Elsevier, 2019.

Reference Books:

1. G. J. Mullett, "*Basic Telecommunications: The Physical Layer*", Cengage Learning, 2002.
2. A. Pearmine, "*Connected Vehicle: In Internet of Things and Data Analytics Handbook*", Wiley, 2017.

Research Papers:

1. J. Wang, J. Liu and N. Kato, "Networking and Communications in Autonomous Driving: A Survey", *IEEE Communications Surveys & Tutorials*, vol. 21, no. 2, pp. 1243-1274, Apr. 2019.
2. S. Kuutti, S. Fallah, K. Katsaros, M. Dianati, F. Mccullough and A. Mouzakitis, "A Survey of the State-of-the-Art Localization Techniques and Their Potentials for Autonomous Vehicle Applications", *IEEE Internet of Things Journal*, vol. 5, no. 2, pp. 829-846, Apr. 2018.

EV6101	**Charging Infrastructure: Battery Charging, Protection and Sizing Lab**	**L-T-P-C: 0-0-3-2**

Lab Experiments:

- Characteristics of EV supply equipment: Battery specifications of different EV segments, Charging methods and power ratings, Battery swapping.
- Study of EV charging standards for interoperability.
- Study of Extreme fast charging configurations using LV transformer. (a) AC-coupled charging station, (b) DC-coupled charging station.
- Study of Battery pack, sizing & calculation of the parameters to develop an EV charging infrastructure.
- Study on DC/DC converter topologies for fast and ultra-fast charging.

EV6103	**Autonomous, Connected Vehicles Lab**	**L-T-P-C: 0-0-3-2**

Lab Experiments:

The student will be assigned ten laboratory experiments to complete. These experiments might include Internet research about the course topics, hands-on activities with sensors and microcontrollers, data networks, wireless transceivers, wireless networks, and simple embedded controller projects. More complex laboratory project(s) that create(s) a complete system (e.g., Smart Robot Car Kit, etc.) is also suggested.

Semester IV

S. No.	Course Code	Course Name	L	T	P	C
1	PR6102	Research Project (Stage-I)	0	0	24	12
2	PR6104	Comprehensive Viva	0	0	0	02
		Total	**0**	**0**	**24**	**14**

PR6102	Research Project (Stage-I)	L-T-P-C: 0-0-24-12

Course Objectives:

- To identify a specific problem for current societal and industrial needs and collect information about it through a thorough review of literature.
- To develop the methodology to solve the identified problem.
- To train the students in preparing project reports and to facing reviews and viva-voce examinations.

Course Content:

Students will do their projects in their own industry, at Tata Technologies Limited or at IIIT Ranchi. The student individually works on a specific topic approved by the head of the division. During the project, each candidate will have a guide from IIIT Ranchi and Tata Technologies Limited, who is familiar with this area of interest. The student can select any topic that is relevant to the area of electric vehicle technology. The topic may be theoretical or include case studies. At the end of the semester, a detailed report on the work done should be submitted which contains a clear definition of the identified problem, a detailed literature review related to the area of work, and methodology for carrying out the work. The students will be evaluated through a viva-voce examination by a panel of examiners.

Course Outcomes:

- Discover potential research areas in the field of Electric vehicle technology.
- Conduct a survey of the available literature in the preferred field of study.
- Compare and contrast the several existing solutions for the research challenge.
- Demonstrate an ability to work in teams and manage the conduct of the research study.
- Formulate and propose a plan for creating a solution for the research plan identified.
- To report and present the findings of the study conducted in the preferred domain.

Semester V

S. No.	Course Code	Course Name	L	T	P	C
1	PR7101	Research Project (Stage-II)	0	0	32	16
		Total	**0**	**0**	**32**	**16**

PR7101	Research Project (Stage-II)	L-T-P-C: 0-0-32-16

Course Objectives:

- To solve the identified problem based on the formulated methodology.
- To develop skills to analyze and discuss the test results and make conclusions.

Course Content:

The student should continue the Research Project (Stage-I) on the selected topic as per the formulated methodology under the same supervisor. At the end of the semester, after completing the work to the satisfaction of the supervisor and review committee, a detailed report should be prepared and submitted to the head of the department. The students will be evaluated based on the report submitted and the viva-voce examination by a panel of examiners.

Course Outcomes:

- Apply mathematical knowledge and research-based knowledge to solve engineering problems.
- Use techniques, skills, and modern engineering tools necessary for engineering practice and be able to manage projects in multidisciplinary environments, either as a member or a leader of a team.
- Apply engineering knowledge to assess societal, health, safety, legal, and cultural issues, as well as the responsibilities that come with them in engineering practice.
- Communicate effectively and to present ideas clearly and coherently to specific audience in both the written and oral forms.
- Make links across different areas of knowledge and to generate, develop and evaluate ideas and information so as to apply these skills to the project task.
- Capable of preparing project reports, facing reviews and viva voce examinations.

Courses for Elective I

S. No.	Course Code	Course Name	L	T	P	C
1	HV5001	Wireless Sensor Networks	2	1	0	3
2	HV5003	Machine Learning	2	1	0	3
3	HV5005	Embedded System Design	2	1	0	3
4	HV5007	Wireless Power Transfer Technologies	2	1	0	3

HV5001	Wireless Sensor Networks	L-T-P-C: 2-1-0-3

Course Objectives:

- To understand the fundamentals of wireless sensor networks and its application to critical real time scenarios.
- To study the various protocols at various layers and its differences with traditional protocols.
- To understand the issues pertaining to sensor networks and the challenges involved in managing a sensor network.

Course Content:

Unit 1: Introduction

Fundamentals of wireless communication technology, the electromagnetic spectrum radio propagation, characteristics of wireless channels, modulation techniques, multiple access techniques, wireless LANs, PANs, WANs, and MANs, Wireless Internet.

Unit 2: Introduction to adhoc/sensor networks

Key definitions of adhoc/ sensor networks, unique constraints and challenges, advantages of ad-hoc/sensor network, driving applications, issues in adhoc wireless networks, issues in design of sensor network, sensor network architecture, data dissemination and gathering.

Unit 3: MAC Protocols

Issues in designing MAC protocols for adhoc wireless networks, design goals, classification of MAC protocols, MAC protocols for sensor network, location discovery, quality, other issues, S-MAC, IEEE 802.15.4.

Unit 4: Routing Protocols

Issues in designing a routing protocol, classification of routing protocols, table-driven, on-demand, hybrid, flooding, hierarchical, and power aware routing protocols.

Unit 5: QoS and Energy Management

Issues and Challenges in providing QoS, classifications, MAC, network layer solutions, QoS frameworks, need for energy management, classification, battery, transmission power, and system power management schemes.

Course Outcomes:

- Able to understand how to building a WSN network.
- Analysis of various critical parameters in deploying a WSN.

Text Books:

1. C. S. R. Murthy and B. S. Manoj, "*Ad Hoc Wireless Networks: Architectures and Protocols*", Pearson Education, 1st edition, 2006.
2. J. Zheng and A. Jamalipour, "*Wireless sensor networks: A networking perspective*", Wiley, 1st edition, 2014.

Reference Books:

1. F. Zhao and L. Guibas, "*Wireless Sensor Networks: An Information Processing",* Elsevier, 1st edition, 2005.
2. C. Beard and W. Stallings, "*Wireless Communications Networks and Systems*", Pearson Education, 1st edition, 2015.
3. H. Karl and A. Willig, "*Protocols and Architectures: For Wireless Sensor Networks*", Wiley, 2011.

HV5003	Machine Learning	L-T-P-C: 2-1-0-3

Course Objectives:
To make familiarise the students with basic understanding of the subject under one common platform and making them capable enough to solve any real-life problem using soft computing tools.

Course Content:

Unit 1
Multivariate calculus: gradient, Hessian, Jacobian, chain rule.
Linear algebra: determinants, eigenvalues/vectors, SVD.
Probability theory: conditional probability, marginal probability, Bayes rule.

Unit 2
Local/proximity-based methods: nearest-neighbors, decision trees.
Learning by function approximation
Linear models: (multiclass) support vector machines, ridge regression
Non-linear models: kernel methods, neural networks (feedforward)
Learning by probabilistic modelling
Discriminative methods: (multiclass) logistic regression, generalized linear models
Generative methods: naive Bayes

Unit 3
Discriminative Models: k-means (clustering), PCA (dimensionality reduction)
Generative Models
Latent variable models: expectation-maximization for learning latent variable models
Applications: Gaussian mixture models, probabilistic PCA

Unit 4
Concepts of over-fitting and generalization, bias-variance tradeoffs
Model and feature selection using the above concepts
Optimization for machine learning: (stochastic/mini-batch) gradient descent

Unit 5
Additional Topics (a subset to be covered depending on interest)
Deep learning: CNN, RNN, LSTM, autoencoders
Structured output prediction: multi-label classification, sequence tagging, ranking
Ensemble methods: boosting, bagging, random forests
Recommendation systems: ranking methods, collaborative filtering via matrix completion
Reinforcement learning and applications

Course Outcomes:
- Basic understanding of the subject and to prepare for research interest using recent techniques for solving real life problems.

Text Books:

1. K. P. Murphy, "*Machine Learning: A Probabilistic Perspective*", MIT Press, 2012.
2. C. M. Bishop, "*Pattern Recognition and Machine Learning*", Springer, 1st edition, 2006.

Reference Books:

1. T. Hastie, R. Tibshirani, and J. Friedman, "*The Elements of Statistical Learning: Data Mining, Inference, and Prediction*", Springer, 2nd edition, 2009.
2. A. Blum, J. Hopcroft, and R. Kannan, "*Foundations of Data Science*", Cambridge University Press, 1st edition, 2020.
3. M. Mohri, A. Rostamizadeh, and A. Talwalkar, "*Foundations of Machine Learning*", MIT Press, 2nd edition, 2018.
4. I. Goodfellow, Y. Bengio, and A. Courville, "Deep Learning", MIT Press, 2016.

HV5005	Embedded System Design	L-T-P-C: 2-1-0-3

Course Objectives:

This course will discuss about the basic concepts of embedded system design, with particular emphasis on hands-on and demonstration sessions on system design using ARM microcontrollers. Keeping in view of the recent developments, this course will be based on state-of-the-art microcontroller boards and programming environments. This course will also help the participants to understand the developmental aspects of Internet of Things (IoT) based designs.

Course Content:

Unit 1

Introduction to Embedded Systems and Microcontrollers.
Instruction Set Architecture of ARM Microcontroller, and Assembly Language Programming.

Unit 2

D/A and A/D converter, Sensors, Actuators and their Interfacing.
Microcontroller Development Boards and Embedded Programming platforms.

Unit 3

Hands-on and Demonstration I: Temperature sensing unit, Light sensing unit, Sound sensing unit
Hands-on and Demonstration II: Feedback control system, Relay control unit, Driving electrical appliances like motors, bulb, pump, etc.

Unit 4

Hands-on and Demonstration III: Object tracking using GPS and GSM.
Hands-on and Demonstration IV: Introduction to Internet of Things, Smart home concepts, Motion sensing using accelerometer, control of appliances over SMS.

Course Outcomes:

- Get familiarized with programming environment to develop embedded solutions.
- Program ARM microcontroller to perform various tasks.
- Understand the key concepts of embedded systems such as I/O, timers, interrupts and interaction with peripheral devices.

Text Books:

1. F. Vahid and T. Givargis, "*Embedded System Design: A Unified Hardware/Software Introduction*", Wiley, 2006.
2. A. N. Sloss, D. Symes and C. Wright, "*ARM System Developer's Guide: Design and Optimizing System Software*", Morgan Kaufman, 2004.

Reference Books:

1. W. Wolf, "*Computers as Components: Principles of Embedded Computing System Design*", Morgan Kaufman Publishers, 4th edition, 2017.

HV5007	Wireless Power Transfer Technologies	L-T-P-C: 2-1-0-3

Course Objectives:

- The fundamental principles of WPT for cable-free transfer of power.
- Theories for inductive power transfer (IPT) based on the coupled inductor model and low-order circuit compensation.
- Specific converter topologies for lighting and battery charging applications.
- Technology trends in the adoption of WPT for key consumer applications.

Course Content:

Unit 1

Basic Circuit Theory: Review of transformers. Leakage inductance. Circuit compensation principles.

Low-order compensations; series and parallel compensations. Resonance and operating frequency. Efficiency equation.

Unit 2

Power Converters Fundamentals: DC-DC converters. AC-DC converters and inverters. PWM and soft switching principles. Basic topologies with transformers. Input, output and transfer characteristics of power converters. Incorporation of leaky transformer. Control methods.

Unit 3

Compensation Configurations: Types of compensation for inductor power transfer. Characteristics for various termination requirements. Design for load-independence output voltage and output current. Efficiency optimization.

Unit 4

Applications: Circuit requirements for various loading conditions. Characteristics of LED loads, resistors and battery loads. Appropriate compensation design. Lighting systems.

Battery charging profiles. Electric vehicle charging. Energy efficiency metric for charging.

Unit 5

Technology Trends: Demand for safe power transfer and durable operation. Portable and smart devices. Mobile communication devices. IoT devices and systems. Sensors. Solid-state lighting development. Battery technologies. Electric vehicle development.

Renewable source integration trends. Future trends and demand for wireless power transfer.

Course Outcomes:

- Understand the characteristics of power transfer through coupled inductors and the significance of leakage inductance.
- Analyze and design appropriate compensation circuits and efficient power converters for WPT applications.
- Understand technical requirements for applications involving solid-state loads and battery loads using WPT technologies.
- Appreciate the factors affecting adoption of WPT in consumer applications including lightings, charging of smartphones and electric vehicles.

Text Books:

1. C. T. Rim and C. Mi, "*Wireless Power Transfer for Electric Vehicles and Mobile Devices*", Wiley-IEEE Press, 1st edition, 2017.
2. J. I. Agbinya, "*Wireless Power Transfer*", River Publishers, 2012.

Research Papers:

1. Z. Huang, S. C. Wong, and C. K. Tse, "Design of a single-stage inductive-power-transfer converter for efficient EV battery charging", *IEEE Transactions on Vehicular Technology*, vol. 66, no. 7, pp. 5808-5821, Jul. 2017.
2. L. Xu, Q. Chen, X. Ren, S. C. Wong, and C. K. Tse, "Self-oscillating resonant converter with contactless power transfer and integrated current sensing transformer", *IEEE Transactions on Power Electronics*, vol. 32, no. 6, pp. 4839-4851, Jun. 2017.
3. W. Zhang, S. C. Wong, C. K. Tse, and Q. Chen, "Load-independent duality of current and voltage outputs of a series or parallel compensated inductive power transfer converter with optimized efficiency", *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 3, no. 1, pp. 137-146, Mar. 2015.
4. J. Hou, Q. Chen. X. Ren, X. Ruan, S. C. Wong, and C. K. Tse, "Precise characteristics analysis of series/series-parallel compensated contactless resonant converter", *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 3, no. 1, 101-110, Mar. 2015.
5. J. Hou, Q. Chen, S. C. Wong, C. K. Tse, and X. Ruan, "Analysis and control of series/series-parallel compensated resonant converters for contactless power transfer", *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 3, no. 1, pp. 124-136, Mar. 2015.

Courses for Elective II

S. No.	Course Code	Course Name	L	T	P	C
1	HV5002	IoT Sensors & Actuator	2	1	0	3
2	HV5004	Solar Photovoltaic Energy Conversion Systems	2	1	0	3
3	HV5006	Data Analytics and Visualization	2	1	0	3

HV5002	IoT Sensors & Actuator	L-T-P-C: 2-1-0-3

Course Objectives:

- To understand about the fundamentals of Internet of Things and its building blocks along with their characteristics.
- To understand the recent application domains of IoT in everyday life.
- To understand the protocols and standards designed for IoT.
- To understand the other associated technologies like cloud computing in the domain of IoT.

Course Content:

Unit 1: IoT Introduction and Fundamentals

Deciphering the term IoT. Applications where IoT can be deployed. Benefits/challenges of deploying an IoT. IoT components: Sensors, front-end electronics (amplifiers, filtering, digitization), digital signal processing, data transmission, choice of channel (wired/wireless), back-end data Analysis. Understanding packaging and power constraints for IoT implementation.

Unit 2: Signals, Sensors, Actuators, Interfaces

Sensors: types, signal types, shape and strength. Sensor non-idealities: Sensitivity and offset drift, noise, minimum detectable signal, nonlinearity. Read-out circuits: Instrumentation-amplifier, SNR definition, noise-bandwidth-power tradeoff. Circuit component mismatch and mitigation techniques (calibration, chopping, autozeroing etc.). Power/energy considerations. Basic signal processing (filtering, quantization, computation, storage).

Unit 3: Networking and Cloud Computing in IoT

Review of Communication Networks, Challenges in Networking of IoT Nodes, range, Bandwidth. Machine-to-Machine (M2M) and IoT Technology Fundamentals, Medium Access Control (MAC) Protocols for M2M Communications. Standards for the IoT. Basics of 5G Cellular Networks and 5G IoT Communications, Low-Power Wide Area Networks (LPWAN). Wireless communication for IoT: channel models, power budgets, data rates. IoT Security and Privacy, MQTT Protocol, Publisher and Subscriber Model. Cloud computing platform (open source) and local setup of such environment. Embedded software relevant to microcontroller and IoT platforms (enterprise or consumer), user interfaces.

Unit 4: Data Analysis for IoT applications

Statistics relevant to large data. Linear regression. Basics of clustering, classification.

Course Outcomes:

- The students will be thorough about the technology behind the IoT and associated technologies.
- The students will be able to use the IoT technologies in practical domains of society.
- The students will be able to gain knowledge about the state-of-the-art methodologies in IoT application domains.

Text Books:

1. P. Raj and A. C. Raman, "*The Internet of Things: Enabling Technologies, Platforms, and Use Cases"*, CRC Press, 2017.
2. A. Bahga and V. Madisetti, "*Internet of Things: A Hands-On Approach*", Universities Press, 1st edition, 2014.

Reference Books:

1. R. Buyya and A. V. Dastjerdi, "*Internet of Things: Principles and Paradigms*", Morgan Kaufmann, 2016.
2. S. Greengard, "*The Internet of Things*" MIT Press, 2021.

HV5004	Solar Photovoltaic Energy Conversion Systems	L-T-P-C: 2-1-0-3

Course Objectives:

- To explain the concept of solar energy systems.
- To develop an understanding of power electronics and switching mode power converters for PV energy applications.
- To study stand-alone PV schemes with battery energy storage and grid-connected PV schemes.

Course Content:

Unit 1

Introduction: Fossil fuel energy usage and global warming; role of renewable energy in sustainable development; renewable energy sources; global potential for solar electrical energy systems.

Solar radiation: Terrestrial solar spectrum; clear sky direct-beam radiation; total clear sky insulation on a collecting surface; radiation on the collector in tracking systems; calculation of average monthly insolation from measured data.

Unit 2

PV cells and modules: Photovoltaic cell and its simple model; i-v and p-v characteristics; PV modules and arrays; effect of shading, use of bypass and blocking diodes; influence of temperature; types of solar cells and their performance; schemes for maximum power point tracking (MPPT); solar PV concentrators.

Unit 3

PV inverters: Grid-connected single phase PV inverter schemes and control; power processing schemes based on single string, multi-string and ac module technologies; types of grid interface; power electronic converters used in single phase PV systems and their operation; transformer less inverters, centralized grid-connected three-phase inverters for large PV installations.

Unit 4

Schemes with battery energy storage: Power processing schemes and control for stand-alone applications; batteries for energy storage types, charging, battery sizing and turn-around efficiency; other types of energy storage for PV systems; grid connected schemes with standby energy storage.

Unit 5

System level issues: Design related issues; grounding, dc arcing and other safety related issues; islanding; harmonics; electro-magnetic interference; energy yield and economics of a PV installation.

Course Outcomes:

- Students will be able to explain the solar energy conversion.
- Ability to design power electronic converters for stand-alone solar systems.
- Ability to design power electronic converters for grid connected solar systems.
- Ability of integrating power electronic converters with renewable energy sources.
- Skill in developing MPPT techniques for PV systems.
- Proficiency in design and development of hybrid energy systems.

Text Books:

1. G. M. Masters, "*Renewable and Efficient Electric Power Systems*", Wiley-IEEE Press, 2^{nd} edition, 2013.
2. M. Jamil and M. Rizwan, and D. P. Kothari, "Grid Integration of Solar Photovoltaic Systems", CRC Press, 1^{st} edition, 2017.

Reference Books:

1. R. Messenger and A. Abtahi, "*Photovoltaic Systems Engineering*", CRC Press, 4^{th} edition, 2017.
2. C. S. Solanki, "*Solar Photovoltaics: Fundamentals, Technologies and Applications*", PHI Learning, 3^{rd} edition, 2015.

Research Papers:

1. G. Spagnuolo et al., "Renewable Energy Operation and Conversion Schemes: A Summary of Discussions during the Seminar on Renewable Energy Systems", *IEEE Industrial Electronics Magazine*, vol. 4, no. 1, pp. 38-51, Mar. 2010.
2. M. G. Villalva, J. R. Gazoli and E. R. Filho, "Comprehensive Approach to Modeling and Simulation of Photovoltaic Arrays", *IEEE Transactions on Power Electronics*, vol. 24, no. 5, pp. 1198-1208, May 2009.
3. S. H. Hanzaei, S. A. Gorji and M. Ektesabi, "A Scheme-Based Review of MPPT Techniques With Respect to Input Variables Including Solar Irradiance and PV Arrays' Temperature", *IEEE Access*, vol. 8, pp. 182229-182239, Oct. 2020.
4. X. Li, Q. Wang, H. Wen and W. Xiao, "Comprehensive Studies on Operational Principles for Maximum Power Point Tracking in Photovoltaic Systems", *IEEE Access*, vol. 7, pp. 121407-121420, Aug. 2019.

HV5006	Data Analytics and Visualization	L-T-P-C: 2-1-0-3

Course Objectives:
This course is designed to teach students how to analyze different types of data using Python. Students will learn how to prepare data for analysis, perform simple statistical analysis, create meaningful data visualizations and predict future trends from data.

Course Content:

Unit 1
Introduction to data analytics, Overview of Data base, SQL, Big Data, Cloud, Introduction to probability, Sampling and sampling distributions.

Unit 2
Hypothesis testing, Two sample testing and introduction to ANOVA, Two way ANOVA and linear regression.

Unit 3
Linear regression and multiple regression, Concepts of MLE and Logistic regression, ROC and Regression Analysis Model Building.

Unit 4
C Test and introduction to cluster analysis, Clustering analysis, Classification and Regression Trees (CART).

Unit 5
Case Study pertaining to Electric Vehicle.
Practical on MySQL or PostgreSQL or any other software.
Practical on KNIME Software.
Practical on Tableau or Power Bi.

Course Outcomes:
- Able to understanding basics of python for performing data analysis.
- Ability to understanding the data, performing preprocessing, processing and data visualization to get insights from data.
- Use different python packages for mathematical, scientific applications and for web data analysis.
- Develop the model for data analysis and evaluate the model performance.

Text Books:

1. W. McKinney, "*Python for data analysis: Data wrangling with Pandas, NumPy, and IPython*", O'Reilly Media, 2nd edition, 2017.
2. M. Lutz, "*Learning Python: Powerful Object-Oriented Programming*", O'Reilly Media, 5th edition, 2013.

Reference Books:

1. A. Downey, J. Elkner, and C. Meyers, "*Learning with Python*", Dreamtech Press, 1st edition, 2015.
2. D. Taieb, "*Data Analysis with Python: A Modern Approach*", Packt Publishing, 1st edition, 2018.

Courses for Elective III

S. No.	Course Code	Course Name	L	T	P	C
1	HV6001	Intelligent Transportation System	2	1	0	3
2	HV6003	IoT Architecture & Computing	2	1	0	3
3	HV6005	Computer Vision for Automated Electric Vehicles	2	1	0	3

HV6001	Intelligent Transportation System	L-T-P-C: 2-1-0-3

Course Objectives:

The subject should be of interest to students interested in the general area of transportation; performance, control and management of transportation systems; urban systems; the deployment of advanced technology systems; and transportation policy and societal issues

Course Content:

Unit 1

Fundamentals of ITS: Definition of ITS, the historical context of ITS from both public policy and market economic perspectives, Types of ITS; Historical Background, Benefits of ITS.

Unit 2

Sensor technologies and Data requirements of ITS: Importance of telecommunications in the ITS. Information Management, Traffic Management Centers (TMC). Application of sensors to Traffic management; Traffic flow sensor technologies; Transponders and Communication systems; Data fusion at traffic management centers; Sensor plan and specification requirements; Elements of Vehicle Location and Route Navigation and Guidance concepts; ITS Data collection techniques – Detectors, Automatic Vehicle Location (AVL), Automatic Vehicle Identification (AVI), GIS, video data collection.

Unit 3

ITS User Needs and Services and Functional areas –Introduction, Advanced Traffic Management systems (ATMS), Advanced Traveler Information systems (ATIS), Commercial Vehicle Operations (CVO), Advanced Vehicle Control systems (AVCS), Advanced Public Transportation systems (APTS), Advanced Rural Transportation systems (ARTS).

Unit 4

ITS Architecture –Regional and Project ITS architecture; Concept of operations; ITS Models and Evaluation Methods; Planning and human factor issues for ITS, Case studies on deployment planning and system design and operation; ITS and safety, ITS and security, ITS as a technology deployment program, research, development and business models, ITS planning.

Unit 5

ITS applications: Traffic and incident management systems; ITS and sustainable mobility, travel demand management, electronic toll collection, ITS and road-pricing.; Transportation network operations; commercial vehicle operations and intermodal freight; public transportation applications; ITS and regional strategic transportation planning, including regional architectures: ITS and changing transportation institutions Automated Highway Systems- Vehicles in Platoons – Integration of Automated Highway Systems. ITS Programs in the World – Overview of ITS implementations in developed countries, ITS in developing countries.

Course Outcomes:

- Able to Differentiate different ITS user services.
- Able to select appropriate ITS technology depending upon site specific conditions.
- Able to design and implement ITS components.

Text Books:

1. M. A. Chowdhury and A. W. Sadek, "*Fundamentals of Intelligent Transportation Systems Planning*", Artech House, 2003.
2. L. A. Klein, "*Sensor technologies and Data requirements of ITS*", Artech House, 2001.

Reference Books:

1. P. K. Sarkar and A. K. Jain, "*Intelligent Transport Systems*", PHI Learning, 1st edition, 2018.
2. J. M. Sussman, "*Perspectives on Intelligent Transportation Systems*", Springer, 2005.

Research Papers:

1. J. G. Ibnez, S. Zeadally, and J. C. Castillo, "Sensor Technologies for Intelligent Transportation Systems", Sensors, vol. 18, no. 6, Apr. 2018.
2. J. Q. Li, F. R. Yu, G. Deng, C. Luo, Z. Ming, and Q. Yan, "Industrial Internet: A Survey on the Enabling Technologies, Applications, and Challenges", *IEEE Communications Surveys & Tutorials*, vol. 19, no. 3, pp. 1504-1526, July 2017.
3. S. Djahel, R. Doolan, G. Muntean, and J. Murphy, "A Communications-Oriented Perspective on Traffic Management Systems for Smart Cities: Challenges and Innovative Approaches", *IEEE Communications Surveys & Tutorials*, vol. 17, no. 1, pp. 125-151, Jan. 2015.

HV6003	IoT Architecture & Computing	L-T-P-C: 2-1-0-3

Course Objectives

- To learn how to design and implement IoT applications that manage big data, streaming data, and/or distributed data.
- To understand Smart Objects and IoT Architectures.
- To learn about various IOT-related protocols.
- To build simple IoT Systems using Arduino and Raspberry Pi.
- To understand data analytics and cloud in the context of IoT.

Course Content:

Unit 1

Fundamentals of IoT: Evolution of Internet of Things, Enabling Technologies.

IoT Architectures: oneM2M, IoT World Forum (IoTWF) and Alternative IoT models, Simplified IoT Architecture and Core IoT Functional Stack, Fog, Edge and Cloud in IoT, Functional blocks of an IoT ecosystem, Sensors, Actuators, Smart Objects and Connecting Smart Objects.

Unit 2

IoT Protocols: IoT Access Technologies: Physical and MAC layers, topology and Security of IEEE 802.15.4, 802.15.4g, 802.15.4e, 1901.2a, 802.11ah and LoRaWAN, Zigbee protocol.

Network Layer: IP versions, Constrained Nodes and Constrained Networks, Optimizing IP for IoT: From 6LoWPAN to 6Lo, Routing over Low Power and Lossy Networks.

Application Transport Methods: Supervisory Control and Data Acquisition, Application Layer Protocols: CoAP and MQTT.

Unit 3

Design and Development: Design Methodology, Embedded computing logic, Microcontroller, System on Chips, IoT system building blocks, Arduino–Board details, IDE programming, Raspberry Pi and Interfaces.

Unit 4

Data Analytics and Supporting Services: Structured Vs Unstructured Data and Data in Motion Vs Data in Rest, Role of Machine Learning-No SQL Databases, Hadoop Ecosystem, Apache Kafka, Apache Spark, Edge Streaming Analytics and Network Analytics, Xively Cloud for IoT, Python Web Application Framework, Django, AWS for IoT, System Management with NETCONF-YANG, Kibana, Fault tolerant data processing on devices.

Unit 5

Case Studies/Industrial Applications: Cisco IoT system, IBM Watson IoT platform, Manufacturing, Converged Plantwide Ethernet Model (CPwE), Power Utility Industry, GridBlocks Reference Model, Smart and Connected Cities: Layered architecture, Smart Lighting, Smart Parking Architecture and Smart Traffic Control.

Course Outcomes:

- Able to describe the term IoT in different contexts.
- Analyze various protocols for IoT.
- Design a PoC of an IoT system using Rasperry Pi and Arduino.
- Apply data analytics and use cloud offerings related to IoT.
- Analyze applications of IoT in real-time scenario.

Text Books:

1. D. Hanes, G. Salgueiro, P. Grossetete, R. Barton, and J. Henry, "*IoT Fundamentals: Networking Technologies, Protocols and Use Cases for Internet of Things"*, Cisco Press, 1st edition, 2017.
2. A. Bahga and V. Madisetti, "*Internet of Things: A hands-on Approach*", Universities Press, 1st edition, 2015.

Reference Books:

1. O. Hersent, D. Boswarthick, and O. Elloumi, "*The Internet of Things – Key applications and Protocols*", Wiley, 2015.
2. J. Holler, V. Tsiatsis, C. Mulligan, S. Karnouskos, S. Avesand, and D. Boyle, "*From Machine-to-Machine to the Internet of Things: Introduction to a New Age of Intelligence*", Academic Press, 2014.

HV6005	Computer Vision for Automated Electric Vehicles	L-T-P-C: 2-1-0-3

Course Objectives:

This syllabus introduces the main concepts from the broad field of computer vision needed to advance perception methods for self-driving vehicles. This course will introduce you to the main perception tasks in autonomous driving, static and dynamic object detection, and will survey common computer vision methods for robotic perception. By the end of this course, you will be able to work with camera models, image processing, and machine learning techniques.

Course Content:

Unit 1

Basics of 3D Computer Vision: The Camera Sensor, Camera Projective Geometry, Camera Calibration, Visual Depth Perception Stereopsis and Computing the Disparity, Basics of Image processing and image filtering.

Unit 2

Visual Features - Detection, Description and Matching: Introduction to Image features and Feature Detectors, Feature Descriptors, Feature Matching, Handling Ambiguity in Matching, Outlier Rejection, Visual Odometry.

Unit 3

Feedforward Neural Networks: Feed Forward Neural Networks, Output Layers and Loss Functions, Neural Network Training with Gradient Descent, Data Splits and Neural Network Performance Evaluation, Neural Network Regularization, Convolutional Neural Networks.

Unit 4

2D Object Detection: The Object Detection Problem, 2D Object detection with Convolutional Neural Networks, Training vs. Inference, using 2D Object Detectors for Self-Driving Cars, Semantic Segmentation: The Semantic Segmentation Problem, ConvNets for Semantic Segmentation, Semantic Segmentation for Road Scene Understanding, Putting it together (Final Project) Perception of dynamic objects in the drivable region.

Course Outcomes:

- Work with the pinhole camera model and perform intrinsic and extrinsic camera calibration.
- Detect, describe, and match image features and design your own convolutional neural networks.
- Apply these methods to visual odometry, object detection, and tracking.
- Apply semantic segmentation for drivable surface estimation.

Text Books:

1. M. Sonka, V. Hlavac, and R. Boyle, "*Image processing, analysis, and machine vision*", Cengage Learning, 4^{th} edition, 2014.
2. I. Goodfellow, Y. Bengio, and A. Courville. "*Deep Learning: Adaptive Computation and Machine Learning series*", MIT Press, 2016.

Reference Books:

1. R. Szeliski, "*Computer Vision: Algorithms and Applications*", Springer, 1^{st} edition, 2011.
2. S. S. Shwartz and S. B. David, "*Understanding machine learning: From theory to algorithms*", Cambridge University Press, 1^{st} edition, 2014.

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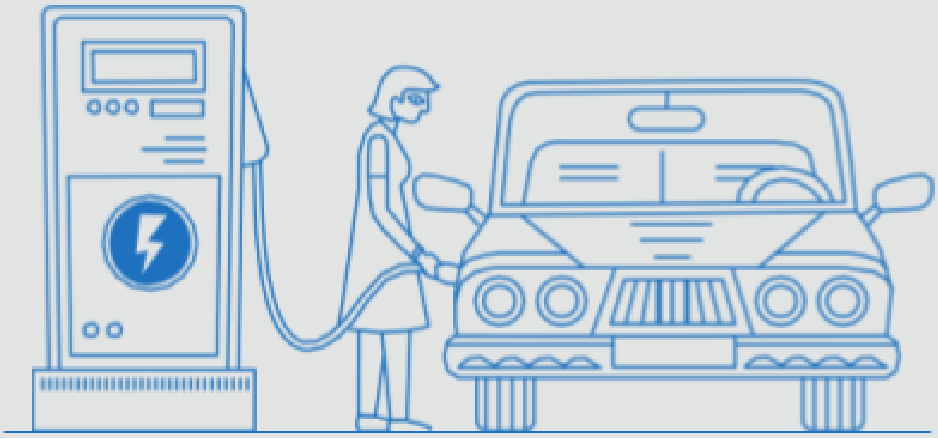

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