ONE YEAR FULL TIME POST GRADUATE DIPLOMA IN ELECTRIC MOBILITY (PG-DEM)

About the Course

Mobility with internal combustion engines (ICE) has been the backbone of Industrial Revolution. Now, with Electric Mobility we are moving towards the future with immense technological opportunities. Due to fossil fuels depletion and environmental pollution Electric mobility has become an unavoidable part of the energy transition from ICE to Electrical. With opportunities come challenges; there will be fundamental changes for the user's vehicle manufactures, governments and policy makers. The vehicle technology will become truly interdisciplinary.

The first step in facing technological challenges and exploiting opportunities is to learn, understand the technology. The one-year Post-Graduate Diploma in Electric Mobility (PG-DEM) is the course made for those who want to make them ready for the exciting careers in future mobility solutions. The course is designed for the fresh graduates and experienced professionals working in the industries.

The course is the brainchild of the Maratha Chamber of Commerce Industries and Agriculture (MCCIA), an organization that think for holistic development of the Nation and have contributed immensely in the Industrial development of Maharashtra, making it the Numero-Uno.

College of Engineering Pune (COEP) is the torch bearer of Engineering education in Pune and India. The professionals of MCCIA ,faculty of COEP, and ARAI together with other institutes and industries in India, will develop you for upcoming challenges and opportunities in transition from ICE Mobility to Electric Mobility

The course includes class room lectures, video lectures, presentations and tutorials, which are all reinforced with practical on state-of-the-art EV infrastructure. You will be exposed to current developments in ELECRICAL VEHICLE technology, charging issues, Government policies through case studies and real-world projects. One of the prime objectives of the course is to create innovators in the field of Electric mobility and accordingly the spectrum of learning is very wide that goes from fundamentals to advanced technology.

What you'll learn

- Electric Vehicles system design and integration
- Energy Storage Systems such as Lithium-Ion Batteries, supercharges and fuel Cells
- Powertrains and controls in EV
- Thermal management and mechanical design of EV components and systems
- International standards, Government policies and regulations for electric mobility

STRUCTURE OF ONE YEAR FULL TIME POST GRADUATE DIPLOMA IN ELECTRIC MOBILITY (PG-DEM)

Trimester I

Sr. No.	Course Code	Course Name	Teaching Scheme			Credits
			L	T	P	
1	PGEM1	Bridge Course a) Fundamentals of Automotive Electrical And Electronic Systems (for Mechanical group) b) Fundamentals of Automotive Mechanical Systems (for Electrical group)	3	0	0	3
2	PGEM2	Applied Mathematics	2	1	0	3
3	PGEM3	EV System Design and Architecture	3	0	0	3
4	PGEM4	Energy Storage Systems for Electric Vehicles	2	1	0	3
5	PGEM5	EV Motor Drives and Power Electronics	2	1	0	3
6	PGEM6	Lab 1	0	0	4	2
7	PGEM7	Mini Project 1	0	0	4	2
		Total	12	3	8	19
		Total Academic Engagement and Credits	**23**			**19**

Trimester II

Sr. No.	Course Code	Course Name	Teaching Scheme			Credits
			L	T	P	
1	PGEM8	Vehicle Dynamics and Traction Systems	2	1	0	3
2	PGEM9	Sensors and Controls in Electric Vehicles	2	1	0	3
3	PGEM10	IOT for Electric Vehicles	3	0	0	3
4	PGEM11	Elective 1	2	0	0	2
5	PGEM12	Elective 2	2	0	0	2
6	PGEM13	Lab 2	0	0	4	2
7	PGEM14	Mini Project 2	0	0	8	4
		Total	11	2	12	19
		Total Academic Engagement and Credits	**25**			**19**

Trimester III

Sr. No.	Course Code	Course Name	Teaching Scheme			Credits
			L	T	P	
1	PGEM14	Industrial In-Plant Training (15-18 Weeks)	0	0	0	12
		Total	0	0	0	12
		Total Academic Engagement and Credits	**0**			**12**
Course Total Credit						**50**

Sr.No	List of Electives
a	Thermal Design and Management of EV Systems
b	Safety and Automotive Standards
c	Energy Management and Vehicle Integration
d	Advance Electric Drives
e	Embedded Systems and in vehicle communication protocols
f	FEM and CFD for Electric Vehicles
g	Design Validation Process

Bridge Courses

1 a) Fundamentals of Automotive Electrical and Electronic Systems

Electric circuit elements, KVL, KCL, series-parallel connections, superposition theorems, equivalentcircuit, steady state and transients in ac and dc, power in ac and dc circuits, power factor improvement, poly phase ac circuit, concept of phasors and phasor diagram, magnetic circuits and transformers, working principle and construction of ac and dc machines used in automobile applications, lamps used in automobile applications.

Characteristics and applications of Diode, Zener diode, BJT, SCR and MOSFET. DC Power supply, simple circuits using OPAMP, elementary treatment to multi-vibrator, filters Schmitt trigger, feedback amplifiers, oscillators etc.

Boolean logic, basic gates, truth tables, K maps, combinatorial and sequential circuits, DAC and ADC, introductory Boolean Algebra and switching functions, finite state machines, design of synchronous FSMs, FSM minimization, asynchronous FSMs. Bipolar Logic Families, MOS logic families, and their electrical behaviour. Memory Elements, Timing circuits, Elementary combinational and sequential digital circuits: adders, comparators, shift registers, counters. Logic Implementation using Programmable Devices.

Books:

1. Incent Del Toro, Electrical Engineering Fundamental, Prentice Hall, 1989
2. K.A.Krishnamurthy and M.R.Raghuveer, Electrical and Electronics Engineering for Scientists,Wiley Eastern Ltd., 1993
3. H. Taub and D. Schilling, Digital Integrated Electronics, McGraw Hill, 1977.
4. D.A. Hodges and H.G. Jackson, Analysis and Design of Digital Integrated Circuits, InternationalStudent Edition, McGraw Hill 1983.
5. B.G. Streetman, Solid State Electronic Devices, Prentice Hall of India, New Delhi, 1995
6. I.J.Nagrath, Basic Electrical Engineering, Tata McGraw Hill,India. 1988.

1 b) Fundamentals of Automotive Mechanical Systems

Internal Combustion Engines: Construction, types and working of I.C. engines, Mechanical Vibrations: Elements of a vibratory system, S.H.M., degrees of freedom, modeling of a system, concept of linear and non-linear systems, equivalent spring, linear and torsional systems. Undamped free vibrations, Forced vibrations of longitudinal and torsional systems. Basics of Vehicle Dynamics: Vehicle coordinate system, earth fixed coordinate system, longitudinal, lateral and vertical vehicle dynamics, vehicle springing system-requirements, sprung mass and unsprung mass. Automotive System Design, Automotive Chassis and Systems, Front Axle and Steering System, Vehicle Suspension Systems, Wheels and Tyres, Acceleration and Braking Characteristics, Braking Systems,Vehicle Safety Systems, Vehicle Chassis, Automotive Hydraulics and Pneumatics, Automotive A/C systems: types and properties of refrigerants, refrigerant oils, refrigerant piping. Future refrigerants, Air conditioning components. Vehicle Performance and Testing, Automotive NVH. Alternative Fueland Emission Control. Materials used in automotive systems.

Books:

1. Internal Combustion Engines, Ganesan,Tata McGraw-Hill Education, 2004
2. Mechanical Vibrations, S. S. Rao Pearson Education
3. Fundamentals of Vehicle Dynamics, Gillespie Thomas D, SAE USA 1992.
4. Theory of Ground Vehicles, John Wiley and Sons, Wong J Y, New York, 1978 5. "Tyre andVehicle Dynamics", Ham B, Pacejka SAE Publication – 2002
5. Automotive air conditioning, William H Crouse and Donald L Anglin
6. Motor Vehicles, Newton, Steed and Garrot, 13th Edition, Butterworth London
7. Vehicle and Engine Technology, Heisler, Second Edition SAE International Publication.Advanced Vehicle Technology, Heisler,Second Edition SAE International Publication.
8. The Automotive Chassis, J. Reimpell H. Stoll, J.W. Betzler, SAE International Publication

2. Applied Mathematics

Matrices and linear equations, Applications to systems of linear equations, vector spaces, subspaces, linear independence and dependence of vectors, bases, dimensions. Row and Column spaces, rank. Linear mappings, representation by matrices, rank-nullity theorem, Eigen values, Eigen vectors,Inner product spaces, orthogonality, Gram-Schmidt process, Diagonalization of special matrices.

Laplace and Fourier Transforms and their applications.

Runge-Kutta methods, stiffness and multistep methods, boundary value and eigen value problems, Finite difference methods for elliptic and parabolic equations.

Books:

1. Advanced Engineering Mathematics by Erwin Kreyszig, John Wiley & Sons, Inc., 10th edition.
2. Introduction to Linear Algebra (2nd edition) by Serge Lang, Springer
3. Elementary Linear Algebra (10th edition) by Howard Anton and Chris Rorres, John Wiley andsons.
4. Schaum's outlines of Linear Algebra (5th edition) by Seymour Lipschutz, Marc Lipson, McGraw-Hill Education (India) Private Limited, New Delhi.
5. Linear Algebra and its applications (4th edition) by Gilbert Strang, Cengage Learning (RS).
6. Advanced Engineering Mathematics by Chandrika Prasad and Reena Garg, Khanna PublishingCompany Private Limited, New Delhi.
7. Numerical Methods for Engineers by Steven C. Chapra, Raymond P. Canale, McGraw-Hill(special Indian edition), 5th edition 2010.
8. Higher Engineering Mathematics by Dr B S Grewal, Khanna Publication, 40th edition 2007.
9. Introductory methods in Numerical Analysis by S S Sastry, PHI, Latest Edition.
10. Computed Oriented Numerical Methods, (5th edition) by R.S. Salaria, Khanna PublishingCompany Private Limited, New Delhi.

3. EV System Design, Architecture and Integration

Motivation for hybrid and electric vehicles: Engineering case, legislative push, incentives, market pull. EV : micro to mild to PHEV to HEV to REEV to EV - Hybrid-Electric Vehicle Power trains, Vehicle Energy Storage System Design, System and sub-systems, Modelling and design of EVs as a system, Motors & motive power spilting concepts, and interface within power train system; Power train architecture -Parallel, Series and Combined, Types of EVs, Vehicle layout and packaging options, Energy devices & combinations, Duty Cycles in Indian cities; performance, Sustainability assessment, Industry Activity and Market Reaction, HEV market drivers and technology trends, Customer related issues, HEV technology readiness levels. Vehicle Based HEV Performance specifications. Modelling of electrical and mechanical sub systems: Systems Modelling and Simulation, Modelling methodologies for HEV energy management. Control strategies for energy management and driveability. High voltage architecture options within HEVs and component selection. Power electronics and machine drives. Systems Integration and Analytical Tools and Vehicle Development Process Overview, Hybrid Components and Architectures: Major components in hybrid Power Train, Controls integration, Component sizing and integration tradeoffs, Hybrid architecture overview, System Design and Development Considerations, Vehicle integration (ex. performance, drivability, NVH), Power Train integration, HV/LV electrical systems, Chassis, Displays/information, HVAC, Verification and Validation Considerations, Component test considerations, System test considerations, Fleet testing, Hybrid and electric vehicle component characteristics and key design attributes, Mathematical derivation of energy and power requirements for specific vehicle use cases. Fuel economy and energy assessment over legislative and real-world driving cycles, System integration for whole vehicle requirements-based design.

Books:

1. Iqbal Husain, Electric and Hybrid Vehicles –Design Fundamentals, CRC Press
2. Mehrdad Ehsani, Yimin Gao, Sebastian E.Gsay, Ali Emadi, Modern Electric, HybridElectric and Fuel Celll vehicles-Fundamentals - Theory and Design", CRC Press
3. Bosch' Automotive Handbook, 8 th Edition

4.Energy Storage Systems for Electric Vehicles

Energy storage requirements for vehicle applications, Storage technologies and metrics for comparison, Distribution of Energy, Storage Form of Energy, Intermediary Conversion, Control and Diagnostic, Ragone Chart, Theory of Ragone Plots. Ragone Plot of a Battery, Case of the Capacitor, Different Types of Accumulators, Accumulators with Aqueous Electrolyte, Lead–Acid Accumulator, Alkaline Accumulators, The Nickel-Iron Battery Nickel–Cadmium Accumulator, Ni- MH Accumulator, Accumulators with Nonaqueous Electrolyte Lithium-Metal Accumulators, Lithium-Metal Polymer Cells, Lithium-Ion Accumulator Lithium–Iron Phosphate (LFP) Cells, Lithium-ion Polymer (Li-Po) Cells, Lithium–Titanate Cells (LTO), Large Size Accumulators, Sodium–Sulfur (NaS) Battery, Vanadium Redox Flow Battery (VRB), Chemical Reactions of the VRB Battery. Modeling of Batteries Thermal Behavior of a Battery, Thermal Modeling MultiphysicsModeling, Battery

Management Systems (BMS), Lithium-Ion Batteries Aging Effects.
Battery characterisation and testing systems & Battery life cycle, Modular battery packs, packaging, thermal control and legislative implications. Supercapacitors : Materials and Construction, Basic Model, Specific Behavior of Supercapacitors, Design of a Super-capacitive Bank, Series and Parallel Connections, Power Capability, Charging and Discharging Procedure of Supercapacitors, Energy Efficiency and Power Availability Thermal Aspects. Hydrogen Fuel Cells: Alkaline Electrolysis, Polymer Electrolyte Membrane (PEM) Electrolysis, High-Temperature Steam Electrolysis, Hydrogen Generation and Storage of Hydrogen, Conversion from Hydrogen to Electricity, Power Needed for the Fuel Conditioning, Efficiency of the Fuel Cells, Overall Efficiency.

Books:

1. Energy Storage by Robert A. Huggins, Springer Publication
2. Energy storage (A new approach) by Ralph Zito Wiley Publication
3. Handbook of Energy Audit, Albert Thumann P.E. CEM, William J. Younger CEM, The FairmontPress Inc., 7th Edition.
4. Energy Management Handbook, Wayne C. Turner, The Fairmont Press Inc., 5th Edition,Georgia.
5. Energy Storage Systems, Alfred Rufer, CRC Press

5. EV Motor-drives and Power Electronics Part 1: Electric Motors

General architecture and requirement of EV, load characteristics, energy sources, principle of electromechanical energy conversion, motors and generator operation, types of electric machine.
Characteristics, performance, control and applications of dc motors, induction motors and synchronous motors, permanent magnet motors, BLDC, switched reluctance motors, scalar/vector control of ac motors, sensorless control, different configuration of EV, series/parallel/series-parallel, dynamometer, speed/position sensors and signal conditioning, voltage sensors, temperature sensors,, vehicle mechanics, test-beds, characteristics like torque vs. rpm, efficiency vs. rpm, power vs. rpm, power electronics based control of electric motors, testing for robustness and safety. Electric and regenerative breaking. Microcontrollers/DSP based control strategies, PI control, cascade control, scalar and vector control, battery bank, sensors, programming tools - IDE, compiler, Assembler, loader, control of various motors for EV applications using power electronics, battery charger, plug- in charger, vehicle to grid and grid to vehicle.

Part 2 : Power Electronics

Diodes, Thyristors, Bipolar Junction Transistors, Metal–Oxide–Semiconductor Field Effect Transistors, Insulated Gate Bipolar Transistors, Power electronics switches, power electronic converters: dc-dc converters and types (buck, boost, buck-bust, fly back etc.), isolated converters, inverters based on MOSFET/IGBT, gate driver circuits and sensors, Basic Principle of DC–DC Converter, Step-Down (Buck) Converter, Steady-State Operation, Output Voltage Ripple, Step-Up (Boost) Converter, Step-Down/Up (Buck–Boost) Converter, DC–DC Converters Applied in Hybrid Vehicle Systems, Isolated Buck DC–DC Converter,

Four-Quadrant DC–DC Converter, DC-DC

Converters: Buck, Boost, Fly-Back converters etc., Isolated Dc-Dc Converters, Tools for controller algorithm development: Simulation tools (MATLAB/VISSIM/ PSIM), Tools for, circuit development (P-spice, Multi Sim), Compilers, Assemblers, Loaders, Debuggers, Emulators etc. Basic Concepts ofDC–AC Inverters, Single-Phase DC–AC Inverter, Three-Phase DC–AC Inverter, BLDC Motor and Control, Operation of BLDC Motor, Torque and Rotating Field Production, BLDC Motor Control, BLDC Motor Torque–Speed Characteristics and Typical Technical Parameters, Sensorless BLDC Motor Control, AC Induction Motor and Control, Basic Principle of AC Induction Motor Operation, Controls of AC Induction Motor, Basic Configuration of PHEV / BEV Battery Charger, PowerFactor and Correcting Techniques, Controls of Plug-In Charger.

Books:

1. Chang Liang Xia,"Permanent Magnet Brushless Dc Motor Drives and Controls" Wiley 2012.
2. Rashid M.H., "Power Electronics Circuits, Devices and Applications", Prentice Hall India,Third Edition, New Delhi, 2011.
3. Bimal K Bose, "Modern Power Electronics and AC Drives", Pearson Education, secondEdition, 2003.
4. Dubey. G.K., "Thyristorised power controllers", New age International, New Delhi, 2002.
5. Bhimbhra P.S., "Power Electronics", Khanna Publishers, New Delhi, 2005
6. Miller. T. J. E., "Brushless Permanent Magnet and Reluctance Motor Drives", ClarendonPress, Oxford, 1989.
7. Kenjo. T and Nagamori. S, "Permanent Magnet and Brushless DC Motors", Clarendon Press,Oxford, 1989.
8. Kenjo. T, "Stepping Motors and their Microprocessor Control", Clarendon Press, Oxford,
9. Robert .L.Boylsted,and Louis Nashelsky, "Electronic Devices and Circuit Theory", PearsonEducation,9th edition,2009.
10. David A Bell, "Fundamentals of Electronic Devices and Circuits", OxfordUniversity Press, 2009.
11. Roy Choudhury and Shail Jain, "Linear Integrated Circuits", 2nd Edition, New AgeInternational Publishers, 2003

6. Vehicle Dynamics and Traction Systems

Introduction to vehicle dynamics - Dynamics of the motor vehicle, Vehicle fixed coordinates system,Earth fixed coordinates system, Details of vehicle systems, wheel angles, Typical data of vehicles.

Tires System,Mechanics of Pneumatic tires-tire forces,Forces and Structure,Longitudinal forces at various slip angles,rolling of tire,Tire models, Estimation of tire road friction, Cornering property.Longitudinal dynamics - Forces and moments on vehicle, Equation of motion, Tire forces, rolling resistance, weight distribution, Tractive effort and Power available from the engine, Calculation of Maximum acceleration Braking torque, Braking Force, Brake Proportioning, Braking Efficiency, Stopping Distance, Prediction of Vehicle performance. ABS, stability control, Traction control.

Lateral Dynamics - Steering geometry, Types of steering systems, Fundamental condition for true Rolling, Development of lateral forces. Steady state handling characteristics. Yaw velocity, Lateral Acceleration, Curvature response & directional stability.
Vertical Dynamics - Human response to vibrations, Sources of Vibration, Suspension systems, Functions of suspension system. Body vibrations: Bouncing and pitching. Doubly conjugate points. Body rolling. Roll center and roll axis, Stability against body rolling.The power delivered by the propulsion unit**,** The aerodynamics of the vehicle, Drive Wheel Motor Torque Calculations, Vehicle resistance, Tire Ground Adhesion and maximum tractive effort, rollingresistance, grade resistance, inertia calculation, Estimation of battery storage capacity and motor hp based on tractive effort calculations, calculation of tractive effort and reactions for different drives, traction control devices.

Books:

1. Thomas D. Gillespie, "Fundamentals of Vehicle Dynamics", 2013, Society of AutomobileEngineers Inc., ISBN: 978-1560911999
2. J. Y. Woung , "Theory of Ground Vehicles", John Willey & Sons, NY.
3. Rajesh Rajamani , "Vehicle dynamics and control", Springer publication.
4. J. G. Giles , "Steering, Suspension & Tyres", Ilete Books Ltd., London.
5. W. Steed , "Mechanics of Road Vehicles", Ilete Books Ltd. London.
6. P. M. Heldt , "Automotive Chassis", Chilton Co. NK.
7. Reza N Jazar , "Vehicle Dynamics : Theory and Application", Springer publication.
8. Automobile Mechanics, “Crouse/Anglin”,TATA Mcgraw-Hill.
9. William H. Crouse., “Automotive Mechanics”, Tata McGraw Hill Publishing House
10. Joseph Heitner, “Automotive Mechanics”, C.B.S Publishers And Distributors
11. Hans Hermann Braess, Ulrich Seiffen, “Handbook of Automotive Engineering “, SAEPublications

7. Sensors and Controls in Electric Vehicles

Feedback, tracking, regulator system, feed forward system. Basic Concepts of control systems like Transfer function, Modelling Pole and zero, Lag - lead network. Standard test signals and order of control system Analysis in time and Frequency Domain. Basic concept of PID controller, and tuning methods. Resistive Potentiometers, stain gauge, LVDT, Capacitive Piezoelectric, Hall Effect sensors,magnetostricitive, magnetoresisitive, Optical displacement sensors, Ultrasonic distance Sensor, Piezoresistive, Linear encoder, Proximity sensors. Rotational Displacement: Revolution counter,Resistive potentiometers, DC tachometer, AC tachometer, optical tachometer, Rotary encoder, eddy current , drag cup type tachometer, magnetic, bridge configuration, Rosettes, Tactile sensors, Piezoelectric sensors Electronic Differential Pressure Sensors Various Temperature sensors and the signal conditioning required like Thermistor, Thermocouples and Pyrometers. Types of sensors for electric drive, Current sensors and signal conditioners. MEMS Sensors for Engine Management, Battery Monitoring Sensors, State of the Charge Sensing, MEMS-Based Sensors for Passenger Safety, MEMS-Based Sensors for Skidding and Rollover Detection, Tire Pressure Sensors, Electronic Stability Control of Vehicles, Sensors for Antitheft, Vehicle Navigation Sensors and Control. Recent Trends in MEMS-Based Sensors in Electric Vehicles. Electric machine

control and the control system interface, effective control of torque production in electric machines. Sub-optimal and optimised supervisory control strategies for off-line and real-time energy management. Sub- optimal and optimised supervisory control strategies for off-line and real-time energy management.

Books:

1. Katsuhiko Ogata, "Modern Control Engineering" 5th edition, Prentice Hall of India PrivateLtd., New Delhi, 2010.
2. Nagrath I J and Gopal.M., "Control Systems Engineering", 5th edition, New Age International(P)Ltd.,Publishers 2008.
3. M. Gopal, "Control Systems: Principles and Design", 3rd Edition, McGraw,Hill, 2008.
4. Benjamin C Kuo, "Automatic Control system", Prentice Hall of India PrivateLtd., New Delhi,2009
5. R.C. Dorf and R.H. Bishop, "Modern Control Systems", 12th Edition, Prentice,Hall, 2010
6. Sawhney.A.K, "A course in Electrical and electronic Measurement and Instrumentation",Dhanpat Rai & Sons, New Delhi, 2008.
7. Albert D Halfride & William D Cooper, "Modern Electronic instrumentation andmeasurement techniques", Prentice Hall of India Pvt Ltd., 2007.
8. Stout MB, "Basic Electrical Measurements", Prentice Hall of India Pvt Ltd., 2007.
9. Rajendra Prasad, "Electrical Measurements & Measuring instruments", C Publishers, 4thEdition , 2004.
10. Cooper W.D & Hlefrick A.D., "Electronic Instrumentation & Measurement Technique", IIIEdition, Prentice Hall of India – 199

8. IoT for Electric Vehicles

Internet of Things: Introduction, Wireless sensor networks need for IoT, Edge resource pooling andcaching, client side control, and configuration, Basics of Networking, Smart objects as building blocks for IoT, Embedded systems platforms for IoT, IO drivers.
Operating system for IoT: requirement of OS, examples: mbed, Contiki, RIOT

IoT Communication Protocols: IPV6, 6LowPAN, CoAP, MQTT, Machine-to-Machine Communications.

Software Defined Networks (SDN): From Cloud to Fog and MIST networking for IoT Communications, Principles of Edge/P2P networking, Cloud and Fog Ecosystem for IoT Review of architecture, Security and privacy in Fog
Database for IoT: OLAP and OLTP, NoSQL databases, Row and column Oriented databases, Introduction to Columnar DBMS CStore, Run: Length and Bit vector Encoding, Integrating Compression, and Query Execution in Columnar databases.
Radar sensor Detectors for vehicle safety: Introduction to Radar sensor detectors, Types (Long range, medium, short range and ultra-short, mechanically scanning LIDAR), Working, benefits,

Intelligent Transport Systems (ITS): Communication standards in IOT for ITS like, MQTT, DDS, AMQP, BLUETOOTH, ZIGBEE, WIFI, Security and surveillance systems

Advanced driver assistance systems (ADAS): ADAS domain controller, Automotive thermal camera, Camera module without processing, Conditionally automated drive controller, Drive assist ECU, Driver monitoring, Driver vital sign monitoring, Front/Rear camera, advance features.
Internet of vehicles and VANET: Types of IOV, Benefits of IOV, Difference between IOV and VANET, Connected cars IoT Transportation, Activity Monitoring.

Books:

1. A Bahaga, V. Madisetti, "Internet of Things- Hands on approach", VPT publisher, 2014.
2. McEwen, H. Cassimally, "Designing the Internet of Things", Wiley, 2013.
3. Cuno Pfister, "Getting started with Internet of Things", Maker Media, 1st edition, 2011.
4. Samuel Greenguard, "Internet of things", MIT Press.

Web resources:

1. https://developer.mbed.org/handbook/AnalogIn
2. http://www.libelium.com/50_sensor_applications/
3. M2MLabs Mainspring http://www.m2mlabs.com/framework

List of Practical:

1. Experiments on interfacing (eg. transmitting the measure physical value from the sensor node over the Air, Reading Temperature and Relative Humidity value from the sensor, Proximity detection with IR LED, Reading Light intensity value from light sensor)
2. Experiments on interfacing with –DAQ (IO Expander, Relay Control, I2C based 12 channel ADC)
3. WSN based Applications for establishing various network topologies
4. Study and Implement IoT Communication protocol (MQTT) using Raspberry Pi

Electives:

8 a) Thermal Design and Management of EV systems

Review of Thermodynamics, Fluid Mechanics, and Heat Transfer. Motor Sizing vs Heat Generation, Operational Temperature Limitations of Electrical Insulation, Design concepts for Heat Extraction inMotors for EV systems, Modelling and simulation of heat transfer in motors, Rendering of Heat extraction solutions, Sensors and Protection solutions. Thermal control in vehicular battery systems: battery performance degradation at low and high temperatures, Passive, active, liquid, air thermal control system configurations for HEV and EV applications, Battery Heat Transfer, Introduction to battery modelling, tracking current demand, voltage, and State of Charge as functions of time for given drive cycles, Development of thermodynamic relationships for cell heat generation, Lumped cell and

pack models for transient temperature response to drive cycles , Model parametric study results, Determination of convection and friction coefficients for air and liquid systems in various geometric configurations, flow around cylinders, flow between plates, flow through channels, thermal system model and parametric study, Temperature control and heat transfer using phase change materials, Thermal Management of Power Electronics components and systems. Thermal Management of Power train and electric machines. Model based simulations of thermal systems and CFD Analysis of battery packs, electric motors and power electronic systems. Thermal and heat transfer considerations in Supercapacitors. Thermodynamics, heat generation and cooling of hydrogen fuel cell systems.

Books:

1. Nag. P.K, Engineering Thermodynamics, 5th Edition, Tata McGraw Hill Education,New Delhi,2013.
2. Jerry Sergent, Al Krum, Thermal Management Handbook: For Electronic Assemblies, 1998,Mc Graw- Hill.
3. Vehicle thermal Management Systems Conference Proceedings, 1st Edition; 2013, CoventryTechno centre, UK
4. Younes Shabany, Heat Transfer: Thermal Management of Electronics, 2010, CRC Press.
5. T. Yomi Obidi, Thermal Management in Automotive applications, 2015, SAEInternational

8 b) Safety and Automotive Standards

Standards Roadmap for Electric Vehicles - SAE; UL; IEC - Performance and Safety

Applicable Battery Standards - Battery Transportation & Safety - Battery Pack: SAE J2464/J2929- Compare and Contrast the various industry standardsVehicle and Charging Standards – FMVSS

Performance Standards - Charging interfaces; SAE J1772 charge protocol - USABC/FREEDOMCAR - Battery Characterization and life cycle testing - Video Demonstrations - Mechanical Shock; Short Circuit; Overcharge; - Fire Exposure

Supply standards:

Electric Vehicle Supply Equipment (EVSE) Descriptions - Governing Bodies for Regulations - Certification Requirements and Options

Electric Vehicle Performance Standards:

AIS 038: Construction Functional safety tests, AIS 039: Measurement of electric energy, AIS040: Measurement of range, AIS041: Measurement of Max power and 30 Minute powers, AIS048:Traction battery used in electric vehicles, AIS004 Part 1 & Part 3"Electromagnetic radiation from Motor Vehicle & electromagnetic compatibility of motor vehicle

8 c) Energy management and vehicle integration Modeling electrical sub systems

Systems modelling and Simulation - Modelling methodologies for HEV energy management. -Control strategies for energy management and drive ability. Electrical System Design - High voltage architecture options within HEVs and component selection. - Power electronics, including DC-DC converters (unidirectional and bidirectional) and machine drives. - Electrical machine designs, performance prediction, ancillary requirements and manufacturability. - Battery and ultra-capacitor technologies, vehicle integration, and performance characteristics (materials, performance, reliability, safety, recycling).

Regenerative Braking - Real-world energy storage requirements and driver behaviour assessment. - Brake feel and customer acceptance - Mechanical System Design: New transmission options including split path design approaches and systems (planetary, CVT, dual clutch). – Engine calibration and optimisation. - New engine cycles and fuelling options. - Mechanical energy storage systems such as flywheels and hydraulic accumulators.

Top down and bottom up systems thinking for Engineering & Integration; System Engineering for xEVs: Crucial Technologies that go in to system engineering of xEV systems; new technologies that can disrupt the evolution of xEV systems; - India Specific Vehicle Population - xEV Components to System Assembly - 2W EV Vehicle Systems Engineering & Integration - 3W EV Vehicle Systems Engineering & Integration - 4W EV 1 ton class Cargo systems - Off Road vehicle Systems (in plant cargo systems, Golf Carts etc) - 4W xEV hybrid systems integration - Buses and Large Vehicle Systems Engineering Solutions.

Systems Integration and Analytical Tools

Vehicle Development Process Overview - Requirements Development - Hybrid Components and Architectures - Major components in hybrid Power Train - Controls integration - Component sizing and integration trade-offs - Hybrid architecture overview - System Design and Development Considerations - Vehicle integration (ex. performance, drivability, NVH) - Power Train integration (ex. energy, power, efficiency, torque, thermal management) - HV/LV electrical systems (ex. safety, DC/AC voltage, charging system, efficiency, cables, connectors, fuses, - Chassis (ex. braking,vehicle dynamics, powertrain to chassis dynamics, ride and handling, steering, fuel system) - Displays/information (ex. messages, information aids, usage efficiency aids) - HVAC (ex. HVcompressor, HV heater, cabin comfort, efficiency considerations) - Verification and ValidationConsiderations - Verification and validation test requirements and planning - Component test considerations - System test considerations - Fleet testing.

Books:

1. Iqbal Husain,"*Electric and Hybrid Vehicles –Design Fundamentals"*, CRC Press
2. Mehrdad Ehsani, Yimin Gao, Sebastian E.Gsay, Ali Emadi, *"Modern Electric, Hybrid Electricand Fuel Celll vehicles-Fundamentals - Theory and Design"*, CRC Press
3. *"Bosch' Automotive Handbook",* 8th Edition

8 d) Advanced Electric Drives

Review of drive fundamentals, various quadrants of electric drives, types of industrial loads, duties of electric motors, heating and cooling, calculations of load on motor. Review of fundamentals of DC Drives and Induction motor drives. Converters topologies for low, medium and high power drives. Direct torque and vector control methods for AC drives. Sensor and Senseless control, Rippleminimization techniques for DTC. Drives for the slip ring induction machine, DFIG and its four quadrant control, Construction and working of BLDC, PMSM, Synchronous Reluctance and Switched Reluctance motors. Speed control of these motors. Stepper motor drives. Construction and working of axial flux and transverse flux reluctance and permanent magnet machines, linear synchronous machines.

Books:

1. R. Krishnan, 'Switched Reluctance Motor Drives – Modeling, Simulation, Analysis, Design andApplication', CRC Press, New York, 2001.
2. T. Kenjo and S. Nagamori, 'Permanent Magnet and Brushless DC Motors', Clarendon Press,London, 1988.
3. M.H. Rashid "Power Electronics", 3rd Ed, PHI Pub. 2004.
4. G. K. Dubey, "Fundamentals of Electrical Drives", Narosa Publishing house
5. B. K. Bose, "Modern Power Electronics and AC Drives", Pearson Education, Asia, 2003

8 e) Embedded Systems and In-Vehicle Communication Protocols

Embedded systems, classification, Automotive grade microcontrollers, Renesas RL78 and RZ series performance comparisons, Renesas RZ series ARM architecture—technology overview, Architectural Features of ARM Cortex A7 series: Block Diagram, CPU modes, register organization,ROM, RAM, timers, data and address bus, Memory and I/O interfacing concepts, memory mapped I/O. CISC Vs RISC design philosophy. Interfacing of peripherals using Renesas ARM Microcontroller: LED, sensors, ADC, Timer, PWM, UART, SPI, I2C, CAN, LIN. Introduction of ARM RZ series development tools (software and hardware).
Automotive standards and protocols: CAN protocol, LIN protocol, Flex Ray, OBD-II, Byteflight, Automotive Audio Bus, (A^2B) protocol, AFDX, etc. Automotive standards like AUTOSAR, MISRA-C, Hardware in loop testing of Automotive ECU using ARM RZ series microcontroller, Simulation of Adaptive cruise control, speed control, etc.

Books:

1. James Larminie, John Lowry, Electric Vehicle Technology Explained, Wiley, 2003
2. Sloss Andrew N, Symes Dominic, Wright Chris, ―ARM System Developer's Guide: Designingand Optimizing‖, Morgan Kaufman Publication,2004.
3. Young A.P. & Griffiths, " Automotive Electrical Equipment" , ELBS & New Press-1999
4. Tom Weather Jr. &Cland c. Ilunter, "Automotive computers and control system" Prentice HallInc., New Jersey
5. Crouse W.H., "Automobile Electrical Equipment" ,McGraw Hill Co. Inc., New York, 1995.
6. Bechhold, " Understanding Automotive Electronic", SAE,1998.
7. Robert Boshe " Automotive Hand Book" (5th edition),2000.

8 f) FEA and CFD for EV Analysis

Introduction to different approaches used in FEA such as direct approach, Variational approach, weighted residual (Galerkin). Displacement function, Global and local coordinate systems, Order of element, primary and secondary variables, shape functions and its properties. Formulation of elemental stiffness matrix and load vector for spring, bar, beam, truss and Plane frame. Transformation matrix for truss and plane frame, Assembly of global stiffness matrix and loadvector, Properties of stiffness matrix, half bandwidth, Boundary conditions elimination method and penalty approach, Symmetric boundary conditions, Stress calculations. Finite Element Analysis of Automotive systems and powertrains with FEA tools.

Introduction to Finite Volume Method, One-dimensional and two-dimensional Diffusion and Convection problems. SIMPLE Algorithm, Flow and Heat Conduction Problem. Analysis with CFD tools: steps in pre-processing, geometry creation, mesh generation, selection of physics and material properties, specifying boundary condition, Physical Boundary condition types, initialising and solution control for the solver, Residuals, analysing the plots of various parameters. Reynolds Averaged Navier-Stokes equations (RANS), Thermal Analysis of battery pack and power electronics components using CFD.

Books:

1. Cook, R. D., Malkus, D. D. and Plesha, M. E., Concepts and Applications of Finite ElementAnalysis 2. Seshu, P., Textbook of Finite Element Analysis
2. Seshu, P., Textbook of Finite Element Analysis
3. Chandrupatla, T. R. and Belegundu, A. D., An Introduction to the Finite Element Method inEngineering
4. S. V. Patankar, Numerical Heat Transfer and Fluid Flow, McGraw-Hill
5. Versteeg, H. K. and Malalasekara, W. (2008). Introduction to Computational FluidDynamics: The Finite Volume Method. Second Edition (Indian Reprint) Pearson Education.
6. Ansys Fluent Manual
7. Ansys Structural Analysis Manual

8 g) Design Validation Process

Validation methods - High-Level Validation and verification tests (Creep, Coast, repeated acceleration tests, Top speed test, steady speed test, maximum acceleration test, deceleration test), Zero Emission Vehicle (ZEV) capability test, hardware in-loop test, Real-time ECU test analysis.

Mechanical Design validation - Design validation of vehicle balance, validation study of vehicle drive train, design, development and validation of a complete in wheel motor assembly prototype. torque/speed coupling, and vehicle dynamics, Optimize cost, performance, and reliability with advanced stress, sensitivity, and statistical analyses, noise and vibration simulation

Electrical Design validation - Design methodology of batteries for PHEV and EV, validation of vehicle energy storage and power delivery systems, range and energy storage validation, Test the BMS/ battery parameters, learn the selection methodologies of motors, Sizing

validation - motor sizing validation, EMI/EMC reduction methodologies and testing , Design, test, and verify control strategies, power management, validation of vehicle electronics, controls and instrumentation, Eco- design and validation of EVs , Design and Verification of Hybrid and Electric Vehicles

Books:

1. Electric and Hybrid Vehicles: Design Fundamentals by Iqbal Husain
2. Convert It! by Michael P. Brown
3. Electric Vehicle Technology Explained by James Larminie

ONE YEAR FULL TIME POST GRADUATE DIPLOMA IN PRODUCT LIFECYCLE MANAGEMENT (PG-PLM)

About the Course

In today's rapidly evolving industrial landscape of I4.0, efficient management of product lifecycles is critical for organizations to stay competitive. Product Lifecycle Management (PLM) plays a pivotal role in streamlining processes, reducing time-to-market, and ensuring product quality. To address the growing demand for skilled PLM professionals, there is requirement of a comprehensive PLM course, encompassing software training, lab practices, and internship projects. Industry expects universities to impart skills related to PLM processes.

The need for proficient PLM professionals is escalating across various industries including manufacturing, automotive, aerospace, and consumer goods. However, there's a notable gap in the availability of specialized training programs tailored to PLM and industry requirements. This course aims to bridge this gap by equipping students with the necessary knowledge and skills to excel in PLM roles.

The PLM course will cover a wide array of topics including but not limited to: Introduction to Product Lifecycle Management, PLM Software Tools and Applications, Data Management and Version Control, Collaborative Product Development, Change Management, Integration with Enterprise Systems, - Project Management in PLM Context etc..

The course will be delivered through a combination of offline and online lectures to ensure flexibility and accessibility for students and subject experts. Additionally, hands-on lab practices will be conducted to provide practical experience with PLM software tools. Furthermore, students will undertake internship projects with industry partners, enabling them to apply their knowledge in real-world scenarios and gain valuable industry exposure.

Upon completion of the PLM course, graduates will be well-equipped to pursue a multitude of rewarding career opportunities. PLM professionals are in high demand across industries, with roles such as PLM Analyst, PLM Consultant, Product Data Manager, and PLM Administrator offering lucrative career prospects. By catering to the industry's demand for proficient PLM professionals, this course will not only enhance the employability of graduates but also contribute to the continued advancement of organizations leveraging PLM practices.

STRUCTURE OF ONE YEAR FULL TIME POST GRADUATE DIPLOMA IN PRODUCT LIFECYCLE MANAGEMENT (PG-PLM)

Semester I

Sr. No.	Course code	Course Name	Teaching Scheme				Credits
			L	T	P	S	
1	PGPLM1	PLM an PDM Fundamentals (36)	3	0	0	3	3
2	PGPLM2	Business Process Management (36)	3	0	0	3	3
3	PGPLM3	PLM Functional (36)	2	1	0	2	3
4	PGPLM4	PLM Administration (36)	2	1	0	2	3
5	PGPLM5	PLM Customization (36)	2	1	0	4	3
6	PGPLM6	PLM Functional Lab (48)	0	0	4	0	2
7	PGPLM7	PLM Administration Lab (48)	0	0	4	0	2
8	PGPLM8	CAD/CAE Lab (24)	0	0	2	0	1
9	PGPLM9	Programming, web and Networking Technologies Lab (24)	0	0	2	0	1
10	PGPLM10	PLM Customization Lab (24)	0	0	2	0	1
11	PGPLM11	Project I	0	0	0	2	6
		Total	12	3	12	16	25
		Total Academic Engagement and Credits	**27**				**28**

Semester II

Sr. No.	Course code	Course Name	Teaching Scheme				Credits
			L	T	P	S	
12	PGPLM12	Industry practices and PLM Implementation	3	0	0	3	3
13	PGPLM13	Seminar	0	0	0	2	1
14	PGPLM14	Industry internship Project II	0	0	0	18	18
		Total	0	0	0	21	22
		Total Academic Engagement and Credits	**3**				**22**
Course Total Credit							**50**

Course: PLM an PDM Fundamentals

Course Code	PGPLM1	**Scheme of Evaluation**	CE & ESE

Teaching Plan	3-0-0-3 = 6	**T1 & T2**	20 Each
Credits	3	**ESE**	60

Course Objectives: Upon completion of this course, students will be able to:

1. Understand the fundamental concepts, significance, and benefits of Product Lifecycle Management (PLM) and Product Data Management (PDM) in modern industries.

2. Recognize the components, elements, and key management issues surrounding PLM and PDM implementation.

3. Analyze the integration of Industry 4.0 technologies with PLM and PDM systems and their impact on digital transformation.

4. Develop comprehensive strategies for PLM and PDM implementation aligned with company vision and objectives.

5. Implement advanced techniques such as data analytics, predictive maintenance, and digital twin technology to optimize product lifecycle processes.

Syllabus:

Unit No.	Content	Lecture	Self-study
01.	**Introduction to Product Lifecycle Management (PLM)** Background and Overview of Product Lifecycle Management, Need, Benefits, and Significance of PLM, Components and Elements of PLM, Emergence of PLM Strategies, Customer Involvement and PLM Vision, Principles for Developing and Implementing PLM Strategy, Integration of Industry 4.0 technologies with PLM systems and their impact on digital transformation.	**6L**	**3S**
02	**Product Lifecycle Environment** Understanding Product Data and Product Workflow, Link between Product Data and Product Workflow, Key Management Issues around Product Data, Company's PLM Vision and Strategy Alignment, Developing a Comprehensive PLM Strategy, Change Management for PLM Implementation, Optimizing product lifecycle processes using data analytics techniques for analyzing product lifecycle data and implementing predictive maintenance strategies.	**6L**	**2S**

03	**Components and Practices of PLM** Different Phases of Product Lifecycle and Corresponding Technologies, Product Development Processes and Methodologies, Foundation Technologies and Standards for PLM, Interoperability standards and their significance, Information Authoring Tools and Core Functions in PLM, Functional Applications such as Configuration Management, Human Resources and Organizational Structures in PLM	**6L**	**2S**
04	**Introduction to Product Data Management (PDM)** Benefits and Terminology of PDM, CIM Data and Engineering Data Management, Architecture and Functions of PDM Systems, Engineering Workflow and PDM Acquisition, Resolving Data Issues and Product Data Interchange, Need for Collaboration and Internet Developments in Client Server Computing, Data governance frameworks and cybersecurity measures specific to PDM systems	**6L**	**2S**
05	**Components and Configuration Management in PDM** Components of a Typical PDM Setup: Hardware and Document Management, Creation and Viewing of Documents, Parts, and Documents Version Control, Configuration Management: Base Lines and Product Structure, Generic Products and Variants: Product Configuration and Variant Creation, Projects, Roles, and Automation of Information Flow in PDM, Change Management: Change Issue, Request, Investigation, Proposal, and Activity, Digital twin technology and its application in virtual prototyping, simulation, and product optimization	**6L**	**2S**
06	**Deployment Models and Advanced Topics in PDM** Defining Deployment Methodology and Performance Considerations, Network Latency and Scalability in PDM Systems, Standard Technologies Available for PDM Deployment, Advanced Topics: Digital Twins, Simulation Techniques, and Virtual Prototyping, Business Process Innovation and Implementation in PDM Environment, Ethical Considerations and Societal Impacts of PDM and PLM Integration, cloud deployment models	**6L**	**2S**

Course Outcomes: Course Outcomes: Students will be able to

1. Understand the link between product data and workflow in the product lifecycle environment.

Comprehend the integration of Industry 4.0 technologies with PLM and PDM systems.

2. Apply data analytics techniques for analyzing product lifecycle data and implementing predictive maintenance strategies. Apply digital twin technology for virtual prototyping, simulation, and product optimization.

3. Analyze different phases of the product lifecycle and corresponding technologies. Analyze the foundation technologies, standards, and functional applications in PLM and PDM.

4. Evaluate the effectiveness of PLM and PDM strategies in optimizing product lifecycle processes. Evaluate the ethical considerations and societal impacts of PDM and PLM integration.

5. Design comprehensive PLM and PDM strategies tailored to specific industry needs. Develop innovative approaches for business process innovation and implementation in PDM environment.

Reference Books:

1. T. Williams, "The Principles of Product Development Flow: Second Generation Lean Product Development," Celeritas Publishing, United States, 2009.

2. M. Grieves, "Product Lifecycle Management: Driving the Next Generation of Lean Thinking," McGraw-Hill Education, United States, 2006.

3. J. Stark, "Product Lifecycle Management: 21st Century Paradigm for Product Realisation," Springer, United States, 2011.

4. M. Weske, "Business Process Management: Concepts, Languages, Architectures," Springer, Germany, 2018.

5. J. Stark, "Product Lifecycle Management: 21st Century Paradigm for Product Realisation," Springer, United States, 2011.

6.2. R. H. Hayes, "Managing and Using Information Systems: A Strategic Approach," John Wiley & Sons, United States, 2020.

7. M. N. Waldron, "Competitive Manufacturing Management: Continuous Improvement," Springer, United States, 2019.

8. M. O. Efe, "Enterprise Architecture and Integration: Methods, Implementation, and Technologies," IGI Global, United States, 2013.

Course: BUSINESS PROCESS MANAGEMENT

Course Code	PGPLM2	**Scheme of Evaluation**	CE & ESE
Teaching Plan	3-0-0-3 = 6	**T1 & T2**	20 Each
Credits	3	**ESE**	60

Course Objectives: Upon completion of this course, students will be able to:

1. Evaluate and analyze business processes within the context of Product Lifecycle Management (PLM) and Industry 4.0.

2. Design and implement efficient business processes utilizing modern PLM software tools and techniques.

3. Synthesize theoretical knowledge with practical skills to address real-world challenges in PLM and Industry 4.0 environments.

4. Collaborate effectively in interdisciplinary teams to develop innovative solutions for process improvement and digital transformation.

5. Critically assess the ethical and societal implications of business process management in the context of Industry 4.0.

Syllabus:

Unit No.	**Content**	**Lecture**	**Self-study**
01.	**Introduction to Business Process Management and PLM** Overview of business process management principles, Introduction to Product Lifecycle Management (PLM), Role of PLM in digital transformation and Industry 4.0	**6L**	**3S**
02	**Process Modeling and Analysis** Techniques for process modelling, Process analysis methods, Case studies and practical exercises	**6L**	**2S**
03	**Process Management** Design process management, Project and Change management in the context of PLM and Industry 4.0,	**6L**	**2S**
04	**Process Optimization and Automation** Principles of process optimization, Automation technologies in Industry 4.0, Implementation of process automation solutions	**6L**	**2S**

05	**Digital Twin and Simulation** Concept of digital twin in PLM, Simulation techniques for process optimization, Virtual prototyping and validation	**6L**	**2S**
06	**Business Process Innovation and Implementation** Strategies for business process innovation, Ethical considerations and societal impacts of business process management	**6L**	**2S**

Course Outcomes: Students will be able to

1. Explain the significance of business process management in the context of PLM and Industry 4.0. Interpret the role of digital technologies in transforming business processes.

2. Utilize PLM software tools to model, simulate, and optimize business processes. Implement process automation solutions using Industry 4.0 technologies such as IoT and AI.

3. Assess the effectiveness and efficiency of existing business processes in the context of PLM and Industry 4.0. Analyse data generated from PLM systems to identify areas for process improvement.

4. Critique different approaches to process optimization and automation, considering their suitability for specific organizational contexts. Evaluate the impact of business process management initiatives on organizational performance and competitiveness.

6. Design innovative business processes that leverage advanced PLM capabilities and Industry 4.0 technologies. Develop implementation plans for integrating PLM and business process management strategies within organizations.

Reference Books:

1. M. Grieves, "Product Lifecycle Management: Driving the Next Generation of Lean Thinking," United States: McGraw-Hill Education, 2006.

2. M. Laguna and J. Marklund, "Business Process Modeling, Simulation and Design," United States: Pearson, 2017.

3. R. Brown, B. Krishnamachari, and T. Q.S. Quek, "Introduction to Industry 4.0: The Industrial Internet of Things," United States: CRC Press, 2019.

4. T. M. Siebel, "Digital Transformation: Survive and Thrive in an Era of Mass Extinction," United States: RosettaBooks, 2019.

5. J. A. McDonald and M. Grieves, "Digital Twins: Principles, Practices, and Real-World Applications," United States: CRC Press, 2020.

Course: PLM FUNCTIONAL

Course Code	PGPLM3	**Scheme of Evaluation**	CE & ESE
Teaching Plan	2-1-0-2 = 5	**T1 & T2**	20 Each
Credits	3	**ESE**	60

Course Objectives: Upon completion of this course, students will be able to:

1. Design and implement efficient business processes utilizing modern PLM software tools and techniques.

2. Synthesize theoretical knowledge with practical skills to address real-world challenges in PLM and Industry 4.0 environments.

Syllabus:

Unit No.	**Content**	**Lecture**	**Tutorials**	**Self-study**
01.	Overview of popular PLM software, Teamcenter PLM terms and concepts, rich client user interface,	**4L**	**2T**	**3S**
02	Locate, view, and report on product data, Create Teamcenter PLM items and update properties, Protect and access product data	**4L**	**2T**	**2S**
03	View, build, and edit product structure, standard product data in product structures	**4L**	**2T**	**2S**
04	Locate and view visualization data and perform basic markup and measurement functions	**4L**	**2T**	**2S**
05	Assign tasks using Teamcenter PLM, perform tasks, and track the completion of tasks in a workflow process,	**4L**	**2T**	**2S**
06	Find, interrogate, and create change objects, Verify the change configuration	**4L**	**2T**	**2S**

Course: PLM ADMINISTRATION

Course Code	PGPLM4	**Scheme of Evaluation**	CE & ESE
Teaching Plan	2-1-0-2 = 5	**T1 & T2**	20 Each
Credits	3	**ESE**	60

Syllabus:

Unit No.	Content	Lecture	Tutorials	Self-study
01.	Application Administration Processes, Managing the Teamcenter Organization,	**4L**	**2T**	**3S**
02	Data Security Implementation and Best Practices, Managing Projects to Control Access to Data	**4L**	**2T**	**2S**
03	Managing Preferences, Custom Query Definitions, Managing Custom Report Definitions, PLM XML Import Export, Workflow Process Development and Administration, Rich Client Interface Configuration Using Stylesheets	**4L**	**2T**	**2S**
04	Overview of Teamcenter PLM's two-tier and four-tier architecture, PLM database creation such as Oracle, MSSQL, Corporate server installation, Common licensing server	**4L**	**2T**	**2S**
05	Overview of File Management System (FMS), Installation of Two-tier rich client, Server manager for Teamcenter PLM and Teamcenter J2EE Web Tier, Teamcenter .NET Web tier and Teamcenter PLM server manager	**4L**	**2T**	**2S**
06	Four-tier rich client installation by using Over-the-web Install and TEM, Business Modeler IDE installation, FSC performance cache server, Administering the in-product system, Dispatcher, Store and Forward, Embedded visualization for the four-tier and two-tier rich clients, PLM NX Integration for the two-tier and four-tier rich clients, installing and accessing Teamcenter online help	**4L**	**2T**	**2S**

Course: PLM CUSTOMIZATION

Course Code	PGPLM5	**Scheme of Evaluation**	CE & ESE
Teaching Plan	2-1-0-2 = 5	**T1 & T2**	20 Each
Credits	3	**ESE**	60

Syllabus:

Unit No.	**Content**	**Lecture**	**Tutorials**	**Self-study**
01.	Data models and BMIDE configuration, C / C++ programming, Java, ReactJS, HTML, Networking and Security	**4L**	**2T**	**40S**
02	**Business Modeler Administration** Business Modeler IDE process, Business objects and properties, Lists of values in BMIDE, Options, constants, and rules in BMIDE, Users, groups, and roles in BMIDE, Preferences in BMIDE, Organizations in BMIDE, Data security in BMIDE, Process templates in BMIDE	**4L**	**2T**	**2S**
03	**Server Customization -I** Overview of Teamcenter PLM Server Side (ITK) Customization, ITK Overview and Batch Programs, SOA Overview and Batch Programs,	**4L**	**2T**	**2S**
04	**Server Customization -II** Workflow Handlers, Property Operations, Application Extensions, Services and Service Operations, Rich Client Customization, Rich Client Style Sheets	**4L**	**2T**	**2S**
05	**Teamcenter Client Customization** Rich client Configuration and dialog, StyleSheets, Kernel API and its components, Service Oriented Architecture (SOA), Teamcenter Services framework, Teamcenter Services Organization,	**4L**	**2T**	**2S**

	BMIDE for Teamcenter Services, Generated Client Stub- bindings			
06	**Active Workspace client (AWC) Configuration and Customization** Overview Active Workspace, Gateway Tiles, Active Workspace Icons, Indexing in Teamcenter, Active Workspace Style Sheets, Declarative and GWT, CSS Modules, Custom Themes	**4L**	**2T**	**2S**

Course: PLM FUNCTIONAL LAB

Course Code	PGPLM6	**Scheme of Evaluation**	CE & ESE
Teaching Plan	0-0-4-0 = 4	**T1 & T2**	20 Each
Credits	1	**ESE**	60

Syllabus:

Unit No.	**Content**	**Practical**	**Self-study**
01.	**Rich client Navigation** Navigating the user interface of the rich client to perform various activities, customization of Toolbars, Using My Work list, Teamcenter Mail and applications like Workflow Viewer to view and perform allocated tasks.	**8L**	**2S**
02	**Item and dataset creation** Create new items and datasets	**8L**	**2S**
03	**Structure creation** Create new structures combining various items, manage BOM using Revision Rules and Modular Variants	**8L**	**2S**
04	**Workflow assignment** Access workflow features to engage in the change management process	**8L**	**2S**
05	**Business objects** Viewing their properties, Create and manage default business objects like Item, Dataset, etc.	**8L**	**2S**
06	**Miscellaneous**	**8L**	**2S**

Course: PLM ADMINISTRATION LAB

Course Code	PGPLM7	**Scheme of Evaluation**	CE & ESE
Teaching Plan	0-0-4-0 = 4	**T1 & T2**	20 Each
Credits	2	**ESE**	60

Syllabus:

Unit No.	**Content**	**Lecture**	**Self-study**
01.	**Setting up organization in Teamcenter** Defining the organizational structure like users, roles and groups in Teamcenter for executing the business process, Query Builder, organising the data based on the global standards, creating organization wide preferences, Defining projects and objects, miscellaneous tasks performed by the admin	**8L**	**2S**
02	Installation and configuration of database server (Oracle), Teamcenter 2-Tier installation, Rich client and BMIDE using Teamcenter Environment Manager (TEM), Teamcenter 4-Tier installation, Teamcenter active workstation installation, Using Over The Web (OTW) installer to load ICDs and install Web Tier, Distribution Server instance	**8L**	**2S**
03	**PLM Business Modeler Administration (BMIDE) Projects** Conceptualization and creation of a data model, Updating of existing data model	**8L**	**2S**
04	**Teamcenter PLM Server Side (ITK) Customization** create new data models and maintain them, writing new ITK utilities for data creation and modification, writing a DLL and integrating with Workflow designer using BMIDE & ITK	**8L**	**2S**
05	**PLM Client Side (RAC) Customization** Rich client stylesheet customization, Rich client plugin development, Teamcenter services- accessing SOA APIs, Services customization to extend the Teamcenter SOA solution	**8L**	**2S**
06	**Teamcenter PLM Active Workspace (AWC) Customization** Setup active workspace environment, Declarative commands, SOA access	**8L**	**2S**

Course: PROJECT I

Course Code	PGPLM8	**Scheme of Evaluation**	Report and Presentation
Teaching Plan	0-0-0-2 = 2	**Mid term review**	30
Credits	6	**ESE**	70

1. Apply knowledge and skills acquired throughout the program to a real-world PLM project.
2. Present findings and recommendations in the form of a detailed project report.

Course: INDUSTRY PRACTICES AND PLM IMPLEMENTATION

Course Code	PGPLM9	**Scheme of Evaluation**	CE & ESE
Teaching Plan	3-0-0-3 = 6	**T1 & T2**	20 Each
Credits	3	**ESE**	60

Course Objectives: Upon completion of this course, students will be able to:

Syllabus:

Unit No.	**Content**	**Lecture**	**Self-study**
01.	Ongoing Industry practices and PLM Implementation	**6L**	**3S**
02	Ongoing Industry practices and PLM Implementation	**6L**	**2S**
03		**6L**	**2S**
04		**6L**	**2S**
05	Cloud based data base management AI for PLM	**6L**	**2S**
06		**6L**	**2S**

Course: PROJECT II

Course Code	PGPLM10	**Scheme of Evaluation**	Report and Presentation
Teaching Plan	0-0-0-8 = 8	**Mid term review**	30
Credits	15	**ESE**	70

1. Industry internship to gain practical experience in PLM implementation.
2. Collaborate with industry partners to solve a specific problem or optimize a product lifecycle.
3. Present findings and recommendations in the form of a detailed project report.