SRM University

M.Tech Automotive Hybrid Systems Engineering

(Collaborative program with NFTDC, Hyderabad)

(Proposed curriculum from the academic year 2015-16)

Core courses

COURSE CODE	COURSE NAME	L	T	P	C
AH2101	Automotive Engine Systems	3	0	2	4
AH2102	Automotive Chassis & Transmission Systems	3	2	0	4
ME2105	Mechanical Vibrations	3	0	2	4
AH2103	Automotive Electronics for xEVs	3	0	2	4
AH2104	HEV / xEV System Design Architecture	3	2	0	4
AH2105	xEV Motor drives and controllers	3	0	3	4

Optional / Elective Courses (Program Electives)

COURSE CODE	COURSE NAME	L	T	P	C
AH2121	Materials and Manufacturing processes for Automotive systems	3	0	0	3
AH2122	Thermal Management of Hybrid systems	3	0	0	3
AH2123	Energy Devices for xEV Drives	3	0	0	3
AH2124	Advanced Power Electronics for xEVs	3	0	0	3
AH2125	Instrumentation and Control	3	0	0	3
AH2126	System Engineering and Integration	3	0	0	3

Supportive courses

COURSE CODE	COURSE NAME	L	T	P	C
*MA2007	Applied Mathematics for Engineers	3	0	0	3
AH2191	Digital Electronics and Networks (for Mechanical Engineering graduates)	3	0	0	3
AH2192	Computer Aided Design (for Non-Mechanical Engineering graduates)	3	0	0	3
AH2193	Combustion Thermodynamics and Heat Transfer (for Non-Mechanical Engineering graduates)	3	0	0	3

***** Compulsory

Other Courses

COURSE CODE	COURSE NAME	L	T	P	C
AH2194	Project Management - I	1	0	0	1
AH2195	Project Management - II	1	0	0	1
AH2197	Seminar	0	0	2	1
AH2198	Project work Phase I	0	0	12	6
AH2199	Project work Phase II	3	0	36	18

L - Lecture hours, T - Tutorial hours, P - Practical Hours, C - Credits

Guidelines for choosing courses

Category	No. of Courses				Credits
	I Semester	II Semester	III Semester	IV Semester	
Core courses	3	3	-	-	24
Optional / Elective Courses	1	1	2	1	15
Supportive courses	1	1	-	-	6
Seminar / other courses (1 credit)	1	1	1	-	3
Project work Phase I	-	-	1	-	6
Project work Phase II	-	-	-	1	18

Total number of credits to be earned for the award of degree : 72

SRM University

M.Tech Automotive Hybrid Systems Engineering

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(Proposed syllabus from the academic year 2015-16)

Core courses

		L	T	P	C
AH2101	**AUTOMOTIVE ENGINE SYSTEMS**	**3**	**0**	**2**	**4**
	Total Contact Hours-75				
	Prerequisites				
	Nil				
PURPOSE					
The purpose of this course is to impart knowledge about automotive engine systems.					
INSTRUCTIONAL OBJECTIVES					
1.	To understand intake and exhaust systems				
2	To understand carburetion and injection in engines				
3	To understand supercharging, turbo charging and scavenging in engines				

UNIT-I - INTAKE AND EXHAUST SYSTEMS

Intake system components - Discharge coefficient, Pressure drop - Air filter, intake manifold, Plenum, Ram pressure charging, Connecting Pipe - Exhaust system components - Exhaust manifold and exhaust pipe - Spark arresters - Exhaust mufflers, Types, operation.

UNIT II - CARBURETION AND GASOLINE INJECTION

Properties of air-fuel mixtures - Mixture requirements for steady state and transient operation, Mixture formation studies of volatile fuels, design of elementary carburetor Chokes - Effects of altitude on carburetion

Petrol injection - Open loop and closed loop systems, mono point, multi point and direct injection systems - Principles and Features, Electronic fuel injection systems.

UNIT III - DIESEL INJECTION SYSTEMS

Requirements - Air and solid injection - Function of components - Jerk and distributor type pumps. Pressure waves - Injection lag - Unit injector - Mechanical and pneumatic governors - Fuel injector - Types of injection nozzle - Nozzle tests - Spray characteristics - Injection timing - Factors influencing fuel spray atomization, penetration and dispersion of diesel - pump calibration-CRDI system components and working.

UNIT IV -LUBRICATION AND COOLING SYSTEMS

Need for cooling system – components-Thermosyphon and Forced circulation-pressure cooling system - properties of coolant, additives for coolants

Need for lubrication system - Mist lubrication system, wet and dry sump lubrication - Properties of lubricants, Grading of Lubrication oil-consumption of oil.

UNIT V - SUPERCHARGING AND SCAVENGING SYSTEMS

Effects on engine performance - engine modification required - Thermodynamics of supercharging and turbo charging - Turbo lag- Turbocharging methods – VGT- Engine exhaust manifold arrangements-Types and methods of supercharging-Limitations.

Classification of scavenging systems -scavenging pumps-Mixture control through Reed valve induction - Shankey diagram -perfect displacement, perfect mixing.

REFERENCES:

1. Ganesan V, *Internal Combustion Engines*, 4th edition, Tata McGraw Hill Book Cop., 2015
2. Mathur. M. L, and Sharma. R. P., *A course in Internal Combustion Engines*, Dhanpat Rai Publications Pvt.Ltd., 1998
3. Ramalingam, K. K. *Internal Combustion Engine*, Scitech Publication (India) Pvt.Ltd. 2000
4. Domkundwar, V. M. *A course in Internal Combustion engines*, Dhanpat Rai and Co., 1999
5. Duffy Smith, *Auto Fuel Systems*, The Good Heart Willcox Company Inc., Publishers, 1987
6. Edward F, Obert, *Internal Combustion Engines and Air Pollution*, Intext Education Publishers, 1980.

		L	T	P	C
AH2102	**AUTOMOTIVE CHASSIS & TRANSMISSION SYSTEMS**	**3**	**2**	**0**	**4**
	Total Contact Hours-75				
	Prerequisites				
	Nil				
PURPOSE					
To study chassis and transmission systems used in automobiles					

UNIT I - CLUTCH & GEAR BOX

Different types of clutches and requirement of transmission system – Principle, construction, torque capacity and design aspects of friction clutches – Objective of the gear box -Different types of gear boxes-Determination of gear box ratios & design of gear box for different vehicle applications – Typical problems.

UNIT II - DRIVE-LINE STUDY, FRONT AXLE & REAR AXLE

Propeller shaft, Universal joints, Final drive – Different types, double reduction and twin speed final drives - Rear axle construction – Full floating, three quarter floating and semi-floating arrangements – Differential lock, Non-slip differential, Hotchkiss and torque tube drives – Effect of driving thrust and torque reaction, radius rods – Front axle construction, materials, constant velocity universal joint and front wheel geometry.

UNIT III- STEERING, SUSPENSION, WHEELS AND BRAKING SYSTEM

Condition of true rolling motion of road wheels during steering- Ackermann and Davis steering – Different type of steering gear boxes and linkages – Hydraulic and Electronic power steering. Factors influencing ride comfort – Independent suspension- Rubber, pneumatic, hydro-elastic suspension, shock absorbers.

Construction of wheels and tyres – Braking torque developed by leading and trailing shoes – Disc brake theory – Factors affecting brake performance – Engine Exhaust Brake – Power brake-Regenerative braking – ABS.

UNIT IV- HYDRO-DYNAMIC, HYDRO-STATIC & ELECTRIC DRIVES

Fluid coupling and Torque converters: Principle, construction and performance – Reduction of drag torque in fluid coupling – Converter couplings – Multi-stage and poly-phase torque converters – Construction and working principle of typical Janny hydro-static drive – Principle of early and

modified Ward Leonard electrical control system – performance characteristics – advantages and limitations.

UNIT V- AUTOMATIC TRANSMISSION, OVERDRIVE, HYDRAULIC CONTROL SYSTEMS AND APPLICATIONS

Ford-T model gear box – Wilson gear box – Cotal electromagnetic transmission, Chevrolet turboglide transmission – Powerglide transmission – Mercedes Benz automatic transmission – Hydraulic control systems of automatic transmission.

References:

1. Heldt. P. M., *Torque converters*, Chilton Book Co., 1992
2. Newton and Steeds, *The Motor vehicle*, Iliffe Publishers, 1985
3. Judge. A.W., *Modern Transmission systems*, Chapman and Hall Ltd., 1990
4. SAE Transactions 900550 & 930910
5. Crouse. W.H., Anglin. D.L, *Automotive Transmission and Power Trains construction*, McGraw Hill, 1976
6. Birch, *Automotive Braking Systems*, Thomson Asia, 1999
7. Birch, *Automotive Chassis Systems*, Thomson Asia, 2000
8. Birch, *Automotive Suspension and Steering Systems*, Thomson Asia, 1999
9. Newton, Steeds & Garrot, *The Motor vehicle*, SAE - Butterworths, India, 13th edition, 2001
10. Judge A.W., *Mechanism of the car*, Chapman and Halls Ltd., London, 1986
11. John Peter Whitehead, Donald Bastow, *Car Suspension and Handling*, 4th Edition, Allied publishers limited, SAE Department, 2004
12. Automotive Transmissions **Authors:** Naunheimer**, H.,** Bertsche**, B.,** Ryborz**, J.,** Novak**, W. Springer-2011**

		L	T	P	C
ME2105	**MECHANICAL VIBRATIONS**	**3**	**0**	**2**	**4**
	Total Contact Hours-75				
	Prerequisites (for non-mechanical Engineering students)				
	Basic knowledge on vibrations				
PURPOSE					
To present an overview about mechanical vibrations and its relation to design and analysis of vibrating systems.					
INSTRUCTIONAL OBJECTIVES					
1.	The procedure to derive the governing equation(s) of motion of an SDOF, MDOF, and continuous systems.				
2.	To determine frequencies and mode shapes of a given vibrating system modeled appropriately.				
3.	To analytically determine free and forced response of damped and un-damped SDOF systems.				
4.	To numerically determine the frequencies and mode shapes of MDOF systems				
5.	To perform preliminary vibration analysis of non-linear systems				
6.	Recognize the need for lifelong learning and develop the ability to engage in the same.				

UNIT IMULTI-DEGREE-OF FREEDOM (MDOF) SYSTEMS

Review of SDOF systems – need, mathematical model, free and forced un-damped and damped response - MDOF systems – Derivation of equations of motion of 2-DOF systems using Newton's II Law - 1, 2, and 3-DOF systems using Lagrange's method (just use of the method without proof). Eigen values and eigen vectors – relation to a vibration problem, determination of frequencies and mode shapes using analytical methods for 2-DOF systems and numerical methods (Holzer, matrix iteration methods) for 2 and 3-DOF systems. Un-damped free and forced response of a 2-DOF system using analytical methods; damped free and forced response of 2 and 3-DOF systems numerically (Finite Difference method using MS-Excel or MATLAB)

UNIT II VIBRATION CONTROL

Reduction of vibration at the source (brief mention), Balancing of Rotating Machines - Single-Plane and Two-Plane balancing, Whirling of Rotating Shafts - Modeling of the rotor system, critical speeds, response of the system, Balancing of Reciprocating Engines - Single cylinder engine – unbalanced forces due to gas pressure and inertia of moving parts - Balancing in a multi-cylinder engine (procedure and an illustrative problem). Vibration Isolation (SDOF system) – displacement transmissibility (from support) and force transmissibility (to support), Vibration Absorber - Tuned (un-damped) Vibration Absorber as a 2-DOF system - Damped Vibration Absorber (2-DOF system).

UNIT III ANALYTICAL DYNAMICS

Introduction to variational principles in dynamics - Hamilton's Principle - Lagrange's equation (derivation)

UNIT IV CONTINUOUS SYSTEMS

Transverse Vibration of a String or Cable - Equation of motion, Initial and boundary conditions, frequency equation, first few modes, free vibration of a string with both ends fixed, Longitudinal Vibration of a Bar or Rod and Torsional Vibration of a Shaft or Rod - Equation of motion – comparison with that of string or cable, Bending Vibration of Beams - Equation of motion, initial and boundary conditions, frequency equations for simply supported, cantilever, and fixed-fixed beams.

UNIT V NON-LINEAR VIBRATION

Introduction - Examples of non-linear vibration problems - Approximate Analytical Method – Lindstedt's method - Preliminary analysis of Duffing's and van der Pol's equations.

PRACTICAL 30
TOTAL 75

References:

1. Rao.S.S, "*Mechanical Vibrations*", 4th Edition, Pearson Education Inc. Delhi 2009.
2. Rao.J.S and Gupta.K, "*Introductory course on theory and practice of mechanical vibrations*", New Age International, New Delhi, 1999.
3. Thomson.W.T, "*Theory of Vibration and its Applications*",5th Edition, Prentice Hall, New Delhi, 2001.
4. Meirovitch.L, "*Elements of Vibration Analysis*", 2ndEdition, Mc Graw-Hill Book Co., New York,, 1993.
5. Keith Mobley.R, "*Vibration Fundamentals*", Plant Engineering Maintenance Series, Elsevier, 2007.

		L	T	P	C
AH2103	**AUTOMOTIVE ELECTRONICS FOR xEVs**	**3**	**0**	**2**	**4**
	Total Contact Hours-75				
	Prerequisites				
	Nil				
PURPOSE					
To understand electronic control units (ECUs) for xEVs, Basics of motor Controller, Battery Management systems (BMS), Thermal Management ECU.					

UNIT I - Basics in Power Electronics

Introduction – Why Power Electronics? Overview of Power Density, Effects of air vs. liquid cooling, Effects of efficiency, Converter Topologies, Buck, boost, transformer, Inverter Topology, 6-pack inverter, Space Vector Control, Sources of Loss in Power Electronics, Conduction, switching, leakage, and control losses, Power Semiconductors, Insulated Gate Bi-polar Transistor (IGBT), Metal-Oxide-Silicon Field Effect Transistor (MOSFET), Emerging technologies: Moore's law, silicon carbide.

UNIT II - Power Electronics for Electric Drives

Semiconductor power diodes, transistors, Thyristors, Triacs, GTOs, MOSFETs and IGBTs – static characteristics and principles of operation; triggering circuits; phase control rectifiers; bridge converters

UNIT III - Convertors

Single and three phase AC-DC converters- Half wave and Full wave controlled rectifier with R, RL, RLE load – Continuous and discontinuous operation modes of operation, Harmonics and ripple. DC –DC converter; Principles of step-down and step-up converters –buck-boost and Cuk converters.

UNIT IV - Battery Management Systems

Block Diagram - Main Functions of a BMS, Sensing Requirements, Cell/module level: cell voltage, cell/module temperature, (humidity, smoke, air/fluid flow), Pack level: current, pre-charge temperature, bus voltage, pack voltage, isolation, Control Requirements, Contactor control, pre-charge circuitry, Thermal system control, Cell Balancing: Active versus passive, strategies, Estimation Requirements, Strategies: different approaches and benefits of model-based approach, How to create a model via cell tests, State of Charge estimation; State of Health estimation, Power estimation, Energy estimation (range estimation)

References:

1. Rashid, M.H., "*Power Electronics – Circuits, Devices and Applications*", Prentice Hall of India, Third Edition, New Delhi, 2011.
2. Sen .P C, "*Power Electronics*", Tata Mc Graw Hill Education, Twelfth Edition .
3. Bhimbra.P. S. "*Power Electronics*", Khanna publishers, Fifth edition, 2005.
4. Singh.M.D and Kanchandani-"*Power Electronics*"-Tata McGraw-Hill & Hill Publication Company Ltd New Delhi-2002.
5. Joseph Vithayathil, "*Power Electronics*", Mc Graw Hill series in Electrical and Computer Engineering , USA., 1995.

6. Dubey.G.K, Doradia.S.R, Joshi, A. and Sinha.R.M, "*Thyristorised Power Controllers*", New age International, New Delhi, 2002.
7. Bergveld, H.J., Kruijt, W.S., Notten, P.H.L "*Battery Management Systems -Design by Modelling*" Philips Research Book Series 2002.
8. Davide Andrea," *Battery Management Systems for Large Lithium-ion Battery Packs*" Artech House, 2010

		L	T	P	C
AH2104	**HEV / xEV SYSTEM DESIGN ARCHITECTURE**	**3**	**2**	**0**	**4**
	Total Contact Hours-75				
	Prerequisites				
	Nil				
PURPOSE					
To present an overview about hybrid electric vehicle system design architecture and its sub-systems.					

Design & Engineering – xEV

xEV : micro to mild to PHEV to HEV to REEV to EV - Hybrid-Electric Vehicle Power trains - Vehicle Energy Storage System (VESS) Design - Computational Systems Design (CSD) - Transportation Electrification

Introduction to Advanced Electric Vehicles: Fundamentals of xEVs and key challenges and opportunities of AEV technologies - Engineering philosophy of various xEVs (HEV, PHEV and BEV, REEV)

Component selection and design and architecture: Examples & Case studies;

Controls Modelling and Design for xEV: System and sub-systems, Modelling and design of xEVs as a system, principles of controls engineering for xEV.

Energy Storage Systems: Energy storage systems used; Battery electro-chemistry, battery design and construction, charging and discharging, power density, Battery interface with motive sources

Power Electronics for Electric Vehicles: Power electronics including switching, AC-DC, AC-AC conversion, electronic devices and circuits used for control and distribution of electric power

Electric Drives / Electromechanical Energy Conversion: Motors & motive power spilting concepts, and interface within power train system;

Innovation and System Architecture for xEVs: Case studies on proven systems and failed system architectures.

Hybrid Electrical Vehicles : Part 1: Introduction - **System Overview** - Power train architecture - Parallel, Series and Combined - Types of xEVs - Vehicle layout and packaging options. - Energy devices & combinations - examples & Case Studies - **Environmental Impact** - Regulatory Issues (CO_2 gas and particulate emissions) - Duty Cycles in Indian cities; performance (off cycle, durability) - Sustainability assessment; cradle to grave environmental impact. - **Industry Activity**

and Market Reaction - HEV market drivers and technology trends - Customer related issues - HEV technology readiness levels - **Vehicle Based HEV Performance specifications**.

Part II : **Vehicle Systems : Modelling, electrical and mechanical sub systems** - Systems Modelling and Simulation - Modelling methodologies for HEV energy management. - Control strategies for energy management and driveability. **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.

References:

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

		L	T	P	C
AH2105	**xEV MOTOR DRIVES AND CONTROLLERS**	**3**	**0**	**3**	**4**
	Total Contact Hours - 90				
	Prerequisites				
	Nil				
PURPOSE					
To study different motor drives and controllers used in xEV / HEVs.					

xEV components and architecture: Internal combustion engine-characteristics General architecture of xEV-Energy source, electric machines, power electronics converters, controllers, sensors, loads. Types of xEVs - series, parallel, series-parallel etc. Mild hybrid, PHEV, REEV, EV.

Energy source: Batteries, parameters(capacity, SOC, charge/discharge ratesetc.);Lead-acid batteries, Li-Ion batteries, Battery management systems, Fuel cells ,Ultra capacitors.

Electric machines: DC machines-Characteristics, AC machines-Induction machines, permanent magnet machines, switched reluctance machines,

Power electronic converters: DC-DC converters and types (Buck, Boost, Fly back etc.); isolated converters, Inverters based on MOSFET (IGBT gate driver circuits

Controllers: Microcontrollers/DSP based controllers, PI control, cascade control, scalar control, vector control, DQ modelling, Induction motor scalar/vector control, PM machine control(scalar/vector), SRM control

Sensors: Types of sensors for electric drive, Current sensors and signal conditioners

xEV Motor: Different configuration of xEV, series, parallel,series-parallel Electric Drive Architecture: Battery bank, inverter, controller, sensors, DC-DC converter, load

Battery bank Power converters: DC-DC converter, Inverters, Sensors, Micro controller/DSP. Scalar control, Vector control, Programming tools - IDE, compiler, Assembler, loader, Dynamometer, Motor

Performance characteristics - Speed sensors and signal conditioning, Position sensors and signal conditioning, Voltage sensors, temperature sensors

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.

Testing Of Electric Drives: Vehicle mechanics, test-beds, dynamometers, electric loads, performance characteristics(Torque Vs. Rpm, Efficiency Vs. Rpm, Power Vs. Rp

References:

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, second Edition, 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*", Clarendon Press, 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, 1989.
9. Krishnan R, "*Switched Reluctance Motor Drives*", Modelling, Simulation, Analysis, Design and applications, CRC press. 5. P.P. Aearnley, 'Stepping Motors – A Guide to Motor Theory and Practice', Peter Perengrinus, London, 1982.
10. Davide Andrea," *Battery Management Systems for Large Lithium-ion Battery Packs*" Artech House, 2010 .
11. Somanath Majhi., "*Advanced Control Theory A relay Feedback Approach*", Cengage Learning, 2009.

Optional / elective courses (program electives)

		L	T	P	C
AH2121	**MATERIALS AND MANUFACTURING PROCESSES FOR AUTOMOTIVE SYSTEMS**	**3**	**0**	**0**	**3**
	Total Contact Hours-45				
	Prerequisites				
	Nil				
PURPOSE					
To study different materials and manufacturing processes used in the manufacturing of automotive systems.					

Materials:
Selection of Materials for design Developments in automobile technology - criteria for material selection - Functional requirements- Mechanical properties, Thermal properties, electrical properties, magnetic properties, chemical properties, -Economics, suitability for recycling and disposal after use. Need and development of lightweight materials on vehicle design, Aluminium, Magnesium and Ti wrought and cast alloys used in automotive applications. Advanced materials for automobile, power sources materials for super capacitors and electrolytic cells for automobiles.

Processing of Composites:
Composites- metallic, non- metallic and other specialty materials used in automotive design- Fabrication Techniques, Properties and performance. Role of Nano technology , Smart Materials, Recent development in auto components

Conventional Manufacturing Processes:
Auto Components made of conventional manufacturing processes. Casting and Machining Processes, Cutting and Joining Processes, Characteristics and fabrication of plastically deformed bodies. Powder Metallurgy (PM) components- Powder Metallurgy process

Additive and Precision Manufacturing
Working Principles, Methods, Sheet lamination processes, Stereo Lithography, Laser Sintering, Fused Deposition Method, Directed Energy Deposition (DED) - Laser engineered net shaping, directed light fabrication, direct metal deposition, 3D laser cladding Applications and Limitations, Rapid tooling, Techniques of rapid manufacturing; Ultrasonic Machining (USM), Electro Chemical Machines (ECM), Electro Chemical Grinding (ECG), Chemical Machining (CHM), Electrical Discharge Machining (EDM), Electron Beam Machining (EBM) and Ion Beam machining (IBM) processes.

Surface engineering- auto components subjected to wear, heat and corrosion environments. Conventional surface engineering practices- carburizing, Nitriding, carbo-nitriding - Electro plating.
Advanced surface engineering practices – HVOF, Plasma and Laser assisted microstructural modification, PVD-CVD_Ion implantation – DLC coatings- Carbide Nitride Coatings. Characterization and performance of modified surfaces.

References:

1. K.K.Chwala, “Composite Materials”, springer 1987
2. Sharma P.C, "A Text Book of Production Engineering", S.Chand and Co. Ltd., IV Edition, 2008.
3. Budinski.K.G and Budinski.M.K, “Engineering Materials Properties and selection”, Prentice Hall of India Private Limited, New Delhi, 2004.
4. Serope Kalpakjian, “Manufacturing Engineering and Technology”, Third Edition, Addison-Wesley Publishing Co., Boston, 2009.
5. Madou.M.J, “Fundamentals of micro fabrication”, CRC Press, USA, 1997.
6.Chua.C.K, “Rapid Prototyping”, John Wiley, New York, 1997.
7. Hilton.P.D and Marcel Dekker, “Rapid Tooling”, New York, 2000.

		L	T	P	C
AH2122	**THERMAL MANAGEMENT OF HYBRID SYSTEMS**	**3**	**0**	**0**	**3**
	Total Contact Hours-45				
	Prerequisites				
	Nil				
PURPOSE					
To study thermal management of hybrid systems.					

Brief Review of Thermodynamics, Fluid Mechanics, and Heat Transfer: First Law of Thermodynamics for open and closed systems; internal energy, enthalpy, and specific heat - Second Law of Thermodynamics for closed systems; Tds equations, Gibbs function - Fluid mechanics: laminar vs. turbulent flow, internal flow relationships, Navier Stokes equations - Heat transfer: simple conduction, convection, and radiation relationships; Nusselt number relationships for convective heat transfer; energy equation.

Thermal Management of Motors: Motor Sizing vs Heat Generation - Operational Temperature Limitations of Electrical Insulation - Design concepts for Heat Extraction in Motors for xEV systems - Modelling and simulation of heat transfer in motors - Rendering of Heat extraction solutions - Sensors and Protection solutions.

Thermal Management for Batteries and Power Electronics: Introduction - 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 modeling: 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

Thermal Management Systems: Overall energy balance to determine required flowrates - Determination of convection and friction coefficients for air and liquid systems in various geometric configurations: flow around cylinders, flow between plates, flow through channels - Development of a complete thermal system model and parametric study results - Temperature control and heat transfer using phase change materials - Thermal Management of Power Electronics.

References:

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 Hardcover*", 1998, Mc Graw- Hill.
3. *" Vehicle thermal Management Systems Conference Proceedings*", 1st Edition; 2013, Coventry Techno centre, UK
4. Younes Shabany," *Heat Transfer: Thermal Management of Electronics Hardcover*" 2010 , CRC Press.
5. T. Yomi Obidi**, "***Thermal Management in Automotive applications*", 2015, SAE International.

		L	T	P	C
AH2123	**ENERGY DEVICES FOR xEV DRIVES**	**3**	**0**	**0**	**3**
	Total Contact Hours-45				
	Prerequisites				
	Nil				
PURPOSE					
To study different energy devices used in hybrid electric vehicle drives.					

UNIT I : Power Sources and Energy Storages:
Electrochemical Batteries, Cell and battery voltages, Charge (or Amp hour) capacity, Energy stored, Specific energy, Energy density, Specific power, Amp hour (or charge) efficiency, Energy efficiency . Self-discharge rates, Battery geometry, Battery temperature, heating and cooling needs Battery life and number of deep cycles.

Lead Acid Batteries, Nickel-based Batteries: Introduction, Nickel cadmium, Nickel metal hydride batteries, Sodium-based Batteries, Lithium Batteries, Metal Air Batteries, Battery Charging, The Designer's Choice of Battery, Use of Batteries in Hybrid Vehicles, Battery Modelling,

UNIT II : Alternative and Novel Energy Sources and Stores:
Introduction, Solar Photovoltaic, Wind Power, Flywheels, Ultra capacitors, Super Capacitors, Supply Rails,

UNIT III: Fuel Cells:
Hydrogen Fuel Cells: Basic Principles, Fuel Cell Thermodynamics, Water Management in the PEM Fuel Cell, Thermal Management of the PEM Fuel Cell

UNIT IV: Hydrogen Supply
Introduction, Fuel Reforming, Hydrogen Storage I: Storage as Hydrogen, Hydrogen Storage II: Chemical Methods

UNIT V: Case Study:
• Lifetime Cost of Battery, Fuel-Cell, and Plug-in Hybrid Electric Vehicles
• Relative Fuel Economy Potential of Intelligent, Hybrid and Intelligent–Hybrid Passenger Vehicles
• Cost-Effective Vehicle and Fuel Technology Choices in a Carbon- Constrained World: Insights from Global Energy Systems Modelling
• Fuel Cell Electric Vehicles, Battery Electric Vehicles, and their Impact on Energy Storage Technologies: An Overview

References:

1. Thomas B. Johansson," *Renewable Energy: Sources for Fuels and Electricity*" Islan Press 2009.
2. Iqbal Husain, "*Electric and Hybrid Vehicles Design Fundamentals*"Published by: *CRC Press*, Boca Raton, Florida, USA, 2003.
3. D. Linden, "*Handbook of Batteries*", Second Edition, McGraw-Hill, New York, 1995.
4. M. Barak (Ed.), T. Dickinson, U. Falk, J.L. Sudworth, H.R. Thirsk, F.L. Tye, "*Electrochemical Power Sources: Primary & Secondary Batteries*", IEE Energy Series 1, A. Wheaton &Co, Exeter, 1980.
5. J. O'M. Bockris, D.M. Drazic, "*Electro-Chemical Science*", Taylor & Francis Ltd., London, 1972.

6. "*Automotive Electronics Handbook*", 2nd Edition, R. Jurgen, McGraw Hill, 1999.
7. Adel S. Sedra and Kenneth C. Smith, "*Microelectronic Circuits*", (5th Ed.) 2004.
8. Mohan, Undeland, and Robbins, "*Power Electronics*", John Wiley and Sons, Third Edition.
9. "*Automobile Electric/Electronic Systems*", Robert Bosch GmbH, 1995.
10. Muhammad H. Rashid, "*Power electronics handbook"*, Third Edition, 2011.

		L	T	P	C
AH2124	**ADVANCED POWER ELECTRONICS FOR xEVs**	**3**	**0**	**0**	**3**
	Total Contact Hours-45				
	Prerequisites				
	Nil				
PURPOSE					
To study the power electronics components required for xEVs and its characteristics.					

UNIT I: BASIC POWER ELECTRONIC DEVICES

Diodes, Thyristors, Bipolar Junction Transistors, Metal–Oxide–Semiconductor Field Effect Transistors, Insulated Gate Bipolar Transistors

UNIT II: DC/DC CONVERTER

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

UNIT III: DC–AC INVERTER

Basic Concepts of DC–AC Inverters, Single-Phase DC–AC Inverter, Three-Phase DC–AC Inverter

UNIT IV: ELECTRIC MOTOR DRIVES

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

UNIT V: PLUG-IN BATTERY CHARGER DESIGN

Basic Configuration of PHEV / BEV Battery Charger, Power Factor and Correcting Techniques, Controls of Plug-In Charger.

References:

1. Rashid M.H., "*Power Electronics Circuits, Devices and Applications*", Prentice Hall India, Third Edition, New Delhi, 2011.
2. Bimal K Bose, "*Modern Power Electronics and AC Drives*", Pearson Education, second Edition, 2003
3. Dubey. G.K., "*Thyristorised power controllers*", New age International, New Delhi, 2002.
4. Bhimbhra P.S., "*Power Electronics*", Khanna Publishers, New Delhi, 2005.
5. P.C. Sen, "*Modern Power Electronics*", Wheeler Publishing Co, Third edition, New Delhi, 2008.
6. Ned Mohan, Undeland and Robbin, "*Power Electronics: converters, Application and design*", John Wiley and sons.Inc, Newyork, Reprint 2009.

7. R.Krishnan, "*Electric Motor Drives- Modeling, Analysis and Control*", Prentice-Hall of India Pvt. Ltd., New Delhi, 2007.
8. Davide Andrea,"*Battery Management Systems for Large Lithium-ion Battery Packs*" Artech House, 2010.

		L	T	P	C
AH2125	**CONTROL SYSTEMS & INSTRUMENTATION**	**3**	**0**	**0**	**3**
	Total Contact Hours-45				
	Prerequisites				
	Nil				
PURPOSE					
To study the various instruments for measurement and its characteristics and control systems.					

Basic concepts of control system, open loop, close loop, classification of control systems. Types of control system: Feedback, tracking, regulator system, feed forward system. Transfer function, Pole and zero concept. Modelling and representation of control system-Basic concept. Mechanical, Electrical and equivalent system. Block diagram reduction, signal flow graph, Mason's gain formula.

Modelling and transfer function of control system components such as simple electrical, Mechanical, electromechanical systems, Lag - lead network, potentiometer, etc. Standard test signal –step, ramp, parabolic and impulse signal, type and order of control system, time response of first and second order systems to unit step input, steady state errors – static and dynamic.

Steady state response of a system due to sinusoidal input. Relation between time and frequency response for second order system. Frequency domain specifications, analysis with Bode plot, Polar plot, Nyquist plot, stability analysis using Nyquist plot and Bode plot. Basic concept of PID controller, Design specifications of P,PI, PID controllers, Tuning of PID controllers. Zigler-Nichol Method

UNIT I : Basic Instrumentation; Static and Dynamic characteristics of instruments, dead zone, hysteresis, threshold, resolution, sensitivity, input & output impedance, loading effects, fundamentals of measurements, Types of Error, Statistical Analysis, Probability of Errors, Limiting Errors , calibration of instruments, traceability, calibration report & certification. Analog Indicating Instruments, Bridge Circuits, Oscilloscope, Digital Instruments, Recording Instruments and Analytical Instrumentation

UNIT II : Sensors/Transducers; Measurement principles, classification, Fundamental Standards, units, **Linear Displacement:** Resistive Potentiometers, stain gauge, LVDT, Capacitive Piezoelectric, Hall Effect sensors, magnetostricitive, magnetoresisitive, Optical displacement sensor fibre optic sensor, Ultrasonic distance Sensor, Piezoresistive, Linear encoder, Proximity sensors. **Rotational Displacement**: Revolution counter, Resistive potentiometers, RVDT, DC tachometer, AC tachometer, optical tachometer, Rotary encoder, eddy current , drag cup type tachometer, magnetic, stroboscope, gyroscope.

UNIT III : Force, Torque measurement; Standards and Calibration, Basic methods of force measurement (Spring, beam, diaphragm), Strain gauge; basic principal, gauge factor, types of strain gauge, materials and their properties, bonding material compensation techniques, bridge configuration, Rosettes, Tactile sensors, Piezoelectric sensors

UNIT IV : Pressure Measurement; Standards and calibration Units and relations. Positive Pressure Sensors Manometers – U tube, Well type, inclined tube, Ring balance, Micro manometer, use of seal pots, range of measurement Elastic – Bourdon, Diaphragm, Bellows and their types, materials and their

properties, range of measurement. High Pressure Measurement – Bulk modulus cell, Bridgeman type. Differential Pressure Measurement: Force balance, Motion balance, Capacitance delta cell, Ring balance DP cell.

UNIT V : Vacuum measurement; McLeod gauge, Thermal Conductivity (Pirani, Thermocouple), hot cathode ionization gauge, Molecular momentum (Knudsen) gauge, Cold Cathode ionization (Penning) gauge. Calibrating Instruments – Dead Weight Tester (Pressure, Vacuum).

UNIT VI : Temperature measurement; Temperature Scales, Standards and Units and relations, Classification of temperature sensors. Mechanical Type, Electrical Type: Resistance Temperature Detectors – Principle, materials and their properties, Types and ranges, different sources of errors and compensations. Thermistor: Types (NTC, PTC), Measuring Circuits Thermocouple: Terminology, Types (B, E, J, K, R, S, T), determination of polarity, Sources of errors and their remedies Laws of thermoelectricity, Study of thermocouple tables (calculation of Intermediate temperature and voltage), Lead wire compensation, Cold junction compensation techniques. Non-contact Types: Pyrometers: Total Optical, Infrared

UNIT VII : Other Measurement; A) Level Measurement: Float, Displacer (Torque tube unit), Bubbler, Diaphragm box, DP cell, Ultrasonic, Capacitive, Radioactive, Resistance, Thermal, B) Density Measurement: Chain-balanced float type, Hydrometer (Buoyancy type), U tube type, Hydrostatic Head (Air bubbler, DP Cell), Oscillating Coriolis, pH Measurement, Flow Measurement: Units, Newtonian and non-Newtonian Fluids, Reynolds number, Laminar and turbulent flows, Velocity profile, Bernoulli's equation for incompressible flow, Density, Beta ratio, Reynolds number correction, Square root relation

References:

1. Katsuhiko Ogata, "*Modern Control Engineering*" 5th edition, Prentice Hall of India Private Ltd., 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 and measurement 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, 4th Edition , 2004.
10. Cooper W.D & Hlefrick A.D., "*Electronic Instrumentation & Measurement Technique*", III Edition, Prentice Hall of India – 1991.
11. Bouwens .A.J., "*Digital Instrumentation*", McGraw Hill 1986.

		L	**T**	**P**	**C**

AH2126	SYSTEM ENGINEERING AND INTEGRATION	3	0	0	3
	Total Contact Hours-45				
	Prerequisites				
	Nil				
PURPOSE					
To study the various system integration tools, safety and regulations.					

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 tradeoffs - 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. HV compressor, HV heater, cabin comfort, efficiency considerations) - Verification and Validation Considerations - Verification and validation test requirements and planning - Component test considerations - System test considerations - Fleet testing.

Safety, Testing, Regulations, and 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 standards - Vehicle and Charging Standards - FMVSS - Electric Vehicle Supply Equipment (EVSE) Descriptions - Governing Bodies for Regulations - Certification Requirements and Options - 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.

References:

Lecture notes will be prepared and given.

Supportive courses

		L	T	P	C
MA2007	**APPLIED MATHEMATICS FOR MECHANICAL ENGINEERS**	**3**	**0**	**0**	**3**
	Total Contact Hours-45				
	Prerequisites				
	Nil				

PURPOSE

To develop analytical capability and to impart knowledge in Mathematical and Statistical methods and their applications in Engineering and Technology and to apply these concepts in engineering problems they would come across.

INSTRUCTIONAL OBJECTIVES

At the end of the course, Students should be able to understand Mathematical and Statistical concepts and apply the concepts in solving the engineering problems.

UNIT I TRANSFORM METHODS (9 hours)

Laplace transform methods for one-dimensional wave equation - Displacements in a string - Longitudinal vibrations of an elastic bar – Fourier transform methods for one-dimensional heat conduction problems in infinite and semi-infinite rod.

UNIT II ELLIPTIC EQUATIONS (9 hours)

Laplace equation - Fourier transform methods for Laplace equation – Solution of Poisson equation by Fourier transform method.

UNIT III CALCULUS OF VARIATIONS (9 hours)

Variation and its properties - Euler's equation - Functionals dependent on first and higher order derivatives - Functionals dependent on functions of several independent variables - Some applications - Direct methods - Ritz
methods.

UNIT IV NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS (9 hours)

Numerical Solution of Partial Differential Equations - Solution of Laplace's and Poisson equation on a rectangular region by Liebmann's method - Diffusion equation by the explicit and Crank Nicholson implicit methods -
Solution of wave equation by explicit scheme.

UNIT V REGRESSION METHODS (9 hours)

Principle of least squares - Correlation - Multiple and Partial correlation - Linear and non-linear regression - Multiple linear regression.

References:

1. Sankara Rao K., Introduction to Partial Differential Equations, 4th printing, PHI, New Delhi, April 2003
2. Elsgolts L., Differential Equations and Calculus of Variations, Mir Publishers, Moscow, 1966
3. S.S. Sastry, Introductory Methods of Numerical Analysis, 3rd Edition, PHI, 2001
4. Gupta S.C. and Kapoor V.K., Fundamentals of Mathematical Statistics, Sultan Chand and Sons, New Delhi, Reprint 2003.

		L	T	P	C
AH 2191	**Digital Electronics and Networks**	**3**	**0**	**0**	**3**
	(Mandatory for mechanical engineering & allied disciplines)				
	Total Contact Hours-45				
	Prerequisites				
	Nil				

PURPOSE

To incorporate basic skill sets in Passive Electrical Circuits, Network reduction techniques, Network Theorems, Response of RL, RC, RLC circuits to DC excitation, Semiconductor devices, Analog Circuits, Digital Circuits, Mixed Circuits.

Passive Electrical circuits: (4 hours)

Ideal Voltage and Current Sources, voltage – current relationship in R, L, C components of Electrical circuits, Ohms Law, Energy stored in Inductor and Capacitor, Kirchoffs Voltage and current laws, Review of Networks and Circuits, Elemental laws (v-i characteristics) for Resistors, Inductors, and Capacitors, Circuital laws (Kirchhoff's laws), Sign convention, Basic signals (dc and ac), Elementary signals (impulse, step, ramp, exponential), Synthesis of arbitrary waveforms (rectangular, triangular etc.) from elementary signals, Voltage and Current sources (Independent and Dependent), Ladder and Bridge Circuits.

Network reduction Techniques: (2 hours)

Reduction of Series, parallel, series - parallel circuits, star to delta or delta to star transformations;

Network Theorems: (2 hours)

Thevenin's Theorem, Norton's Theorem, Super position Theorem, Maximum Power Transfer Theorem

Response of RL , RC, RLC circuits to DC Excitation: (2 hours)

Transient response, steady state response to step input, Time constant, Damping factor;
Transients with Energy Storage Elements, First and Second Order Circuits – Time-constant, Damping Ratio, Natural Frequency, Emphasis on Linear Ordinary Differential Equations, Step response of RC, RL, and RLC (series and parallel) Circuits, Resonance in Second Order Circuits.

Semiconductor Devices: (6 hours)

Characteristics of Diodes, Zener Diodes, BJTs, MOSFETs, IGBTs, SCR, Triac, Solid state Relays

Analog Circuits (8 hours)

Operational amplifier, Inverting, Non-inverting amplifiers, Summing amplifier, Difference amplifier, Instrumentation Amplifier, Comparator, 555 timer IC, 556 function generator IC, Active Filters (LPF, HPF, Band Pass); Rectifier circuits- Filter circuits-Zener voltage regulator-Biasing BJT, FET MOS FET amplifiersSmall signal and high frequency model of BJT, FET &MOS FET Single stage BJT, FET and MOSFET amplifiers with and without active loads - Source follower Emitter follower Multistage amplifiers- Differential amplifiers- CMRR Advantages of negative feedback- Four basic feedback configurations-Basic principle of oscillators- RC oscillators Power amplifier -class A , Class B, Class AB & class C

Digital Circuits: (8 hours)

Number systems (Binary, Octal, Hexa Decimal representation), Logic Gates, Flip-Flops, counter circuits, Memory Circuits(RAM, EPROM, FLASH); Number systems, BCD codes and

arithmetic, Gray codes, self-complimenting codes, Error detection and correction principles. Boolean functions using Karnaugh map, Design of combinational circuits, Design of arithmetic circuits. Design of Code converters, Encoders and decoders.

Mixed Circuits: (8 hours)

Multiplexers, De-Multiplexers, Sample & Hold amplifiers, A/D converters, D/A Converters, Three terminal linear Regulators, DC to DC Converters (Buck, Boost)

Linear Integrated Circuits: (5 hours)

Op-amp model- characteristics- analysis op-amp circuits – Instrumentation amplifier- V/I &I/V converter- Transducer bridge amplifier Analysis and design of First order and second order filter circuits and Oscillator circuits Schmitt triggers- A/D &D/A converter- Sample and hold amplifiers - V/F &F/V converter Log amplifier- Multivibrators- Realization of PID Controller, Lead compensator, Lag compensator, Analog multiplier- 555 Timer and its application, voltage regulators. Principles and description of individual blocks of PLL and its application.

References:

1. Edminister J.A., "*Theory and Problems of Electric Circuits*", Schaum's Outline Series, McGraw Hill Book Company, 6th Edition, 2014
2. Sudhakar, A. and Shyam Mohan S.P, "*Circuits and Networks Analysis and Synthesis*", Fourth Edition Tata McGraw Hill Publishing Compamy Ltd., New Delhi, 2010.
3. Robert .L.Boylsted,and Louis Nashelsky, "*Electronic Devices and Circuit Theory*", Pearson Education,9th edition,2009.
4. David A Bell, "*Fundamentals of Electronic Devices and Circuits*", xfordUniversity Press, 2009.
5. Roy Choudhury and Shail Jain, "*Linear Integrated Circuits*", 2nd Edition, New Age International Publishers, 2003.
6. S.Salivahanan and V.S. Kanchana Bhaaskaran, "*Linear Integrated Circuits*", 6th Edition, Tata McGraw-Hill, 2011.
7. Morris. M. Mano and Michael.D.Ciletti, "*Digital Design*", Fourth edition, Pearson Education, 2008.
8. Floyd and Jain, "*Digital Fundamentals*", Eighth edition, Pearson Education, 2003.
9. Sedha.R.S, "*A Text Book of Applied Electronics*", Sultan Chand Publishers, 2008.

		L	T	P	C
AH 2192	**COMPUTER AIDED DESIGN**	**3**	**0**	**0**	**3**
	(Mandatory for non-mechanical engineering graduates)				
	Total Contact Hours-45				
	Prerequisites				
	Nil				
PURPOSE					
To incorporate basic skill sets in Computer aided design including synthetic curves, surfaces and rapid prototyping.					

Introduction to computer-aided design - Motivation, general design philosophies, CAD software, coordinate systems, sketches, orthographic and isometric views, exploded view, rendering

Principles of 3D geometrical modeling - Basic features of solid modeling, part drawing, standard dimensioning and tolerance, constraint relationships in solid modeling - Basic modeling tools in CAD (layers, colors, selection, transformation, offset, array, etc.) - Standard engineering drawing, standard machine elements (gear, shaft, springs, bearings)

Curve and surface fitting in an automated environment - Parametric and non-parametric representation of curves with example using ProE/Creo and Solid Works. - Synthetic, analytic, implicit and explicit methods of curves. - Surface representation in CAD, synthetic (splines and Bezier), and analytic (plane, ruled, revolution, tabulated), orthogonality, tangency. - Solid modeling, regularization, Boolean operation, half space operations, boundary representation (Brep), constructive solid geometry (CSG) - Writing scripts (programs) using MATLAB for curves, surfaces and solids.

Programming - Relation database, objects, class, inheritance, parametric modeling in: AutoCAD, ProE, and SolidWorks. - Macro and Application Programming Interface (API).

CAD/CAM simulation of manufacturing - Animation: basics, implementation in CAD software - Standard parts, fittings, bolts nuts, creating assembly and subassembly drawings - Product data exchange, file types (IEGS, STEP, ACIS, DXF, PARASOLID, STL, etc.)

Computer-aided solid model analysis and rapid prototyping - Simulation program for solving problems such as Solid Works Simulation - Basics of computational techniques, Finite Element Analysis (FEM) using CAD software (preprocessing, meshing , apply boundary condition, solve, post processing) - Geometric Tolerance: perpendicularity, parallelism, eccentricity, surface finish, angularity, flatness, position tolerance, clearance and interferences, using these features in CAD software - Basics of rapid prototyping, hardware and software, molding, design for manufacturing, reverse engineering and data capture techniques.

References:

1. Chris McMohan and Jimmi Browne, "*CAD/CAM Principles, Practice and Manufacturing Management"*, Pearson Education Asia,Ltd., 2000.
2. Donald Hearn and Pauline Baker M. "*Computer Graphics*", Prentice Hall, Inc., 1992.
3. Ibrahim Zeid "*CAD/Cam Theory and Practice*", McGraw Hill, International Edition, 1998.
4. Khandare S.S., "*Computer Aided Design*", Charotar Publishing House, India, 2001.
5. Chua. C.K, "*Rapid Prototyping*", Wiley, 1997.
6. Hilton. P.D. et all, "*Rapid Tooling*", Marcel, Dekker 2000.
7. Beaman J.J et all, "*Solid freeform fabrication*", Kluwer, 1997.
8. Jacohs P.F., "*Stereolithography and other Rapid Prototyping and Manufacturing Technologies*", ASME, 1996.
9. Pham D.T. and Dimov S.S., "*Rapid Manufacturing; the technologies and application of RPT and Rapid tooling*", Springer, London 2001.

		L	T	P	C
AH 2193	**COMBUSTION THERMODYNAMICS AND HEAT TRANSFER**	**3**	**0**	**0**	**3**
	(for non-mechanical engineering graduates)				
	Total Contact Hours-45				
	Prerequisites				
	Nil				
PURPOSE					

To study the thermodynamics in combustion and the heat transfer.

Thermodynamics of actual working fluids:
Working before combustion, thermodynamic properties of fuel air mixture before combustion , use of combustion charts for fuel air mixture, thermodynamics of combustion, approximate treatment of fuel air mixtures.

Fuel air cycles:
Definition, constants, volume fuel air cycle, limited pressure cycle, characteristics of fuel air cycles, comparison of real and fuel cycles. Comparison on real and fuel air cycles.

Air capacity of four stroke engines:
Ideal air capacity , volumetric efficiency, ideal induction process, actual induction process, effect of operating conditions on volumetric efficiency, effect of design on volumetric efficiency, estimating air capacity.

Two stroke engines:
Scavenging process, ideal scavenging process, relationship of scavenging ratio and scavenging efficiency, power to scavenger, supercharged two stroke engines.

Combustion and detonation:
chemistry of combustion, normal combustion in S.I engines, pre ignition and auto-ignition compared, detonation in S.I engines, combustion in C.I engines, detonation in C.I engines, effect of design on detonation. Methods of reducing detonation, preliminary detonation, preliminary facts about fuel and dopes, octane and cetane numbers

Heat losses and cooling:
Area of heat flow engines, temperature profile, engine cooling system.

Engine design:
Selection of type, engine speed and principles of similitude, determination of main dimensions.

Mixture requirements:
Steady running mixture requirements, transient mixture requirements, mixtures requirements fuel injection engines, mixture requirements for S.I engines.

Performance of supercharged engines:
Engine Performance Measure, Commercial, Engine Ratings, Basic Performance Equations for unsupercharged engines, effect of atmospheric conditions, altitude and compression ratio on performance characteristics, performance curves.

Supercharged engines:
Definition Reasons for supercharging, supercharging of S.I engines, supercharging of diesel engines.

References:
1. Sarkar B.K., *Thermal Engineering* , Tata McGraw Hill Co. Ltd., India, 1999.
2. Rayner & Joel, *Basic Engineering Thermodynamics*, Addison Wesley Publishing Company Ltd., 5th Edition, 1996.
3. Nag.P.K., *Engineering Thermodynamics*, Tata McGraw Hill Co. Ltd., India, 1995.

4. Rajput R.K., *Thermal Engineering*, Laxmi Publications (P) Ltd., New Delhi, Edition. 2001.

Other courses

		L	T	P	C
AH 2194	**PROJECT MANAGEMENT - I**	**1**	**0**	**0**	**1**
	Total Contact Hours-15				
	Prerequisites				
	Nil				
PURPOSE					

Project management :

Output or Goal Definition and Systems Approach
Differentiation of Output in terms of knowledge inputs
Work Breakdown Structure (WBS) and Identification of Critical Gaps
Critical Gap issues in knowledge, physical and financial resources
Analysis and solution path identification
Execution strategy and methodology
Validation and Iteration.
Reference : Dr Bala's Lectures on Project Management& System's Approach.

		L	T	P	C
AH 2194	**PROJECT MANAGEMENT - II**	**1**	**0**	**0**	**1**
	Total Contact Hours-15				
	Prerequisites				
	Nil				
PURPOSE					

Project Management in Technology Development Projects
(i) Understanding Technology Readiness Levels (TRLs)
& mapping of TRLs to End to End Technology Development

(ii) TRL-3 : Critical function definition in product and processes
(iii) TRL 4-6 : Prototype and Engineering Scale Model and Imposition of Service Conditions
(iv) TRL - 7 : Pilot Production; techno economic studies and design for scale up
Reference : Dr Balas's Lectures on Project Management & Knowledge Mangement

		L	T	P	C
AH 2194	**SEMINAR**	**0**	**0**	**2**	**1**

	Total Contact Hours - 30				
	Prerequisites				
	Nil				
PURPOSE					

Students have to present a minimum of three seminar papers on the topics of current interest. The evaluation will be based on the knowledge of the student on the subject of presentation, their communication abilities, method of Presentation, the way questions were answered and his / her attention to the other students' seminars.

		L	**T**	**P**	**C**
AH 2194	**PROJECT WORK PHASE - I**	**0**	**0**	**12**	**6**
	Total Contact Hours-75				
	Prerequisites				
	Nil				
PURPOSE					

Students can register for this course only after earning at least 12 credits in the core courses of their study.

		L	**T**	**P**	**C**
AH 2194	**PROJECT WORK PHASE - II**	**3**	**0**	**36**	**18**
	Total Contact Hours-75				
	Prerequisites				
	Nil				
PURPOSE					

Students can register for this course only after earning at least 16 credits in the core courses of their study. Students can enroll for this course only after completing Project Work-Phase I.

Tentative teaching schedule:

FIRST SEMESTER (SRM University)

COURSE CODE	COURSE NAME	L	T	P	C
AH2101	Automotive Engine Systems	3	0	2	4
AH2102	Automotive Chassis & Transmission Systems	3	2	0	4
ME2105	Mechanical Vibrations	3	0	2	4
MA2007	Applied Mathematics for Engineers	3	0	0	3
AH2191/ AH2193	Digital Electronics and Networks (for Mechanical Engineering graduates) Combustion Thermodynamics and Heat Transfer (for Non-Mechanical Engineering graduates)	3	0	0	3
AH2192	Computer Aided Design	3	0	0	3

SECOND SEMESTER (NFTDC)

COURSE CODE	COURSE NAME	L	T	P	C
Theory					
AH2103	Automotive Electronics for xEVs	3	0	2	4
AH2104	EV/HEV System Design Architecture	3	2	0	4
AH2105	xEV Motor drives and controllers	3	0	3	4
AH2122	Thermal Management of Hybrid systems	3	0	0	3
AH2124 AH2125	Advanced Power Electronics for xEVs (for electrical stream) Instrumentation /Mechatronics (For mechanical stream)	3	0	0	3
AH2123	Energy Devices for xEV Drives	3	0	0	3

THIRD SEMESTER (including summer semester of two months) (NFTDC)

COURSE CODE	COURSE NAME	L	T	P	C
SUMMER (2 Months)					
AH2194	Project Management - I	1	0	0	1
AH2121	Materials and Manufacturing processes for Automotive systems	3	0	0	3
THIRD SEMESTER					
AH2126	System Engineering and Integration	3	0	0	3
AH2197	Seminar	0	0	2	1
AH2198	Project work Phase I	0	0	12	6

FORTH SEMESTER (NFTDC)

COURSE CODE	COURSE NAME	L	T	P	C
AH2195	Project Management - II	1	0	0	1
AH2199	Project work Phase - II	3	0	36	18
	Thesis submission and Viva – Voce (at SRMU)				