Vel Tech
Rangarajan Dr. Sagunthala
R&D Institute of Science and Technology
(Deemed to be University Estd. u/s 3 of UGC Act, 1956)

PROPOSED CURRICULUM

M.Tech. Automobile Engineering

with Specialisation in

Powertrain Engineering/Electric & Hybrid Vehicles

Program Structure

Category	No. of Credits
Program core (No. of courses -7)	25
Specialization Core 18/Elective 12	30
Independent Learning	25
Total Credits	**80**

Foundation Course

Sl. No	Course Code	Course Name	L	T	P	C
1		Applied Statistics and Numerical Methods	3	0	2	4

Program Core

Sl. No	Course Code	Course Name	L	T	P	C
1		Prime Movers and Transmission	3	0	4	**5**
2		Automotive Electrical and Electronics Systems	3	0	0	3
3		Electric and Hybrid Vehicles	3	0	2	**4**
4		Two and Three-wheeler Technology	2	2	~~0~~	**3**
5		Automobile Chassis and Body Engineering	3	0	0	3
6		Powertrain Management Systems	3	0	0	3
Total Credits to be earned						25

Specialization courses

Sl. No	Course Code	Course Name	Credits
1		Total Credits to be earned	30

Independent Learning

Sl. No	Course Code	Course Name	L	T	P	C
1		Project Management and Finance	2	0	0	2
2		Online Courses				2
3		Mini Project	0	0		3
4		Project	0	0		18
Total Credits to be earned						25

Powertrain Engineering Specialization

Specialization Core

Sl. No	Course Code	Course Name	L	T	P	C
1		Engine Combustion and Simulation	3	0	2	4
2		Engine Design and Development	3	0	0	3
3		Powertrain NVH	3	0	0	3
4		Automobile Fuels and Emission	3	0	2	4
5		Engine Testing and Certification	3	0	2	4
No. of credits						**18**

Specialization Electives

Sl. No	Course Code	Course Name	L	T	P	C
1		Automotive HVAC	3	0	0	3
2		Hydrogen and Fuel Cell	3	0	0	3
3		Supercharging and Turbocharging	3	0	0	3
4		Experimental Methods and Optimization Technique	3	0	0	3
5		Vehicle Dynamics	3	0	0	3
6		Engine Materials and Manufacturing	3	0	0	3
7		Tribology	3	0	0	3
8		Materials for Automobile	3	0	0	3
9		Finite Element Analysis	3	0	2	4
		Computational Fluid Dynamics	3	0	2	4
No. of credits to be earned						**12**

Total Credits to be earned under Specialization - 30

Electric and Hybrid Vehicles Specialization

Specialization Core

Sl. No	Course Code	Course Name	L	T	P	C
1		Vehicle Mechanics	3	0	0	3
2		Power Electronics for Automobile	3	0	2	4
3		Modelling and Simulation of EHV	3	0	2	4
4		Energy Storage and Management Systems	3	0	2	4
5		Computer Aided Engineering	2	0	2	3
No. of credits						**18**

Specialization Electives

Sl. No	Course Code	Course Name	L	T	P	C
1		Automotive Embedded System	3	0	0	3
2		Automotive Thermal Systems	2	2	0	3
3		Electric Drives and Control	3	0	0	3
4		Automotive Diagnostics	3	0	0	3
5		Micro Electro Mechanical Systems	3	0	0	3
6		In Vehicle Networking	3	0	0	3
7		Intelligent Transport Systems	3	0	0	3
8		Automotive Safety	3	0	0	3
9		Plug-in Electric Vehicles in Smart Grid	3	0	0	3
10		Testing and Certification of Electric and Hybrid Vehicles	3	0	2	4
No. of credits to be earned						**12**

Total Credits to be earned under Specialization - 30

Independent Learning

Sl. No	Course Code	Course Name	L	T	P	C
1		Project Management/ Online Courses	0	0	4	2
2		Mini Project	0	0	10	5
3		Project	0	0	36	18
Total Credits to be earned						**25**

Complimentary Course: (No Credit)

1. Industrial Interaction /Conference/ Publishing Articles
2. Soft Skills

FOUNDATION COURSE

	APPLIED STATISTICS AND NUMERICAL METHODS	L	T	P	C
		3	0	2	4

Course Category: Program core

Course Outcomes

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

CO Nos.	Course Outcomes	Level of learning domain (Based on revised Bloom's)
CO1	Understand the basics of probability, random variables and standard probability distributions with applications	K2
CO2	Understand the two-dimensional random variables and their applications like joint probability distributions, marginal density functions, expectation, covariance, correlation and regression	K2
CO3	Apply the Analysis of Variance (ANOVA) for experimental design – one factor experiment and the techniques CRD and RBD	K3
CO4	Apply the numerical methods for solving Ordinary Differential Equations (ODEs) – single-step and multi-step finite-difference numerical methods	K3
CO5	Apply the numerical methods for solving Partial Differential Equations (PDEs) – finite-difference numerical methods for parabolic, elliptic and hyperbolic PDEs	K3

UNIT I RANDOM VARIABLES, PROBABILITY DISTRIBUTIONS AND APPLICATIONS L - 9 P - 6

Random variables and their applications –discrete and continuous random variables – mean, variance and moments of random variables - probability density and distribution functions – moment generating functions and applications – modelling with Binomial, Poisson, Normal, Exponential distributions and their applications.

PRACTICALS

List of Experiments

1. Probability problems and plotting the binomial distribution with MATLAB
2. Probability problems and plotting the Poisson distribution with MATLAB
3. Probability problems and plotting the normal distribution with MATLAB
4. Probability problems and plotting the exponential distribution with MATLAB

UNIT II TWO-DIMENSIONAL RANDOM VARIABLES AND THEIR APPLICATIONS L - 9 P - 6

Two-dimensional random variables and their applications - joint distribution functions – marginal distributions and marginal density functions – applications of marginal density functions – independent random variables – mathematical expectation, covariance and applications – correlation, regression and engineering applications.

PRACTICALS

List of Experiments

1. Plotting the bivariate normal distribution with MATLAB
2. Finding correlation and plotting regression lines with MATLAB

UNIT III DESIGN OF EXPERIMENTS **L - 9 P-4**

Design of experiments – Basic principles – Replication, randomization and local control – ANOVA – one-way classification– Completely Randomized Design (CRD) and applications – two-way classification –Randomized Block Design (RBD) and applications– Solving experimental design problems with CRD and RBD.

PRACTICALS

List of Experiments

1. Solving one-way classification problems using ANOVA with MATLAB
2. Solving two-way classification problems using ANOVA with MATLAB

UNIT IV NUMERICAL METHODS FOR ORDINARY DIFFERENTIAL EQUATIONS **L - 9 P-4**

Single Step methods – Euler's method – Modified Euler's method –Runge-Kutta method of fourth order for solving first and second order ODEs - multi-step methods – Milne's and Adams- Bashforth predictor corrector methods for solving first order ODEs – applications.

PRACTICALS

List of Experiments

1. Solving first-order ODEs using R-K method with MATLAB
2. Solving second-order ODEs using R-K method with MATLAB
3. Solving systems of differential equations using R-K method with MATLAB

UNIT V NUMERICAL METHODS FOR PARTIAL DIFFERENTIAL EQUATIONS **L – 9 P-4**

Classification of partial differential equations - initial and boundary value problems in engineering - finite difference method for second order PDE – wave equation – heat equation – Laplace equation - explicit method for wave equation - Schmidt method and Bendre-Schmidt method for heat equation – Gauss-Seidel iteration method for Laplace equation.

PRACTICALS

List of Experiments

1. Solving initial-boundary problems for parabolic PDE with MATLAB

Reference Books:

1. V. Sundarapandian, `Probability, Statistics and Queueing Theory', PHI, New Delhi, 2016.
2. R. Panneerselvam, `Design and Analysis of Experiments', PHI, New Delhi, 2017.
3. S.R.K. Iyengarand R.K. Jain, ` Numerical Methods', New Age International, 2009.
4. S. Ross, `A First Course in Probability', Pearson Education India, New Delhi, 2013.
5. D.C. Montgomery, ` Design and Analysis of Experiments', Wiley, New Jersey, 2008.
6. S.S. Sastry, `An Introduction to Numerical Methods', PHI, New Delhi, 1995.
7. B.S. Grewal, `Numerical Methods in Engineering and Science', Khanna, New Delhi, 2015.

Sample Assessment Questions:

UNIT-1

Theory:

1. Suppose the duration X in minutes of long distance calls from your home follows exponential distribution with PDF

$$f(x)=\begin{cases}\frac{1}{3}e^{-\frac{x}{3}} & \text{for } x>0\\ 0 & \text{elsewhere}\end{cases}$$

   (a) Find $P(X>5)$.
   (b) Find $P(3\le X\le 6)$.
   (c) Find the mean of X and variance of X.
2. The monthly demand for Allwyn watches is known to have the following probability distribution:

Demand	1	2	3	4	5	6	7	8
Probability	0.08	0.12	0.19	0.24	0.16	0.10	0.07	0.04

   (a) Determine the expected demand for watches.
   (b) Compute the variance.

Practical:

1. Suppose that a balanced coin is to be flipped 20 times. Model this with a binomial distribution and plot the probability mass function and cumulative distribution. Find also the probability of observing
   (a) ten heads,
   (b) at least 10 heads
   (c) between 8 and 12 heads.
2. An electric bulb manufacturer reports that the average life-span of 100W bulbs is 1100 h with a standard deviation of 100 h. Assume that the life-hours distribution is normal.
   (a) Plot the probability density function.
   (b) Find the percentage of bulbs that will last at least 1000 h.
   (c) Find the percentage of bulbs with life-time between 900 h and 1200 h.

UNIT-2

Theory:

1. The joint probability density function (PDF) of X and Y is given by

$$f(x,y)=\begin{cases}4e^{-2x}y & \text{if } x>0,\ 0<y<1\\ 0 & \text{otherwise}\end{cases}$$

   (a) Find the marginal density functions of X and Y.
   (b) Determine the means of X and Y.
   (c) Check if X and Y are independent.
2. Let X and Y be two independent random variables with means 5 and 10, and standard deviations 2 and 3, respectively. Obtain the correlation coefficient between $U=3X+4Y$ and $V=3X-Y$.

Practical:

1. The Fuel Economy Guide published by the Department ofEnergy reports that for the 1998 compact cars the average city mileage is 22.8with standard deviation 4.5, the average highway mileage is 31.1 with standarddeviation 5.5. In addition, the correlation coefficient between the city and highway mileage is 0.95.
   (a) Using MATLAB, find the percentage of 1998 compact cars that give city mileage greaterthan 20 and highway mileage greater than 28.
   (b) Using MATLAB, find the percentage of 1998 compact cars that give city mileage lower than 18 and highway mileage lower than 30.

UNIT-3

Theory:

1. Explain the three basic principles of the Design of Experiments.
   (a) Replication
   (b) Randomization
   (c) Local Control
2. What are the advantages and disadvantages of the Completely Randomized Design (CRD)?
3. What are the advantages and disadvantages of the Randomized Block Design (RBD)?

Practical:

1. Consider the experimental design problem giving per hectare yield for three varieties of wheat, each grown in four plots:

Plots of Land	Variety of Wheat		
	A_1	A_2	A_3
1	6	5	5
2	7	5	4
3	3	4	3
4	8	7	4

   (a) Using MATLAB, set up the ANOVA table for this model using CRD.
   (b) Also, work out F-ratio and test at 5% level of significance, whether there is significant difference among the average yields in the 3 varieties of wheat.

UNIT-4

Theory:

1. Applying Runge-Kutta fourth order method, solve the first-order differential equation $y' = x + y$ with $y(0) = 1$ at $x = 0.2, 0.4$.
2. Given the first order ODE $y' = x^2(1 + y)$ and $y(1) = 1, y(1.1) = 1.233$, $y(1.2) = 1.548, y(1.3) = 1.979$, evaluate $y(1.4)$ by Adams-Bashforth numerical method.

Practical:

1. Consider the *nonlinear pendulum* given by
   $y'' = -\sin(y)$ with $y(0) = 0.1,\ y'(0) = 0.1$
   Plot the trajectory for the above nonlinear model with the Runge-Kutta fourth order method using MATLAB.
2. Consider the *Van der Pol oscillator* defined by
   $y'' - \mu(1 - y^2)y' + y = 0$ with $\mu = 1,\ y(0) = 0.2,\ y'(0) = 0.2$
   Plot the trajectory for the above nonlinear model with the Runge-Kutta fourth order method using MATLAB.

UNIT-5

Theory:

1. Using Schmidt method, find the numerical solutions of the heat equation $u_t = 0.5u_{xx}$
   with the boundary conditions $u(0,t) = u(4,t) = 0$ and the initial conditions $u(x,0) = x(4 - x)$, taking $\Delta x = 1$. Find the values of u up to $t = 5$.
2. The function u satisfies the wave equation
   $u_{tt} = u_{xx}$,
   the initial conditions $u(x,0) = \frac{1}{8}\sin \pi x,\ u_t(x,0) = 0$ for $0 \le x \le 1$, and the boundary conditions $u(0,t) = u(1,t) = 0$ for $t > 0$. Use the explicit scheme

	to calculate u for $x = 0\ (0.1)\ 1$ and $t = 0\ (0.1)\ 0.5$.
	Practical:
	1. Consider the heat equation: $\pi^2 \frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial x^2}$, $(0 \le x \le 1,\ t \ge 0)$. At $x = 0$ and $x = 1$, the solution satisfies the boundary conditions: $u(0,t) = 0$ $\pi e^{-t} + \frac{\partial u}{\partial x}(1,t) = 0.$ Using MATLAB, compute the numerical solution of the PDE with 20 equally spaced mesh points and determine the surf plot of the solution.

PROGRAM CORE

	PRIME MOVERS AND TRANSMISSION	L	T	P	C
		3	0	4	5

Course Category: Program core

Self-Learning Content: Mechanisms-Inversions-Slider Crank Mechanism-Springs-Helical and leaf springs-Cams-Types of Cams and Followers-Cam profile-Frictional force – Laws of friction-Sliding and Rolling Friction-Power Transmission-Gears-Terminology, Spur, Helical and Bevel Gears, Gear Trains-Belt drives (types)-Chain drives.

Course Outcomes

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

CO Nos.	Course Outcomes	Level of learning domain (Based on revised Bloom's)
CO1	Estimate prime movers performance on the basis of thermodynamic cycles and test rig	K3
CO2	Categorize, interpret and understand the fuel supply system required for petrol and diesel engines	K2
CO3	Describe the construction and operation of different transmission systems	K2
CO4	Explain the requirements and outline the working of drive line systems	K2
CO5	Analyze new technical challenges and advancements in power trainsystems	K2

UNIT I: POWER TRAIN FUNDAMENTALS L - 9 P-12

Automobiles and Systems-Engine Classification-S.I and C.I Engine Operating Cycles-Two and Four Stroke Engines-Scavenging-Efficiencies and Other Performance Parameters- Firing order-Port/Valve Timing Diagram(Demonstration)-Efficiency Improvements-Pollution-Emission Standards-Power Transmission Systems.

List of Experiments:

1. Determination of Thermal Efficiency of the Engine.
2. Measurement of Specific Fuel Consumption of the Engine.
3. Measurement of Regulated Emission from an Engine.

List of Demonstrations:

1. Construction and working of Two and Four Stroke Engines
2. Determination of Port/Valve Timing Diagram

UNIT II: AIR-FUEL INDUCTION SYSTEMS and IGNITION SYSYTEM L – 9 P-8

SI Engines: Fuel Tank-Fuel Filter-Fuel Pump-Air Cleaner/Filter-Carburettor-Petrol Injection Systems-TBI, MPFI and GDI-CI Engines: Injection System-Types-Air & Solid Injection Systems-CRDI-Fuel Injectors-Super Charging and Turbo Charging-Components of Ignition Systems-Battery Ignition System-Magneto Ignition System-Electronic Ignition and Ignition Timing.

List of Experiments:

3. Calibration of Fuel Injection Pump.
4. Adjustment of Fuel Injector Opening Pressure.

List of Demonstrations:

1. Demonstration of Petrol Supply Systems.
2. Demonstration of Diesel Supply Systems.
3. Demonstration on Components of Battery-Coil Ignition System.

UNIT III: TRANSMISSION SYSYTEM **L – 9 P-4**

Clutch-Fluid Coupling-Construction and Function-Decoupling of Power, Speed and Torque Characteristics of Power Transmission-Gear Box-Different Types of Gear Boxes-Determination of Gear Box Ratios for Different Vehicle Applications-Torque Converters-Automatic Transmission - CVT.

List of Experiment:

3. Determination of the Gear Ratios of the given Gear Box.

List of Demonstration:

1. Demonstration on Construction and Function of Clutch.

UNIT IV: DRIVE LINE SYSTEMS **L – 9 P-4**

Effect of Driving Thrust and Torque Reaction-Hotchkiss Drives-Torque Tube Drive-Radius Rods, Propeller Shaft-Universal Joints-Final Drive-Rear Axle-Rear Axle Construction: Full Floating, Three Quarter Floating and Semi-Floating Arrangements-Differential: Conventional Type &Non-Slip Type-Differential Locks.

List of Experiment:

4. Determination of the Rear Axle Ratios of the given Rear Axle.

List of Demonstration:

1. Demonstration on Construction and Function of Differential.

UNIT V: ALTERNATE POWERTRAIN TECHNOLOGY **L – 9 P-4**

Low Heat Rejection (LHR) Engine-Dual Fuel/Multi Fuel Engines-Camless Engine-VVT-Homogeneous Charge Compression Ignition (HCCI)-Homogeneous &Stratified GDI-Controlled Auto-Ignition (CAI).

List of Experiment:

2. Performance and emission test on LHR engine.

DESIGN, IMPLEMENT and OPERATE (DIO) - PROJECT **P-30**

Project-Based Learning on prime movers and transmission

REFERENCE BOOKS:

1. V. Ganesan, 'Internal Combustion Engines', Tata McGraw Hill Book Co, Eighth Reprint, 2010.
2. J.B. Heywood, 'Internal Combustion Engine Fundamentals', McGraw Hill Book Co., 2006.
3. M.L. Mathur and R.P.Sharma, 'Internal Combustion Engines', Dhanpat Rai Publicatuions (P) Ltd., 2007.
4. Challen Bernard, 'Diesel Engine Reference Book', Oxford Butterworth, Heinemann, 1999.
5. T. K. Garrett, K. Newton and W. Steeds, 'Motor Vehicle', Butterworth, Heinemann, 13th Edition, 2000.

Sample Assessment Questions:

UNIT-1	**Theory:** 3. A Four stroke four cylinder gasoline engine has a bore of 60 mm and a stroke of 100 mm. On test, it develops a torque of 66.5 Nm when running at 3000 rpm. If the clearance volume in each cylinder is 60 cc, the relative efficiency with respect to break thermal efficiency is 0.5 and calorific value of the fuel is 42 MJ/kg, determine the fuel consumption in kg/h and the break mean effective pressure. 4. The test carried out on a single cylinder two stroke engine, the bore of

	the cylinder is 200 mm and 250 mm stroke at the speed of 60 rpm. The fuel consumption is 56 kg / min and the torque developed is 500 N-m and the indicated mean effective pressure is 4.9 bar. Calculate (i) Indicated Power iii) Brake Power (ii) Mechanical Efficiency iv) Specific Fuel Consumption
	Practical:
	3. Determine the thermal efficiency of the given engine at different loads of operation. 4. Estimate the TFC and BSFC of the given engine at different loads of operation.
UNIT-2	**Theory:**
	3. What is GDI? How does GDI system work? Explain with a neat sketch. 4. Draw a neat and labeled diagram of Common Rail Diesel Injection (CRDI) system for modern automobile engines and explain its working. 5. With a neat sketch discuss the construction and working of distributor type fuel injection pump.
	Practical:
	2. Calibrate the given jerk type Fuel Injection Pump 3. Adjust the injector opening pressure (IOP) of the given single hole nozzle to 260 bar and compare the injection characteristics of the injector with IOP of 220 bar.
UNIT-3	**Theory:**
	4. With the aid of neat sketches describe the constructional features of diaphragm type clutch. Discuss the advantages and disadvantages of the diaphragm clutch over clutch employing helical springs. 5. What is fluid coupling? Explain its constructional details. Draw and explain its performance curves. 6. Draw a sketch of a Chevrolet “Turbo glide" transmission. Also discuss about the types of CVT.
	Practical:
	2. Determine the Gear Ratios of the given Synchromesh Gear Box. 3. Determine the Gear Ratios of the given Constant Gear Box.
UNIT-4	**Theory:**
	3. Describe about Hotchkiss drive and Torque tube drive with sketches. 4. (i) Discuss in detail about constant velocity universal joints with sketches. (ii) Discuss about radius rods and stabilizer bar with respect to mounting and functions. 5. Explain about the construction and working of semi-floating, three-quarter floating and fully floating axles with neat sketches.
	Practical:
	3. Determine the Rear Axle Ratio of the given Rear Axle.
UNIT-5	**Theory:**
	3. Explain the concept of adiabatic engine. Compare the performance of a LHR engine and conventional engine? 4. What is HCCI engine? Explain the performance and emission characteristics of HCCI engine.
	Practical:
	2. Conduct the performance and emission test on the given LHR engine
DIO PROJECT	**Sample Project Titles**
	1. Design and development of Turbo-compound engine.

	2. Development of a semi-automatic clutch using compressed air.
	3. Helmet controlled ignition system for two wheeler rider safety.

Guidelines to select and carry out the project:

Step 1(Identify): Conceive/identify a problem or an innovative idea for the improvement of the existing technology on prime movers and transmission system.

Step 2(Design): Design the system/component as per the technical requirements

Step 3(Implement): Fabricate the system/ device as per the design carried out in step 2

Step 4(Operate): Assemble and test the system/device so developed

EXAMPLE:

Title of the project: **Development of a semi-automatic clutch using compressed air**

Idea	• To prevent the damage to gear box components • To reduce the driver effort required to disengage the clutch By a clutch operated by compressed air. To operate the clutch pneumatically the following components are required: 1. Air compressor and cylinder 2. Double acting pneumatic cylinders 3. Solenoid operated, spring return DCV
Design	Design double acting pneumatic cylinder: For single plate clutch, 1. According to uniform wear theory, Force required to disengage the clutch has to calculated $T = n\mu F(R_o + R_i)/2$ From this equation force required to disengage the clutch can be calculated. 2. Then diameter of the cylinder or size of the double acting pneumatic cylinder has to be determined by using again the pressure force relation. i.e Pressure = Force/Area From this diameter of the cylinder or size of the double acting pneumatic cylinder can be determined.
Implement	Fabricate the pneumatic operated clutch system with air compressor and cylinder, double acting pneumatic cylinders, solenoid operated spring return DCV, hose pipe and switch.
Operate	Operate and test the system for which it is intended.

	AUTOMOTIVE ELECTRICAL AND ELECTRONIC SYSTEMS	L	T	P	C
		3	0	0	3

Course Category: Program core

Self-Learning Content: Basic Electrical Principles, Electronic Components and Circuits, Digital Electronics, Microprocessor Systems, Measurement, Diagnostics – Electronics, Electrical Wiring, Terminals and Switching, Multiplexed Wiring Systems, Circuit Diagrams And Symbols.

Course Outcomes

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

CO Nos.	Course Outcomes	Level of learning domain (Based on revised Bloom's)
CO1	Describe about working principle of sensors and actuators present in an automobile.	K2
CO2	Explain the construction, characteristics and maintenance of starting and ignition system and diagnose the ignition system fault of any vehicle.	K2
CO3	List out the principles and characteristics of charging system components and also the components involved in electronic fuel control.	K2
CO4	Describe the components and latest technologies present in a lighting systems and automotive instrumentation.	K2
CO5	Describe the components of chassis electrical system and auxiliaries.	K2

UNIT-I: SENSORS AND ACTUATORS L – 9

Introduction, Basic Sensor Arrangement, Types of Sensors, Oxygen Sensor, Cranking Sensor, Position Sensor, Engine Oil Pressure Sensor, Linear and Angle Sensor, Flow Sensor, Temperature and Humidity Sensor, Gas Sensor, Speed and Acceleration Sensor, Knock Sensor, Torque Sensor, Yaw Rate Sensors, Tire Pressure Sensor, Actuators.

List of Demonstration:

1. List and function of Sensors in the Automobile.

UNIT-II: STARTING SYSTEMS AND IGNITION SYSTEMS L - 9

Requirements of the Starting System, Starter Motors And Circuits, Types Of Starter Motor, Diagnosing Starting System Faults, Advanced Starting System Technology. Ignition Fundamentals, Types of Ignition System, Electronic Ignition, Programmed Ignition, Distributor Less Ignition, Direct Ignition, Spark-Plugs, Diagnosing Ignition System Faults, Advanced Ignition Technology.

List of Demonstrations:

1. Construction and working of Starter Motor.
2. Construction and working of Spark Plug.

UNIT-III: CHARGING SYSTEMS AND ELECTRONIC FUEL CONTROL L - 9

Requirements of the Charging System, Charging System Principles, Alternators and Charging Circuits, Diagnosing Charging System Faults, Advanced Charging System Technology. Combustion, Engine Fuelling And Exhaust Emissions, Electronic Control of Carburetion, Fuel

Injection Systems, Diesel Fuel Injection, Diagnosing Fuel Control System Faults, Advanced Fuel Control Technology.

List of Demonstrations:

1. Construction and working of Alternator.
2. Construction and working of Fuel Injection (DI/IDI).

UNIT-IV: LIGHTING SYSTEMS AND INSTRUMENTATION L - 9

Lighting fundamentals, Lighting circuits, Gas discharge and LED lighting, Diagnosing lighting system faults, Advanced lighting technology, new developments in lighting systems. Gauges and sensors, Driver information, Visual displays, GPS, Diagnosing instrumentation system faults, advanced instrumentation technology.

List of Demonstration:

1. Various lighting systems and components.

UNIT-V: CHASSIS ELECTRICAL SYSTEMS AND AUXILIARIES L - 9

Anti-Lock Brakes, Active Suspension, Traction Control, Automatic Transmission, Other Chassis Electrical Systems, Diagnosing Chassis Electrical System Faults, Advanced Chassis Systems Technology. Windscreen Washers And Wipers, Signalling Circuits, Other Auxiliary Systems, Diagnosing Auxiliary System Faults, Advanced Auxiliary Systems Technology.

List of Demonstrations:

1. Working principle of ABS and TCS.
2. Working principle of Active suspension system.

REFERENCE BOOKS:

1. Tom Denton, 'Automotive Electrical and Electronic Systems', Routledge, Taylor and Francis Group, 5th Edition, 2017.
2. Young A.P. and Griffiths. L. 'Automotive Electrical Equipment', ELBS & New Press-1999.
3. William B.Ribbens, 'Understanding Automotive Electronics', 5th edition - Butter worth Heinemann Woburn, 1998.
4. Crouse, W.H. 'Automobile Electrical Equipment', McGraw-Hill Book Co., Inc., New York, 3rd edition, 1986.
5. Kholi.P.L, 'Automotive Electrical Equipment', Tata McGraw-Hill Co., Ltd., New Delhi, 1975.
6. Robert Bosch, 'Automotive Hand Book', SAE , 5th Edition, 2000.

Sample Assessment Questions:

UNIT-1	1. Explain in detail about working principle of oxygen sensor. 2. With neat sketch explain the working principle of crank shaft and cam shaft position sensor.
UNIT-2	1. Discuss in briefly about the planetary gear set starter motor. 2. Explain the working principle of electronic ignition system with neat sketch.
UNIT-3	1. Describe the working principle of alternator. 2. Brief about the Turbocharged direct injection system (TDI).
UNIT-4	1. Write in brief about the LED lighting system technology in an automobile. 2. Describe the driver information systems present in an automobile.
UNIT-5	1. Discuss the working principle of active suspension system in an automobile. 2. Write short notes on windscreen wiper system in an automobile.

	ELECTRIC AND HYBRID VEHICLES	L	T	P	C
		3	0	2	4

Course Category: Program core

Self-Learning Content: Basic working principles of Motors.

Course Outcomes

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

CO Nos.	Course Outcomes	Level of learning domain (Based on revised Bloom's)
CO1	Describe about working principle of electric vehicles.	K2
CO2	Explain the construction and working principle of various motors used in electric vehicles.	K2
CO3	Understand about working principle of electronics and sensor less control in electric vehicles.	K2
CO4	Describe the different types and working principle of hybrid vehicles.	K2
CO5	Illustrate the various types and working principle of fuel cells.	K2

UNIT I Introduction to Electric Vehicles L - 9 P-6

Electric Vehicle – Need - Types – Cost and Emissions – End of life. Electric Vehicle Technology – layouts, cables, components, Controls. Batteries – overview and its types. Battery plug-in and life. Ultra-capacitor, Charging – Methods and Standards. Alternate charging sources – Wireless & Solar.

List of Experiments

4. Study of various components of electric car.

List of Demonstrations

3. Demonstration of wiring layout of electric vehicle.

UNIT II Electric Vehicle Motors L - 9 P-6

Motors (DC, Induction, BLDC) – Types, Principle, Construction, Control. Electric Drive Trains (EDT) – Series HEDT (Electrical Coupling) – Power Rating Design, Peak Power Source (PPS); Parallel HEDT (Mechanical Coupling) – Torque Coupling and Speed Coupling. Switched Reluctance Motors (SRM) Drives – Basic structure, Drive Convertor, Design.

List of Experiments

1. V/f control of three-phase induction motor.
2. Speed control of BLDC motor in two wheeler.
3. Speed control of SRM motor in three wheeler.
4. Simulation of Four quadrant operation of three-phase induction motor.

List of Demonstrations

1. Application of DC series motor in an electric vehicle.

UNIT III Electronics and Sensor-less control in EV L - 9 P-6

Basic Electronics Devices – Diodes, Thyristors, BJTs, MOSFETs, IGBTs, Convertors, Inverters. Safety – Risks and Guidance, Precautions, High Voltage safety, Hazard management. Sensors - Autonomous EV cars, Self Drive Cars, Hacking; Sensor less – Control methods- Phase Flux

Linkage-Based Method, Phase Inductance- Based, Modulated Signal Injection, Mutually Induced Voltage-Based, Observer-Based.

List of Experiments

1. Current/Voltage Control of an Electric vehicle.
2. Sensor & Actuators in an Electric Vehicle.
3. Control Circuit of induction motor.

List of Demonstrations

1. Demonstration of charging circuit in an electric vehicle.

UNIT IV Hybrid Vehicles **L - 9 P-6**

Hybrid Electric vehicles – Classification – Micro, Mild, Full, Plug-in, EV. Layout and Architecture – Series, Parallel and Series-Parallel Hybrid, Propulsion systems and components. Regenerative Braking, Economy, Vibration and Noise reduction. Hybrid Electric Vehicles System – Analysis and its Types, Controls.

List of Demonstrations

- Demonstration of electric hybrid vehicle using breadboard/pcb kits.

UNIT V Fuel Cells for Electric vehicles **L - 9 P-6**

Fuel cell – Introduction, Technologies & Types, Obstacles. Operation principles, Potential and I-V curve, Fuel and Oxidation Consumption, Fuel cell Characteristics – Efficiency, Durability, Specific power, Factors affecting, Power design of fuel Cell Vehicle and freeze capacity. Lifetime cost of Fuel cell Vehicle – System, Components, maintenance.

- **A Case Study on "storage of hydrogen in designing the Fuel Cell"**

Reference Books

1. Hybrid Electric Vehicle System Modeling and Control - Wei Liu, General Motors, USA, John Wiley & Sons, Inc., 2017.
2. Hybrid Electric Vehicles – Teresa Donateo, Published by ExLi4EvA, 2017
3. Electric and Hybrid Vehicles Power Sources, Models, Sustainability, Infrastructure and the Market Gianfranco Pistoia Consultant, Rome, Italy, Elsevier Publications, 2017.
4. Modern Electric, Hybrid Electric, and Fuel Cell Vehicles, MehrdadEhsaniYiminGao Stefano Longo Kambiz M. Ebrahimi, Taylor & Francis Group, LLC, 2018.
5. Hybrid, Electric & Fuel-Cell Vehicles Jack Erjavec, Delmar, Cengage Learning.
6. Electric and Hybrid Vehicles, Tom Denton, Taylor & Francis, 2018.

Sample Questions:

UNIT-1	**Theory:**
	1. Explain in detail about layout of Electric vehicle. 2. Discuss about use of ultra capacitors in an electric vehicle.
	Practical:
	5. Dismantling, Assembling and study of electric scooter. 6. Construction and working of lead acid Battery. 7. Demonstration of wiring layout of electric vehicle.
UNIT-2	**Theory:**
	1. Explain the working principle of BLDC motor. 2. Describe about working principle SRM motors.
	Practical:
	4. V/f control of three-phase induction motor. 5. Speed control of BLDC motor. 6. Speed control of SRM motor.

	7. Simulation of Four quadrant operation of three-phase induction motor.
UNIT-3	**Theory:**
	1. Explain in detail about V-I characteristics of IGBT and MOSFET. 2. Explain in detail about phase linkage control method.
	Practical:
	4. MOSFET based step up and step down chopper. 5. VI Characteristics of SCR, IGBT &MOSFET. 6. Three phase IGBT based PWM inverter control of induction motor.
UNIT-4	**Theory:**
	1. Describe in detail about Regenerartive braking system. 2. Explain in detail about Series hybrid.
UNIT-5	**Theory:**
	5. Explain in detail about PEM fuel cell. 6. Explain in detail about solid oxide fuel cell.

	TWO AND THREE WHEELER TECHNOLOGY	L	T	P	C
		3	0	0	3

Course Category: Program core

Self-Learning Content: Working principle of I C Engine**,** Transmission system, Fuel System, Ignition systems.

Course Outcomes

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

CO Nos.	Course Outcomes	Level of learning domain (Based on revised Bloom's)
CO1	Discuss about the two-wheeler types, frames and transmission system.	K2
CO2	Describe about the three wheeler types, frames and design aspects.	K2
CO3	Explain about steering systems, suspension system and brake systems.	K2
CO4	Discuss about cooling systems, lubrication systems, wheels and tires.	K2
CO5	Explain about the Power transmission Electric two and three wheelers.	K2

UNIT I: **INTRODUCTION OF TWO WHEELER** **L – 9**

Classifications of Two Wheelers – Power Transmission Layout of Two Wheelers - Mopeds, Scooters and Motorcycles - Basic Systems - Technical Specifications. Types of Two Wheeler Frames - Kick Starter System- Self-Start System.

List of Demonstration:

1. Demonstration on performance of a two wheeler using chassis dynamometer.

UNIT II: INTRODUCTION OF THREE-WHEELER **L – 9**

Three Wheeler Vehicles - Auto Rickshaws, Pickup Van, Delivery Van. Types of Three Wheeler Frames-Technical Specifications. Design Considerations – Weight and Dimension Limitations – Requirements.

List of Demonstrations:

1. Demonstration on measurement of given three wheeler vehicle dimensions.
2. Demonstration on construction and working of steering systemin three-wheeler vehicle.

UNIT III: STEERING, SUSPENSION AND BRAKE **L - 9**

Steering System - Ackerman Principle of Steering - Front End Geometry - Steering Gearbox-Types-Recirculating Ball - Rack and Pinion - Power Steering. Suspension - Front and Rear Forks - Springs for Suspension - Telescopic Suspension - Monoshock Suspension - Hydraulic Shock Absorber - Dampers. Design Consideration – Brake - Drum Brakes - Disc Brakes - ABS.

List of Demonstrations:

1. Demonstration on measurement of front end geometry of vehicle-camber, caster, kingpin inclination, toe-in and toe-out.
2. Demonstration on compression and rebounce force of shock absorber.
3. Demonstration on two wheeler suspension system.

UNIT IV: COOLING AND LUBRICATION SYSTEMS, WHEELS AND TYRES L – 9

Types of Cooling System - Air Cooling System - Liquid Cooling System - Forced Circulation System - Pressure Cooling System. Lubrication System - Properties of Lubricating Oil - Types of Lubrication system - Petroil Lubrication - Splash Lubrication - Pressure Lubrication - Constructional details of Wheels and Tyres of Two and Three Wheelers.

List of Demonstrations:

1. Demonstration on removal and fitting of given Tyre.
2. Determination on the properties of given lubrication oil.

UNIT V: ELECTRIC VEHICLE L –9

Power Transmission Layout of Electric Two Wheelers - Motor- Hub Motors - Controller- Alternator- Battery systems- Microcontroller.

List of Demonstration:

1. Demonstration on the components of electric scooter.

Reference Books:

1. K. Newton, W. Steeds and T. K. Garrett, 'Motor Vehicle' Butterworth, Heinemann, 13th Edition, 2000.
2. P E Irving, 'Motorcycle Engineering', Veloce Enterprises, Inc, 2017.
3. Dr.Kirpal Singh, 'Automobile Engineering'- Vol. I and II, Standard Publishers, New Delhi, 2011.
4. V. Ganesan, 'Internal Combustion Engines', Tata McGraw Hill Book Co, Eighth Reprint, 2010.
5. Tom Denton, 'Automotive Electrical and Electronic Systems', Routledge, Taylor and Francis Group, 5th Edition, 2017.
6. Dhruv U. Panchal, 'Two and Three Wheeler Technology', PHI Learning, 2015.

Sample Assessment Questions:

UNIT-1	1. Explain the different components of motor cycle with their functions. 2. List out the troubles in scooters, their causes and remedies. 3. Considering the Indian Models of two wheelers, discuss the merits and demerits of any two high performance vehicles.
UNIT-2	1. Explain in detail about the technical specifications and features of Indian models of auto rickshaw. 2. Discuss about the servicing and maintenance of three wheeler. 3. Draw the layout of three wheeler and name the different components with their functions.
UNIT-3	1. With the aid of neat sketches describe the working of power steering system. Discuss the advantages and disadvantages of the power steering system over rack and pinion type steering system. 2. Explain about disc brake with neat sketch. Write the advantages and disadvantages. 3. Describe the front and rear suspension systems for the three wheelers.
UNIT-4	1. Explain with neat sketch about forced circulation cooling system. 2. Describe about the different types of wheels used in two wheelers with neat sketch. 3. State the requirement of lubrication system and brief about properties of lubricants.

UNIT-5	1. Draw the power transmission layout of electric two wheelers. Compare the conventional two wheeler and electric two wheeler. 2. Describe about the different types of motors used in electric two wheeler and their use. 3. Explain in detail about the construction and working of Lead acid battery.

	AUTOMOBILE CHASSIS AND BODY ENGINEERING	L	T	P	C
		3	0	0	3

Course Category: Program core

Self-Learning Content: Sheet Metal Work-Introduction-Equipment-Tools and Accessories-Various Processes- Classification of Materials-Engineering properties of materials-Beams-Types-Supports and Loads-Shear force and Bending Moment-Springs-Helical and leaf springs-Cams-Types of Cams and Followers-Cam profile-Power Transmission-Gears-Terminology, Spur, Helical and Bevel Gears, Gear Trains-Belt drives (types)-Chain drives.

Course Outcomes

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

CO Nos.	Course Outcomes	Level of learning domain (Based on revised Bloom's)
CO1	Enumerate and Identify different car body and body materials.	K2
CO2	Describe the various commercial vehicle body, driver seat design and body repair tools.	K2
CO3	Outline the design features offrame, front axle and steering system	K3
CO4	Understand the types of suspension system, wheels and tyres	K2
CO5	Illustrate the concepts, types, construction and operation of different braking system used in automobiles.	K2

UNIT I: CAR BODY, BODY MATERIALS AND TRIM MECHANISMS L- 9

Classification of Car Body: Saloon-Convertibles-Limousine-Estate Car-Racing and Sports Car-Car Body Construction- Electric Car Body Construction-Steel Sheet-Timber-Plastic-GRP-Properties of Materials-Corrosion-Anticorrosion Methods-Selection of Paint and Painting Process-Body Trim Items- Body Mechanisms.

List of Demonstration:

1. Demonstration on Construction and Types of Car Body.

UNIT II: COMMERCIAL VEHICLE BODY AND BODY REPAIR L- 9

Types of Bus Body: Based on Capacity-Distance Travelled and Construction-Layout for Various Types of Bus Body-Types of Metal Sections Used-Regulations-Constructional Details: Conventional and Integral-Driver Seat Design-Dimensions of Driver's Seat in Relation to Controls-Types of Commercial Vehicle Bodies-LCV-HCV - Electric Bus Body Construction-Panel Repair-Hand Tools-Power Tools-Repairing Sheet Metal and Repairing Plastics Body.

List of Demonstrations

1. Demonstration on Construction and Types of Commercial Vehicle Body.

UNIT III: LAYOUT, FRAME, FRONT AXLE AND STEERING SYSTEM L- 9

Basic Construction of Chassis, Types of Chassis Layout with Reference to Power Plant Location and Drive-Various Types of Frames-Loads Acting on Vehicle Frame-Materials for Frames-Types of Front Axles and Stub Axles-Front Wheel Geometry-Castor-Camber-King Pin Inclination and Toe In-Toe Out-Condition for True Rolling Motion-Ackerman's and Davis Steering Mechanisms- Reversible and Irreversible Steering-Over Steer and Under Steer-Different Types of Steering Gear Boxes- Power Assisted Steering.

List of Demonstrations:

1. Study of Heavy and Light Duty Vehicle Chassis.
2. Demonstration of Front Axle.
3. Demonstration on Construction and operation of steering system.

UNIT IV: SUSPENSION SYSTEM, WHEELS AND TYRES L- 9

Requirements of Suspension System-Types of Suspension-Constructional Details and Characteristics of Single Leaf-Multi–Leaf Spring-Coil Spring and Torsion Bar-Rubber-Pneumatic and Hydro Elastic Suspension-Independent Suspension System-Shock Absorbers-Types of Wheels-Wheel Rims-Construction of Tyres and Tyre Specifications.

List of Demonstrations

1. Demonstration on Construction and operation of various suspension systems.

UNIT V: BRAKING SYSTEM L- 9

Need for Brake System-Stopping Distance-Leading and Trailing Shoes-Braking Torque-Types and Constructional Details-Drum Brakes and Disc Brakes-Hydraulic Braking System-Mechanical Braking System-Pneumatic Braking System-Power Assisted Braking System-Anti Lock Braking System.

List of Demonstrations

1. Demonstration on Construction and operation of various braking systems.

REFERENCES:

1. Donald E. Malen, 'Fundamentals of Automobile Body Structure Design'SAE International, 2011.
2. Geoff Davies, 'Materials for Automobile Bodies', Butterworth-Heinemann, 2012.
3. Powloski J, 'Vehicle Body Engineering', Business Books Ltd., 1998.
4. James E Duffy, 'Body Repair Technology for 4-Wheelers',Cengage Learning, 2009.
5. Crouse and Anglin, 'Automotive Mechanism', 9th Edition. Tata McGraw-Hill, 2003.
6. Jack Erjavec, 'A Systems Approach to Automotive Technology', Cengage Learning Pub., 2009
7. T. K. Garrett, K. Newton and W. Steeds, 'Motor Vehicle', Butterworth, Heinemann, 13th Edition, 2000.

Sample Assessment Questions:

UNIT-1	1. Discuss the methods of improving downward, forward and rearward visibility of car with relevant sketches. 2. Explain in detail the construction of car body with neat sketches.
UNIT-2	1. (i) Explain in detail the influence of engine, entrance and exit location in bus body design with relevant sketches. (ii) Discuss the different types of metal sections used in a bus body layout 2. (i)List out the points to be considered while designing a driver's seat. (ii)Explain the integral type of bus body construction with a neat sketch
UNIT-3	1. A vehicle of 2.875 m wheel base 1.255 m front and rear wheel track and has its pivot centre 1.155 m apart. If the inside lock angle is 40^{o}calculate (i) Outside lock angle for true rolling (ii) Turning circle radius for outer front wheel and inner rear wheel. 2. (i) With suitable diagram explain Ackerman's steering geometry. (ii) Explain the construction and working principle of rack and pinion type steering gear box.

UNIT-4	1. (i) Explain any two types of independent suspension systems in rear axle. (ii) Discuss the construction of rubber suspension system. 2. (i) Explain the pneumatically operated suspension system with neat sketch. (ii) Explain about shock absorber with reference to construction, mounting and working.
UNIT-5	1. Write short notes on the following: (i) Anti-lock braking system (ii) Effect of weight transfer during braking. 2. (i) Explain the mechanical braking system with its limitations. (ii) Discuss the servo braking system with neat diagram.

	POWERTRAIN MANAGEMENT SYSTEM	L	T	P	C
		3	0	0	3

Course Category: Program Core

Self-Learning Content: Basic Automotive Electrical and Electronics, Engine Layout, Fuel and transmission Component.

Course Outcomes

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

CO Nos.	Course Outcomes	Level of learning domain (Based on revised Bloom's)
CO1	Understand the basic electronic components and its controls.	K2
CO2	Describe the operating conditions and control systems used in SI engine.	K3
CO3	Describe the ignition and injection methods used in CI engine	K3
CO4	Discuss the various emission systems and diagnostics procedure.	K3
CO5	Discuss the electronic diagnosis systems and transmission control system used in the digital dashboard unit.	K3

UNIT I: FUNDAMENTALS OF OBD SYSTEMS **L-9**

Components for Electronic Engine Management System, Open and Closed Loop Control Strategies, PID Control, Look Up Tables, Introduction to Modern Control Strategies Like Fuzzy Logic and Adaptive Control. Switches, Active Resistors, Transistors, Current Mirrors/Amplifiers, Voltage and Current References, Comparator, Multiplier. Amplifier, Filters, A/D and D/A Converters. Actuators and its types.

List of Demonstration:

1. Study of OBD tool kit.

UNIT II : SI ENGINE MANAGEMENT **L-9**

Layout and Working of SI Engine Management Systems like Bosch Motronic (M, ME, MED) Engine Management, System Overview- System Structure. Electronic Control and Regulation-Electronic Diagnosis-Electronic Control Unit and Development. ECU Operating Conditions, Design and Data Processing.

List of Demonstration:

1. Control of Fuel Injection and Ignition System (open loop/closed loop).

UNIT III : CI ENGINE MANAGEMENT **L-9**

Fuel Injection System Parameters Affecting Combustion, Noise and Emissions in CI Engines. Pilot, Main, Advanced Post Injection and Retarded Post Injection. Electronically Controlled Unit Injection System. Layout of the Common Rail Fuel Injection System. Working of Components like Fuel Injector, Fuel Pump, Rail Pressure Limiter, Flow Limiter, EGR Valves.

List of Demonstration:

1. Control of Fuel Injection (open loop/closed loop).

UNIT IV: DIAGNOSIS AND CONTROL SYSTEMS **L-9**

Electronic Control System Overview-Subsystems And Main Functions-Electronics Diagnosis-Self-Diagnosis- Engine Diagnostics - Introduction To Diagnosis, Types Of Engine Diagnostics, Need For OBD, Types Of OBD, General Requirements-Diagnosis System Management-

Individual Diagnosis-Data Transfer Between Automotive Electronic System. Model Based Diagnostic Control- Various Engine Systems Diagnostic (Air System, Fuel System, Exhaust System)

List of Demonstration:

1. Study of DTCs using OBD tool kit.

UNIT V: DIGITAL ENGINEAND VEHICLE CONTROL SYSTEMS L-9

EMS- Engine Functions and Control-General Terms and Performance – Engine Mapping, Control Strategy-Engine Control Sequence-Calibration Technique in EMS, VVT Control, Camless Control, Variable Swirl Mechanisms- Different Types of Automatic Transmission - Control System - Basics Of Driveline Control, Driveline Speed And Torque Control, Gear Shift Control, Anti-Jerk Control, Driveline Diagnostic System- CVT, Advancement in Driveline Control System.

List of Demonstration:

1. Study of CVT, DCT and Torque converter**.**

REFERENCE BOOKS:

1. William, B. Ribbens, 'Understanding Automotive electronics', Butterworth Heinemann, 2017.
2. Robert Bosch, 'Diesel Engine Management ', SAE Publications, 3rd Edition, 2004
3. Robert Bosch, 'Gasoline Engine Management', SAE Publications, 2nd Edition, 2004
4. Lino Guzzella and Christopher H. Onder, 'Introduction to Modeling and Control of Internal Combustion Engine Systems', Springer-Verlag, 2010.
5. Lars Eriksson and Lars Nielsen, 'Modeling and Control of Engines and Drivelines', John Wiley & Sons, 2014.
6. Rolf Isermann, 'Engine Modeling and Control - Modeling and Electronic Management of Internal Combustion Engines', Springer Verlag, 2014.

Sample Assessment Questions:

UNIT-1	1. Draw a layout of Electronic Engine Management System with closed loop strategies. 2. Discuss Analog / digital convertors and Digital / Analog Convertors (i) Explanation iii) Commercial (ii) Types iv) Application and testing
UNIT-2	1. Draw a layout and Working of SI Engine Management Systems and compare Bosch Motronic (M, ME, MED) 2. With a neat sketch explain the diagnosis-electronic control unit and development of ECU operating conditions, design and data processing.
UNIT-3	1. Explain all factors affecting the Fuel Injection System Parameters of Combustion, Noise and Emissions in CI Engines. 2. Discuss the working of Components like Fuel Injector, Fuel Pump, Rail Pressure Limiter, Flow Limiter, and EGR Valves in C.I Engine.
UNIT-4	1. Describe the Electronic Control System- Overview & Subsystems. 2. Engine Diagnostics (i) Explanation iii)Need (ii) Types iv) Requirements & system management
UNIT-5	1. Explain the concept of engine mapping, control strategy-engine control sequence. 2. Tabulate the different types of automatic transmission based on function and its performance.

SPECIALIZATION CORE

FOR

POWERTRAIN ENGINEERING

	ENGINE COMBUSTION AND SIMULATION	L	T	P	C
		3	0	2	4

Course Category: Specialization Core/PTE

Classifications, S.I and C.I engine operating cycles- Two and four stroke engines- Firing order, Port/valve timing diagram, Engine performance-Engine Components & Materials- Fuel and Ignition System-Turbo charging, supercharging, EGR

Course Outcomes

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

CO Nos.	Course Outcomes	Level of learning domain (Based on revised Bloom's)
C01	Describe the importance of simulation tools in modelling of IC engine.	K2
C02	Determine the calorific value and stoichiometric air requirements	K3
C03	Calculate the adiabatic flame temperature at constant volume and constant pressure combustion.	K3
C04	Investigate the various models for SI engine combustion and the influence of model parameters on engine performance and combustion characteristics.	K3
C05	Investigate the various models for CI engine combustion and the influence of model parameters on engine performance and combustion characteristics.	K3

UNIT I: INTRODUCTION TO SIMULATION L 9 P 6

Basic knowledge to simulation, advantages of engine simulation - Classification of engine models- Intake and exhaust flow models - Open and closed cycle models - Simulation of various cycles - Step by step approach in engine simulation.

List of Experiments:

1. Investigate the performance characteristics of multi cylinder diesel engine.
2. Experimental study of CI engine powered by alternative energy sources.

UNIT II: COMBUSTION AND STOICHIOMETERY L 9 P3

Theories of combustion- Laminar and Turbulent flame propagation in engines -First and second law of thermodynamics applied to combustion- combustion equation for hydrocarbon fuels- Heat of reaction - Measurement of U_{RP}, measurement of H_{RP} –- Calculation of minimum air, excess air and stoichiometric air required for combustion - Calculation of higher and lower heat value of fuels.

List of Experiments:

1. Measurement of higher and lower heat value of given fuel

UNIT III: ADIABATIC FLAME TEMPERATURE L 9 P 6

Theoretical flame temperature, complete combustion in C-H-N-O systems - Constant volume adiabatic combustion, constant pressure adiabatic combustion - Calculation of adiabatic flame temperature, isentropic changes of state - Deviation between actual and ideal cycle.

List of Experiments:

1. Determine the adiabatic flame temperature at constant volume combustion.

2. Determine the adiabatic flame temperature at constant pressure combustion.

UNIT IV: MODELING OF SI ENGINE L 9 P 6

SI engine simulation with air as working medium- Fuel air cycle analysis - Temperature drop due to fuel vaporization, engine performance at part throttle and full throttle operation, work output and efficiency calculation - SI engines simulation with progressive combustion - Models for mass burnt fraction.

List of Experiments:

1. Modelling the single cylinder gasoline engine using Wavebuild
2. Simulation of multi-cylinder gasoline engine with exhaust gas recirculation

UNIT V: MODELING OF CI ENGINE L 9 P 9

Zero, one and multi zone models for diesel engine combustion - Wiebe's Model- Whitehouse model- Watson model for diesel combustion - Heat release rate and heat transfer models- Equilibrium calculations - Parametric studies on simulated engine performance.

List of Experiments:

1. Theoretical analysis of single cylinder diesel naturally aspirated engine using Wavebuild
2. Modelling of multicylinder diesel engine with turbocharger
3. Simulation of dual fuel CI engine powered by octane and cetane rating fuels

TEXT BOOKS

1. Ganesan.V. "Computer Simulation of Compression Ignition Engine Process", Universities Press (Ind) Ltd, Hyderbad, 2013.
2. Lakshminarayan, P.A and Aghav Yogesh. V, "Modeling Diesel Combustion", Springer, 2010.

REFERENCES

1. Rolf Isermann, "Engine Modelling and Control", Springer Heidelberg New York Dordrecht London, 2014.
2. Günter P. Merker · Christian Schwarz · Gunnar Stiesch · Frank Otto, "Simulating Combustion, Springer-Verlag Berlin Heidelberg 2006.
3. B.P. Pundir, IC Engines: Combustion and Emissions, Alpha Science International, Ltd, 2010
4. John B.Heywood, Internal Combustion Engine Fundamentals, McGraw Hill, 2006.

	ENGINE DESIGN AND DEVELOPMENT	L	T	P	C
		2	2	0	3

Course Category: Program core

Self-learning Content:
Basic of IC Engine

Course Outcomes
Upon the successful completion of the course, student will be able to

CO Nos.	Course Outcomes	Level of learning domain (Based on revised Bloom's)
CO1	Describe the various engine performance parameters	K2
CO2	Construct crank train for the given specifications which includes the design of piston, connecting rod, crankshaft and flywheel	K3
CO3	Calculate thermal loads and select a suitable material to design cylinder head and block	K3
CO4	Select and design suitable valve train for the given specifications.	K3
CO5	Describe the design procedure involved in Cooling, Lubrication, Intake, Exhaust and Fuel Injection Systems	K2

UNIT I: PARAMETERS L–6 T-6

Compression ratio, Pressure volume and pressure crank angle diagram, frictional mean effective pressure, engine capacity, calculation of bore and stroke length, velocity and acceleration, gas force, inertia and resultant force at various crank angles – Side thrust on cylinder walls, Optimization criteria for improving Thermal, Mechanical and Volumetric efficiency.

List of Demonstrations

1. Determination of Compression ratio
2. Determination of pressure crank angle diagram

UNIT II: DESIGN OF CRANK TRAIN L– 6 T-6

Design of Piston, piston rings, piston pin, Design of connecting rod; big end, small end and shank. Material and failures related to Cylinder, piston, connecting rod, design of crankshaft for light and heavy vehicle; Crankshaft, front end, rear end, journals, crank pin, Crank web. Design of flywheel; Speed fluctuation and stress calculations, turning moment diagram, design of hub, rim and arms of the flywheel, Ring gear Material and failures related to Crankshaft and flywheel.

List of Demonstrations

1. Dismantling and study of piston.
2. Dismantling and study of crankshaft and connecting rod.

UNIT III: DESIGN OF CYLINDER HEAD AND BLOCK L– 6 T-6

Functional requirement, Block material like Gray Iron, Aluminum, Compacted Graphite Iron and Magnesium, Cylinder head alloys, Design layout, Basic block, Bulk head design, and Cylinder liner design approach and Thermal loads. Cylinder arrangement, number of cylinders

List of Demonstrations

1. Dismantling and study of cylinder head and cylinder liners.

UNIT IV: DESIGN OF VALVE TRAIN L– 6 T-6

Effect of valve timing on engine performance, Number of Valves, Design of valves, Valve seat, Valve guide and cotter, Time selection of valve, Cam profile construction, Design of valve spring, Design of camshaft, Single and Double Overhead camshaft design, Design of valve gear train for variable valve timing.

List of Demonstrations

1. Dismantling and study of valve train mechanism.

UNIT V: DESIGN OF COOLING, LUBRICATION, INTAKE, EXHAUST AND FUEL INJECTION SYSTEM L– 6 T-6

Design of cooling system, radiator, water pump, thermostat and fan, Computation of air cooling system Engine friction and wear, Selection of lubricant, lubricating system, pump and filters, Design of intake and exhaust system ,Designof fuel system for CI engine, Governor Design, Design of carburetor **-** electronic carburetor**,** Design of MPFI, GDI, CRDI system.

List of Demonstrations

1. Dismantling and study of fuel injection systems.
2. Dismantlingand study of cooling system

Reference Books

1. Kevin L. Hoag , 'Vehicular Engine Design',SAE international,2005.
2. A.Kolchin and V.Demidov, 'Design of Automotive Engines', MIR Publishers, Moscow, 1984.
3. R.K. Jain, 'Machine Design', Khanna Publishers, New Delhi, 1997.
4. 'Design Data Book', PSG College of Technology, Coimbatore, 2000.
5. Giles J. G 'Engine Design' –., Life Book Ltd. 2000
6. Crouse 'Engine Design' Tata McGraw Publication, Delhi 2002

Web links

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2. https://books.google.co.in/books/about/Design_of_Automotive_Engines.html?id=YmgpYgEACAAJ&redir_esc=y
3. https://www.slideshare.net/BhushanKhairkhar1/design-of-internal-combustion-engine-components-be-mechanical
4. http://www.faadooengineers.com/threads/48333-PSG-Design-Data-Book-pdf
5. http://academica-e.unavarra.es/bitstream/handle/2454/3885/577521.pdf?sequence=4
6. https://www.researchgate.net/publication/282356039_MECHANICAL_DESIGN_OF_INTERNAL_COMBUSTION_ENGINE

Sample Assessment Questions:

UNIT-1	1. Define Compression Ratio (CR) and How is it determined? 2. Define Pressure volume and pressure crank angle with a neat sketch. 3. Explain about engine efficiency

UNIT-2	1. Design a cast iron piston for a single acting four stroke engine for the following specifications. Cylinder bore = 120 mm, stroke = 140 mm, maximum gas pressure = 6 N/mm3, brake mean effective pressure = 0.7 N /mm2, fuel consumption = 0.23 kg/kW/hr speed = 2400 rpm 2. A connecting rod is to be designed for a high speed I.C. engine. The data available are: Diameter of piston 90 mm, mass of reciprocating parts = 1.5 kg, length of connecting rod, centre to centre = 350 mm, stroke = 140 mm, RPM = 2200, (When developing 55 kW, possible over speed = 3000 rpm, compression ratio 6.8:1 approximately.), probable maximum explosion pressure (assumed shortly after dead centre say 3o) = 3 N/mm2. Note: Compression ratio can be used in determining the indicated mean effective pressure, 7 to 8 times of which can be taken as maximum explosion pressure. Since the maximum explosion pressure is explicitly given in the problem, the information on compression ratio is superfluous.
UNIT-3	1. A four stroke diesel engine has the following specifications: Brake power = 5 kW; Speed = 1200 r.p.m.; Indicated mean effective pressure = 0.35 N/mm2 mechanical efficiency =80%. Determine: 1. bore and length of the cylinder; 2. thickness of the cylinder head: and 3. size of studs for the cylinder head. 2. Describe the Design procedure of a cylinder
UNIT-4	1. Design aspects of inlet and exhaust values. 2. The conical valve of an I.C. engine is 60 mm in diameter and is subjected to a maximum gas pressure of 4 N/mm2. The safe stress in bending for the valve material is 46 MPa. The valve is made of steel for which k = 0.42. The angle at which the valve disc seat is tapered is 30°.Determine: 1. thickness of the valve head ; 2. stem diameter ; and 3. maximum lift of the valve
UNIT-5	1. Write briefly about water cooling system with a neat sketch **2.** Explain different types of fuel injection system with neat diagram

	POWERTRAIN NVH	**L**	**T**	**P**	**C**
		2	**2**	**0**	**3**

Course Category: Specialization Core/PE

Self-Learning Content: Basics of Noise & Vibration related issues in an automobile.

Course Outcomes

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

CO Nos.	**Course Outcomes**	**Level of learning domain (Based on revised Bloom's)**
CO1	Understand the sources of noise in a vehicle	K2
CO2	Realize the design features to control noises in a vehicle	K2
CO3	Outline the basics of vibration and noises in a vehicle.	K2
CO4	Illustrate the measurement techniques of noise and vibration.	K2
CO5	Analyse the various parameters of powertrain noises and vibrations	K3

UNIT I INTRODUCTION TO AUTOMOTIVE NVH **L-9**

Automotive NVH sources Pass-by noise limits, Interior noise of vehicles, Sound quality, Ride comfort, Noise and vibration control in vehicles.

List of Demonstrations

1. Demonstration of various vibration measuring instruments.

UNIT II VEHICLE NOISE **L-9**

Sources of noise and vibration. Design features. Common problems. Noise quality. Target vehicles and objective targets.

List of Demonstrations

1. Demonstration of Vibration Analysis using frequency domain analysis.

UNIT III FUNDAMENTALS OF VIBRATION AND NOISE **L-9**

Natural vibration of Single Degree of Freedom System (SDOF) and Multi Degree of Freedom System (MDOF), Undamped, damped and forced vibrations and Vibration of beams, plates & shells. Basics of sound propagation, Quantification of sound, Noise sources, generation and radiation, Machinery noise identification and Noise induced hearing loss.

List of Demonstrations

1. Demonstration of beating phenomenon

UNIT IV VIBRATION AND NOISE MEASUREMENT **L-9**

Vibration transducers and exciters, Sound pressure, intensity and power measurement, Frequency analysis and Digital signal processing.

List of Demonstrations

1. Demonstration of various noise measuring instruments.

UNIT V POWERTRAIN NVH **L-9**

Sound Pressure, Sound Intensity, Sound Intensity Ratio, Sound Intensity Level, Noise level, Sound power level, Change in Noise level, Bare Engine or Basic Engine Noise Level, Noise

generation process in a Diesel engine, Combustion and Mechanical noise, Parameters affecting Combustion forces, Mechanical Impact forces.

Intake and Exhaust System NVH: Plain & three-dimensional waves in an Inviscid stationary and moving medium, Waves in ducts with compliant walls, Requirements of an engine exhaust mufflers, Acoustic considerations, Back-pressure considerations, practical considerations.

List of Demonstrations

1. Demonstration of Vibration Analysis of using Time domain analysis.

Reference books:

1. Malcolm J. Crocker, "Noise and Vibration Control", Wiley, 2007.
2. Cyril M. Harris & Allan G. Piersol, "Shock and Vibration Handbook", McGraw Hill Inc., 2002
3. Proceedings of the Workshop on 'Noise, Vibration & Harshness (NVH) for Automotive Engineering' 18-20 March, 2002, at ARAI, Pune, published by SAE Western India Section and ARAI
4. Prof. Munjal M.L., "Acoustic Ducts and Mufflers", John Wiley, 1987.
5. Nortan MP "Fundamental of Noise and Vibration", Cambridge University Press, 1989.
6. Baxa, "Noise Control of Internal Combustion Engine", John Wiley, 1984.
7. Lewis L, "Industrial Noise Control", McGraw Hill Inc, 1991.
8. Prof. Munjal M.L., "Acoustic Ducts and Mufflers", John Wiley, 1987.
9. Fahy F.J. "Sound Intensity" Elsevier, 1989.
10. Hearn G and Metcalfe, A. "Spectral Analysis in Engineering – Concept & Cases", Arnold, 1995.
11. Boris and Korney, "Dynamic Vibration Absorbers", John Wiley, 1993.

	AUTOMOBILE FUELS AND EMISSION	L	T	P	C
		3	0	2	4

Course Category: Specialization core/PTE

Course Outcomes

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

CO1	Interpret and understand the essential properties, manufacturing techniques and use of liquid fuels in petrol and diesel engines.	**K2**
CO2	Analyze the properties, characteristics and the implementation limits of gaseous fuels like LPG, CNG, and HYDROGEN in I.C engines.	**K3**
CO3	Explain the formation of pollutants in SI engine and describe the Emission control techniques.	**K2**
CO4	Describe the formation of pollutant in CI engine and describe the Emission control techniques.	**K2**
CO5	Outline the emission measurement techniques and various test procedure	**K2**

UNIT I LIQUID FUELS **L-9**

Conventional fuels- Need for alternate fuels, availability and comparative properties of alternate fuels. Biofuels - Biodiesel, Ethanol, - Biofuels from micro algae and SVO: Manufacturing process of alcohol, blending of methanol and ethanol, oxygenated additives, types of vegetable oils for engine application, Esterification, properties, engine design modifications required & effects of design parameters, engine performance & emission characteristics.

List of Experiments

1. Temperature dependence of viscosity of lubrication oil by Redwood Viscometer.
2. Flash, Fire, Cloud and pour point of fuels.
3. Aniline distillation test of gasoline.
4. Calorific value of liquid fuel.
5. Reid vapor pressure test.
6. Copper corrosion test.
7. Density test on different fuels.

List of Demonstrations

1. Transesterification of various vegetable oil.

UNIT II GASEOUS FUELS **L - 9**

Gaseous Fuels - CNG, LPG, BIOGAS, LNG and HCNG: Availability, properties, modifications required in SI engines, performance and emission characteristics, storage, handling & dispensing, safety aspects. Hydrogen and Fuel cells - Production methods, properties, performance and emission characteristics, storage and handling, safety aspects, working principle, classification, description of fuel cell systems, fuel cell components, properties of fuel cells, general performance characteristics, emission characteristics, merits and demerits.

List of Experiments

1. Measurement of calorific value of gaseous fuel
2. Measurement of flow rate of various gaseous fuel.

List of Demonstrations

1. Gasification of Biomass.

UNIT III EMISSIONS FROM SI ENGINES AND ITS CONTROL L – 9

Emission formation in S.I. engines, hydrocarbons, carbon monoxide, nitric oxide & lead, effects of design & operating variables on emission formation, controlling of emission formation in engines, thermal reactors, catalytic converters, charcoal canister control for evaporative emission, positive crank case ventilation system, nano particles.

List of Experiments

1. Measurement of emission from S.I engine in different load conditions on chassis Dynamometer.

UNIT IV EMISSIONS FROM CI ENGINES AND ITS CONTROL L - 9

Diesel combustion, stages, direct & indirect combustion, emission formation, particulate matter & smoke, effect of operating variables on emission formation, PM & NOx trade-off, controlling of emission formation in engines, Exhaust Gas Recirculation (EGR), air injection, cetane number effect, emission after-treatment devices like DOC, DPF, SCR & NOx Absorber.

List of Experiments

1. Emission treatment using after treatment devices.
2. Diesel smoke measurement.

List of Demonstrations

1. Measurement of emission from C.I engine while using various fuel.
2. Demonstration of EGR for NOx reduction

UNIT V EMISSION MEASUREMENT AND TEST PROCEDURE L - 9

Emission scenario & norms, emission sources & effects, fuel properties & their effects on performance & emission. Measurement & instrumentation for HC, CO, CO2, NOx & PM, smoke meters, calibration checks on emission equipment's, dilution tunnel technique for particulate measurement, emission test procedures on engine & chassis dynamometers, constant volume sampling procedure, sampling probes & valves, quantifying emissions, chemical analysis of automotive emission.

List of Experiments

1. Measurement and analysis of formulated emissions.
    a. Fossil fuel
    b. Alternate fuels

REFERENCES

1. Thipse.S.S., Alternative Fuels; Concepts, Technologies and Developments, Jaico Book Distributors, 2010
2. Holt and Danniel, Fuel cell powered vehicles: Automotive technology for the future, SAE, 2001.
3. Ganesan.V., "Internal Combustion Engineering", Tata McGraw-Hill Publishing Co., New Delhi, 2012.
4. Gerhard Knothe, Jon Van Gerpen, Jargon Krahl, The Biodiesel Handbook, AOCS Press Champaign, Illinois 2005.
5. John,B., Heywood, Internal Combustion Engine Fundamentals, McGraw Hill Publishing Co., New York, 1988.
6. B.P.Pundir, " IC Engines Combustion and Emissions" Narosa Publishers, 2010
7. Transactions of SAE on Biofuels (Alcohols, vegetable oils, CNG, LPG, Hydrogen, Biogas)
8. Science direct Journals (Biomass & Bio energy, Fuels, Energy, Energy conversion Management, Hydrogen Energy, etc.) on biofuels.

	ENGINE TESTING AND CERTIFICATION	L	T	P	C
		3	0	2	4

Course Category: Specialization core/PTE

Course Outcomes:

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

CO Nos.	Course Outcomes	Level of learning domain (Based on revised Bloom's)
CO1	Describe the requirements of engine test cell facilities	K2
CO2	Explain the theory of dynamometers and other engine testing equipment	K2
CO3	Understand the engine test standards and modes of engine testing	K2
CO4	Elucidate the engine emission measurement using different emission analyzers for various driving cycles	K2
CO5	Outline the technical advancements in engine testing	K2

UNIT I ENGINE TEST FACILITIES **L - 9**

Test cell requirements, cell console & control room, ventilation, air conditioning & exhaust, cooling, lubrication/fuel supply systems, noise & vibration control in test cells, electrical.

List of Demonstrations

1. Test cell preparation

Unit II ENGINE DYNAMOMETER & TESTS EQUIPMENTS **L - 9**

Engine dynamometers, types of dynamometers, dynamometer panels, engine controllers, data acquisition system, engine dynamometer coupling, fuel consumption meter, air fuel ratio measurement, oil consumption measurement, temperature & pressure measurement, humidity measurement, calibration & maintenance program/ durability.

List of Demonstrations

1. Study and selection of Dynamometers.
2. Study and use of Pressure pickups, Emission Analyzer for Engine testing.

UNIT III ENGINE MEASUREMENTS **L - 9**

Engine test standards, full throttle & part throttle performance, road load testing, ISO mapping, interpolation, friction measurement, durability, maintenance.

List of Experiments

1. Performance and measurement of genset Engine (5 mode)
2. Performance and measurement of Tractor Engine (8 mode)
3. Performance and measurement of C.V Engine (13 mode)
4. Determine the Frictional power on petrol engines.

List of Demonstrations

1. Study of Heat balance of an engine.

UNIT IV ENGINE EMISSION MEASUREMENTS IN VARIOUS MODES **L - 9**

Emission analyzers, emission cycles for diesel commercial vehicles, tractors & gensets, steady state and transient cycles, dilution tunnel, particulate emissions, calibration and maintenance.

List of Experiments

1. Emission measurement of genset Engine (5 mode).
2. Emission measurement of Tractor Engine (8 mode).
3. Emission measurement of C.V Engine (13 mode).

UNIT V ADVANCED ENGINE TESTING **L - 9**

Use of special equipment, fuel injection pressure, combustion pressure, needle lift, gas exchange process, combustion photography, swirl measurement, analysis of data.

List of Experiments

1. Fuel injector calibration.
2. Swirl measurement Test.

List of Demonstrations

1. Demonstration on Construction and Function ofDifferential.

REFERENCES

1. A.J.Martyr, M.A.Plint, Engine Testing Theory and Practice, Elsevier, Third Edition, 2007.
2. Michael James Plint& Tony Martyr, “Engine Testing - Theory & Practice”, 3rd Edition , SAE International ,2007.
3. Heniz Heisler, “Advanced Engine Technology”, Vol.1, SAE International 2002.
4. Richard D Atkins, “An Introduction to Engine Testing & Development”, ISBN 978-0-7680-2099-1, SAE International 2009.

SPECIALIZATION CORE
FOR
ELECTRIC & HYBRID VEHICLES

	VEHICLE MECHANICS	L	T	P	C
		3	0	0	3

Course Category: Specialization Core/EHV

Self-Learning Content: Basic concepts of Forces, Force system and Basics of Vibration terms and its types.

Course Outcomes

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

CO Nos.	Course Outcomes	Level of learning domain (Based on revised Bloom's)
CO1	Solve engineering problems using the principles of statics of particles, magnitude of forces and moments acting on rigid bodies	K2
CO2	Discuss the effects of Static and Dynamic balancing of rotating and reciprocating masses.	K2
CO3	Explain the concept of vibration and its effects.	K2
CO4	Deliberate the effective steering geometry, vehicle handling and directional control of vehicle.	K2
CO5	Explain the dynamic characteristics of the vehicle with suspension system.	K2

UNIT – I: EQUILIBRIUM OF RIGID BODIES L - 9

Introduction - Laws of Mechanics - Vectorial Representation of Forces and Couples- Resolution and Composition of Forces - Forces in Space- Equilibrium of a Particle in Space, Equivalent Systems of Forces -Principle of Transmissibility- Free body diagram- Types of Supports and their Reactions-Moments and Couples- Varignon's Theorem-Equilibrium of Rigid Bodies in Two Dimensions.

List of Demonstration:

1. Demonstration on "Deflection test on Beams".

UNIT – II: BALANCING L - 9

Static and Dynamic Balancing – Balancing of Rotating Masses – Several Masses in Single and Different Planes - Balancing of Reciprocating Masses- Concepts of Primary Balancing And Secondary Balancing - Partial Balancing of Locomotives – Balancing of Multi-Cylinder Inline Engine.

List of Demonstration:

1. Demonstration on "Balancing of Rotating masses".

UNIT III: CONCEPT OF VIBRATION L – 9

Free and Damped Vibration - Forced vibration response of Single Degree of Freedom Systems - Magnification factor – Force Transmissibility - Vibration isolation and absorption – Torsional vibration of shaft – Single and multi-rotor systems – Critical speed of shaft.

List of Demonstrations:

1. Determination of natural frequency of Spring mass system.
2. Determination of critical speeds of shafts with concentrated loads.

UNIT IV: HANDLING CHARACTERISTICS OF ROAD VEHICLES L - 9

Steering Geometry - Steady State Handling Characteristics - Steady State Response to Steering Input - Testing of Handling Characteristics - Transient Response Characteristics- Directional Stability. Introduction to Aerodynamic Forces and Moments - Tire Forces and Moments.

List of Demonstration:

1. Demonstration on "Aerodynamic characteristics of a model car" using wind tunnel.
2. Demonstration on measurement of front end geometry of vehicle-camber, caster, kingpin inclination, toe-in and toe-out.

UNIT V: RIDE CHARACTERISTICS OF VEHICLES L - 9

Human Response to Vibration - Vehicle Ride Models - Active and Semi Active Suspensions- Roll Center, Roll Axis and Vehicle under Side Forces. Influence of Suspension Stiffness- Suspension Damping and Tire Stiffness- Air Suspension System and their Effectiveness.

List of Demonstration:

1. Demonstration on "Vehicle suspension stiffness effectiveness".

REFERENCES:

1. Beer, F. P., and Johnston, E. R., 'Vector Mechanics for Engineers – Dynamics and Statics', Tata McGraw-Hill, New Delhi, 2011.
2. Shigley, J.E. and Uicker, J.J., 'Theory of Machines and Mechanisms', McGraw-Hill, 2012.
3. Singiresu S. Rao, 'Mechanical Vibrations', 5th Edition, Prentice Hall, 2010.
4. Thomas D. Gillespie, 'Fundamentals of Vehicle Dynamics', Society of Automotive Engineers Inc, 1992.
5. Rajesh Rajamani, 'Vehicle Dynamics and Control', Springer, 2005.

	POWER ELECTRONICS FOR AUTOMOBILES	**L**	**T**	**P**	**C**
		3	**0**	**2**	**4**

Course Category: Specialization Core/EHV

Course Outcomes

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

CO Nos.	**Course Outcomes**	**Level of learning domain (Based on revised Bloom's)**
CO1	Understand the working principle of Semiconductor devices	K2
CO2	Describe the construction and operation of Converters.	K2
CO3	Illustrate the construction and operation of Rectifiers and Inverters.	K2
CO4	Explain the construction and working principle of various Electric motor types.	K2
CO5	Make use of power electronics components in hybrid electric vehicle and fuel cell vehicle.	K3

UNIT I: BASIC POWER ELECTRONIC DEVICES L – 9 P-6

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

List of Experiments

1. VI Characteristics of DIODES.
2. VI Characteristics of BJT.
3. VI Characteristics of MOSFET & IGBT.

UNIT II: DC/DC CONVERTER L – 9 P-6

Basic Principle of DC–DC Converter, Step-Down (Buck) Converter, Step-Up (Boost) Converter, Buck–Boost Converter, DC–DC Converters Applied in Hybrid Vehicle Systems, Isolated Buck DC–DC Converter, Four-Quadrant DC–DC Converter.

List of Experiments

1. Design of step up chopper.
2. Design of step down chopper.

UNIT III: RECTIFIERS AND INVERTERS L – 9 P-6

Single-phase Diode Rectifiers, Three-phase Diode Rectifiers, Poly-phase Diode Rectifiers, Filtering Systems in Rectifier Circuits, High-frequency Diode Rectifier Circuits.

Single-phase Voltage Source Inverters, Three-phase Voltage Source Inverters, Current Source Inverters, Closed-loop Operation of Inverters, Regeneration in Inverters, Multistage Inverters.

List of Experiments

1. Three phase IGBT based PWM inverter control of induction motor.
2. Study of driver circuits and generation of PWM signals for three phase inverters.

List of Demonstrations

1. Design a rectifier circuit using bread board.

UNIT IV: ELECTRIC MOTOR DRIVES L – 9 P-6

DC motor operation and its types, 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.

List of Experiments

1. Load test on D.C shunt motor.
2. Speed control of D.C shunt motor.
3. Load test on single-phase induction motor.
4. Load test on three-phase induction motor.

UNIT V: Power Electronics and Control for Hybrid and Fuel Cell Vehicles L – 9 P- 6

Series Hybrid Vehicle Propulsion System, Parallel Hybrid Vehicle Propulsion System, Fuel Cell Vehicles, Power Electronics Requirements, Propulsion Motor Control Strategies, APU Control System in Series Hybrid Vehicles, Fuel Cell for APU Applications.

List of Experiments

1. Study of Series hybrid electric vehicle layout.
2. Study of Parallel hybrid electric vehicle layout.

Reference Books:

1. Rashid M.H., "Power Electronics Circuits, Devices and Applications", Prentice Hall India,Third Edition, New Delhi, 2011.
2. Ali Emadi, “Handbook of Automotive Power Electronics and Drives”, Taylor & Francis Group, First Edition, USA, 2005.
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. P.C. Sen, “Modern Power Electronics”, Wheeler Publishing Co, Third edition, New Delhi,2008.

	ENERGY STORAGE SYSTEM AND MANAGEMENT SYSTEM	L	T	P	C
		3	0	2	4

Course Category: Specialization Core/EHV

Self-Learning Content: Basic working principle of Battery, battery charging Systems and Electrical and electronic circuits.

Course Outcomes

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

CO Nos.	Course Outcomes	Level of learning domain (Based on revised Bloom's)
CO1	Discuss about the different types of energy storage system.	K2
CO2	Describe about the battery characteristic & parameters	K2
CO3	Model different types of batteries	K3
CO4	Apply the concepts of battery management system and design the battery pack.	K3
CO5	Explain about the battery testing, disposal and recycling.	K2

Unit I: ENERGY STORAGE SYSTEM

Batteries: Lead Acid Battery, Nickel based batteries, Sodium based batteries, Lithium based batteries – Li-ion & Li-poly, Metal Air Battery, Zine Chloride battery; Ultra capacitors; Flywheel Energy Storage System; Hydraulic Energy Storage System; Comparison of different Energy Storage System

List of Demonstration:

1. Study of different types of batteries.

Unit II: BATTERY CHARACTERISTICS & PARAMETERS

Cells and Batteries- conversion of chemical energy to electrical energy- Battery Specifications: Variables to characterize battery operating conditions and Specifications to characterize battery nominal and maximum characteristics; Efficiency of batteries; Electrical parameters- Heat generation- Battery design- Performance criteria for Electric vehicles batteries- Vehicle propulsion factors- Power and energy requirements of batteries- Meeting battery performance criteria- setting new targets for battery performance.

List of Demonstration:

1. Study of different types of batteries with their characteristics & detailed specifications.

UNIT-III BATTERY MODELLING

General approach to modelling batteries, simulation model of a rechargeable Li-ion battery, simulation model of a rechargeable NiCd battery, Parameterization of the NiCd battery model, Simulation examples.

List of Demonstration:

1. Develop a simulation model for Lead-acid and Li-ion Batteries.

Unit IV: BATTERY PACK AND BATTERY MANAGEMENT SYSTEM

Selection of battery for EVs & HEVs, Traction Battery Pack design, Requirement of Battery Monitoring, Battery State of Charge Estimation methods, Battery Cell equalization problem,

thermal control, protection interface, SOC Estimation, Energy & Power estimation, Battery thermal management system, Battery Management System: Definition, Parts: Power Module, Battery, DC/DC Converter, load, communication channel, Battery Pack Safety, Battery Standards & Tests.

List of Experiments:

1. SOC Estimation by Open Source voltage for Lead-Acid battery, Ni-MH battery and Li-ion battery.
2. SOC Estimation by specific gravity for Lead-Acid battery.
3. SOC Estimation by Coulomb counting method for Lead-Acid battery and Li-ion battery.
4. Design a circuit for Battery monitoring System for Lead acid battery.
5. Design a circuit for passive cell balancing for Li-Ion battery.

Unit V: BATTERY TESTING, DISPOSAL & RECYCLING

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

List of Experiments:

1. Perform Vibration Test for traction batteries (Lead-Acid/Li-ion) as per AIS 048 standard.
2. Perform Shock Test for traction batteries (Lead-Acid/Li-ion) as per AIS 048 standard.
3. Perform Short Circuit Test for traction batteries (Lead-Acid/Li-ion) as per AIS 048 standard.
4. Perform Overcharge Test for traction batteries (Lead-Acid/Li-ion) as per AIS 048 standard.
5. Perform Roll-Over Test for traction batteries (Lead-Acid/Li-ion) as per AIS 048 standard.

REFERENCES

1. G. Pistoia, J.P. Wiaux, S.P. Wolsky, “Used Battery Collection and Recycling”, Elsevier, 2001. (ISBN: 0-444-50562-8)”
2. Guangjin Zhao, “Reuse and Recycling of Lithium-Ion Power Batteries”, John Wiley & Sons. 2017. (ISBN: 978-1-1193-2185-9)
3. T R Crompton, “Battery Reference Book-3rd Edition”, Newnes- Reed Educational and Professional Publishing Ltd., 2000.
4. Ibrahim Dinçer, Halil S. Hamut and Nader Javani, “Thermal Management of Electric Vehicle Battery Systems”, JohnWiley& Sons Ltd., 2016.
5. Chris Mi, Abul Masrur& David Wenzhong Gao, “Hybrid electric Vehicle- Principles & Applications with Practical Properties”, Wiley, 2011.
6. Mehrdad Ehsani, Yimin Gao, Ali Emadi, “Modern Electric Hybrid Electric and Fuel Cell Vehicles”,Taylor& Francis Group, 2010.
7. James Larminie, John Lowry, “Electric Vehicle Technology Explained”, John Wiley & Sons Ltd, 2003.
8. Arno Kwade, Jan Diekmann, “Recycling of Lithium-Ion Batteries: The LithoRec Way”, Springer, 2018. (ISBN: 978-3-319-70571-2)

	MODELLING AND SIMULATION OF EHV	L	T	P	C
		3	0	2	4

Course Category: Specialization Core/EHV

Self-Learning Content: Basic of modeling and simulation, Matlab/Simulink.

Course Outcomes

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

CO Nos.	Course Outcomes	Level of learning domain (Based on revised Bloom's)
CO1	Understand the modeling of vehicle performance parameters.	K2
CO2	Model battery electric vehicles.	K4
CO3	Describe the drivetrain characteristics.	K2
CO4	Apply the concepts of energy management system.	K3
CO5	Explain the vehicle dynamic control systems.	K2

UNIT-I MODELLING IN PERFORMANCE PARAMETER L - 9

Modelling Vehicle Acceleration - Acceleration performance parameters, modelling the acceleration of an electric scooter, modelling the acceleration of a small car

List of Demonstration:

1. Develop a simulation model for Electric Vehicle to analyze the effect of changing of parameters on vehicle range and performance.
2. Develop a simulation model for different driving cycles and analyze these driving cycles.
3. Develop a simulation model to analyze the effect of Rolling Resistance on vehicle range and performance
4. Develop a simulation model to analyze the effect of vehicle mass on vehicle range and performance
5. Develop a simulation model to analyze the effect of Aerodynamic drag on vehicle range and performance
6. Develop a simulation model to analyze the effect of Hill Climbing force on vehicle range and performance.

UNIT-II MODELLING OF BATTERY ELECTRIC VEHICLES L - 9

Electric Vehicle Modelling - Tractive Effort, Rolling resistance force, Aerodynamic drag, Hill climbing force, Acceleration force, Total tractive effort, Modelling Electric Vehicle Range - Driving cycles, Range modelling of battery electric vehicles, Constant velocity range modelling, Range modelling of fuel cell vehicles, Range modelling of hybrid electric vehicles

List of Demonstration:

1. Develop a simulation model for Series HEV to analyze the effect of changing of parameters on vehicle range and performance.
2. Develop a simulation model for Parallel HEV to analyze the effect of changing of parameters on vehicle range and performance.

UNIT-III DRIVETRAIN CHARACTERISTICS L - 9

Modelling and Characteristics of EV/HEV Powertrains Components- ICE Performance Characteristics, Electric Motor Performance Characteristics - Battery Performance

Characteristics-Transmission and Drivetrain Characteristics-Regenerative Braking Characteristics-Driving Cycles Modelling and Analysis of Electric and Hybrid Electric Vehicles Propulsion and Braking - Longitudinal Dynamics Equation of Motion - Vehicle Propulsion Modelling and Analysis - Vehicle Braking Modelling and Analysis

List of Demonstration:

1. Develop a simulation model to analyze Electric Motor Performance Characteristics
2. Develop a simulation model to analyze Electric Motor Regenerative Braking Characteristics for different Driving Cycles.

UNIT-IV ENERGY MANAGEMENT L - 9

Handling Analysis of Electric and Hybrid Electric Vehicles - Simplified Handling Models Energy/Power Allocation and Management - Power/Energy Management Controllers - Rule-Based Control Strategies - Optimization-Based Control Strategies

List of Demonstration:

1. Develop a Control strategy for Parallel HEV for developed simulation model and analyze it.
2. Develop a Control strategy for Series HEV for developed simulation model of Parallel HEV and analyze it.

UNIT-V VEHICLE DYNAMIC CONTROL L - 9

Control of Electric and Hybrid Electric Vehicle Dynamics - Fundamentals of Vehicle Dynamic Control (VDC) Systems, VDC Implementation on Electric and Hybrid Vehicles – Case Studies, Rechargeable Battery vehicles, Hybrid Vehicles, Fuel Cell Powered Bus

Simulation Tools: Matlab/Simulink, ADVISOR and AVL Cruise.

REFERENCES:

1. James Larminie, John Lowry, “Electric Vehicle Technology Explained”, John Wiley & Sons Ltd, 2003.
2. Amir Khajepour, Saber Fallah and AvestaGoodarzi, “Electric and Hybrid Vehicles-Technologies, Modelling and Control: A Mechatronic Approach”, John Wiley & Sons Ltd, 2014.
3. Antoni Szumanowski, “Hybrid Electric Power Train Engineering and Technology: Modelling, Control, and Simulation”, IGI Global, 2013.
4. Mehrdad Ehsani, Yimin Gao, Ali Emadi, “Modern Electric, Hybrid Electric, and Fuel Cell Vehicles_ Fundamentals, Theory, and Design, Second Edition”, CRC Press, 2010.

	COMPUTER AIDED ENGINEERING	L	T	P	C
		3	0	2	4

Course Category: Specialization Core

Self-Learning Content: Engineering Graphics, AutoCAD, Ansys, NC Coding's, Two- and Three-Dimensional Graphics concepts, Graphics Aids, Part Programming and manufacturing, Computer Aided Quality control.

Course Outcomes

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

CO Nos.	Course Outcomes	Level of learning domain (Based on revised Bloom's)
CO1	Understand the basic fundamentals of Computer Aided Engineering	K2
CO2	Design and validate technological solutions to defined problems and communicate clearly and effectively for the practical application of their work.	K3
CO3	Understand the general steps of finite element methods.	K2
CO4	Formulate and solve basic problems in heat transfer, solid mechanics and fluid mechanics.	K3
CO5	Create Numerical Modelling and its Role in the Field of Fluid Flow and Heat Transfer	K3

UNIT I INTRODUCTION L - 9

Introduction: – Industrial look at CAE, Methods to solve engineering problems – analytical, numerical, experimental and their merits and comparison - importance of meshing, boundary conditions- Product design and development – collaborative design

List of Experiments:

1. Determination of Thermal Efficiency of the Engine in experimentally.
2. Identify the problems in various real time products.
3. Design any model by using modelling software's. (Demo only)

UNIT II COMPUTER AIDED DESIGN AND MODELING L - 9

Introduction to geometric modeling technology and associated computational geometry, Geometric Transformations, Group technology, CAPMS, DFMA, A study of data exchange issues and utilizing available data exchange mechanisms.

List of Experiments:

1. Design the Isometric views of a Shaft Bracket
2. Design a wireframe model of Various shapes using CATIA.
3. Verify the tool path generation Using EDGECAM Software.
4. Manufacturing the model by using 3D Printer. (Demo only)

UNIT III BOUNDARY CONDITIONS AND MESH GENERATION L - 9

Basic concept of finite element method, Discrete and Continuous model, Loads and Constraints, Mesh Generation, mesh refinement, assign material properties, Initial and Boundary value problems, Variational approach- Practical applications of FEA in new design, optimization / cost, Errors in FEA

List of Experiments:

1. Compute the shear force and bending moment diagrams for the beam and find the maximum deflection.

2. Check the qualities of mesh in various aspects.
3. Determine the Static structural analysis of a model using ANSYS (Demo only)
4. Verify the results through experimentally (Demo only)

UNIT IV DISCRETE, CONTINUUM AND ISOPARAMETRIC ELEMENTS L - 9

Bar, Frame, beam elements – Application to static, dynamic and stability analysis, Various types of 2-D-elements – Application to plane stress, plane strain and axis symmetric Analysis, Iso parametric Elements – Applications to field problems like heat transfer and fluid flow.

List of Experiments:

1. Determine the nodal deflections, reactions forces, and stress for the truss system
2. Determine the Stress of a plate with circular hole in its center

UNIT V GOVERNING EQUATIONS OF VISCOUS FLUID FLOWS L - 9

Basics of Computational Fluid Dynamics – Governing Equations of Fluid Dynamics – Continuity, Momentum and Energy Equations – Chemical Species Transport – Physical Boundary Conditions – Time-Averaged Equations for Turbulent Flow – Turbulent–Kinetic Energy Equations – Mathematical Behavior of PDEs on CFD – Elliptic, Parabolic and Hyperbolic Equations.

List of Experiments:

1. Computational analysis of Fluid through pipe.
2. Analysis of Cooling for Fin.

Reference Books:

1. Ibrahim Zeid “CAD/CAM Theory & Practice”, TMH, 2006
2. Belagundu&Chandrupatla, “Finite Element Method”, New Age Int. Pub, 2010
3. Gokhle Nitin; et al; Practical Finite Element Analysis; Finite to Infinite, 88 Budhwar Peth, Pune.
4. Logan DL; A First Course in Finite Element Method; Cegage
5. Krishnamoorthy; Finite Element Analysis; Theory and Programming; MH
6. Belagundu&Chandrupatla, “Finite Element Method”, New Age Int. Pub, 2010
7. Reddy JN; An Introduction to finite element method; TMH
8. Rao, S.S./ The Finite element method in engineering; Peragamon press, Oxford

SPECIALISATION ELECTIVES

FOR

POWERTRAIN ENGINEERING

	AUTOMOTIVE HVAC	L	T	P	C
		3	0	0	3

Course Category: Specialization Elective

Course Outcomes

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

CO Nos.	Course Outcomes	Level of learning domain (Based on revised Bloom's)
CO1	Describe the types of refrigeration systems and its applications and refrigerants properties.	K3
CO2	Apply the concept of psychometry to estimating the heating and cooling load for automobiles.	K3
CO3	Design and implement refrigeration and air conditioning systems using standards.	K3
CO4	Explain the air distribution system and its control	K2
CO5	Diagnose, serviceand controlsthe air-conditioning system.	K3

UNIT I REFRIGERATION **L - 9**

Introduction - Methods of refrigeration - Air Refrigeration System and its applications -Vapour compression refrigeration system - Vapor absorption refrigeration system - Applications of refrigeration & air conditioning -Automobile air conditioning - Air conditioning for passengers, isolated vehicles, transport vehicles-Applications related with very low temperatures. Classification, properties and selection criteria - Commonly used refrigerants - Alternative refrigerants - Eco-friendly refrigerants - Applications of refrigerants -Refrigerants used in automobile air conditioning.

UNIT II PSYCHROMETRY **L – 9**

Review of fundamental properties of psychometric – use of psychometric charts – psychometric processes – Grand and Room Sensible Heat Factors – by pass factor – requirements of comfort air conditioning –factors governing optimum effective temperature, recommended design conditions and ventilation standards. Psychometric properties, tables, charts - Psychometric processes - Comfort charts - Factor affecting comfort - Effective temperature - Ventilation requirements.

UNIT III AIR CONDITIONING SYSTEMSAND LOAD ANALYSIS **L - 9**

Classification and layouts - Central / unitary air conditioning systems - Components like compressors, evaporators, condensers, expansion devices, fan blowers, heating systems etc. Load Analysis: Outside & inside design consideration - Factors forming the load on refrigeration & air conditioning systems - Cooling & heating load calculations - Load calculations for automobiles - Effect of air conditioning load on engine performance

UNIT IV AIR DISTRIBUTION SYSTEMS **L - 9**

Distribution duct system, sizing, supply / return ducts - Types of grills, diffusers, ventilation, air noise level - Layout of duct systems for automobiles and their impact on load calculations.

Air Routine & Temperature Control: Objectives - evaporator care air flow - Through the dash recirculating unit - Automatic temperature control - Controlling flow - Control of air handling systems

UNIT V AIR CONDITIONING SERVICE AND CONTROL **L - 9**

Air conditioner maintenance & service - servicing heater system - Removing & replacing components, Trouble shooting of air conditioning system -Compressor service, methods of dehydration, charging & testing. Air Conditioning Control: Common control such as thermostats- Humidistat us - Control dampers - Pressure cutouts and relays

Reference Books:

1. Refrigeration and Air-Conditioning - W.F. Stoecker and J.W. Jones, Tata McGraw Hill Pub.
2. Paul Lung, "Automotive Air Conditioning", C.B.S. Publisher & Distributor, Delhi
3. Modern Air-Conditioning Practice - Norman C. Harris, Principles of Refrigeration -R.J. Dcssat, Wiley Eastern Pub.
4. Refrigeration and Air-Conditioning - C.P. Arora, Tata McGraw Hill Pub
5. Refrigeration and Air-Conditioning – S.S.Thipse, Jaico
6. Automotive air conditioning by Crouse
7. Harris, "Modern Air Conditioning"
8. Khurmi R.S., and Gupta, J. K., A text book of Refrigeration and Air Conditioning, Eurasia Publishing housing (P) Ltd, New Delhi, 2002
7. Manohar Prasad, Refrigeration and Air conditioning, New Age International (P) Ltd, New Delhi,
9. 1999.
8. Ashrae Hand Book', 4 Vol., Current Ed., Carrier Air Conditioning Co., 'Hand Book of Air
10. Conditioning', Prentice Hall of India, 1974

	HYDROGEN AND FUEL CELL	L	T	P	C
		3	0	0	3

Course Category: Specialization Elective/PTE

UNIT I: HYDROGEN AS FUTURE ENERGY CARRIER L - 9

Hydrogen Production : Thermal Processes , Electrolytic Processes , Photolytic Processes - Hydrogen Distribution - Hydrogen Storage - Hydrogen Storage in High Compressed Gas Form , Hydrogen Storage in Liquid Cryogenic Form , Hydrogen Storage in Solid Materials - Need, Properties, Pollution, Emission standards, World and Indian Scenario.

UNIT II: HYDROGEN IN S.I. ENGINE SYSTEM L – 9

Engine Modifications, Combustion Characteristics – Dual Fueling, Direct Injection of Gaseous and Liquefied Hydrogen.

UNIT III: HYDROGEN IN C.I. ENGINE SYSTEM L - 9

Engine Modification & Combustion Characteristics - Direct Injection – Gaseous and Liquified Hydrogen, Dual Fuel Mode, and Hydrogen Enrichment.

UNIT – IV: FUEL CELLS FOR AUTOMOTIVE APPLICATIONS L - 9

Basic Concepts of Electrochemistry - Proton Exchange Membrane Fuel Cells: Membrane, Electrocatalysts, GDL, Bipolar Plates - Sensitivity of PEM Stacks to Operating Conditions: Polarization Curve, Effect of Operative Parameters on the Polarization Curve - Durability of PEM Fuel Cells

UNIT – V: DESIGN OF HYDROGEN FUEL CELL SYSTEMS FOR ROAD VEHICLES L - 9

Hydrogen Fuel Cell Systems: Preliminary Remarks - Hydrogen Feeling System - Air Feeding System - Thermal Management System - Water/Humidification Management System - Integrated Fuel Cell System: Efficiency, Dynamics, Costs.

Reference Books:

1. Johannes Topler and Jochen Lehmann, Hydrogen and Fuel Cell Technologies and Market Perspectives, Springer, 2016
2. Pasquale Corbo, Fortunato Migliardini andOttorinoVeneri, Hydrogen Fuel Cells for Road Vehicles (Green Energy and Technology), Spinger, 2011.
1. Alternative Fuels (A decade of success and Promise) edited by Reda Moh.Bata, SAE PT-48, ISBN 1-56091 – 593 – 5.
2. Osamu Hirao and Richard K. Pefley, Present and future Automotive Fuels, John Wiley and Sons, 1988.
3. Keith Owen and Trevor Eoley, Automotive Fuels Handbook, SAE Publications, 1990.
4. Richard L. Bechtold, Automotive Fuels Guide Book, SAE Publications, 1997.
5. Hydrogen Fuel Cells forRoad Vehicles, April 2010, Springer.

	SUPERCHARGING AND TURBOCHARGING	L	T	P	C
		3	0	0	3

Course Category: Specialization Elective/PTE

Course Outcomes

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

CO Nos.	Course Outcomes	Level of learning domain (Based on revised Bloom's)
CO1	Explain the principles of superchargingwith supercharging units.	K2
CO2	Understand thethermodynamics of supercharging.	K2
CO3	Describe the construction and operation of exhaust gas turbocharging.	K2
CO4	Illustrate the new technicaldevelopments inturbocharging system	K2
CO5	Outline theconcept ofmatching the turbocharger and charge air cooling	K2

UNIT I SUPERCHARGING L - 9

Basic Principles and Objectives of Supercharging-Interrelationship Between Charge Mass Flow and Engine Power Output-Influence of Charge Air Cooling-Definitions and Survey of Supercharging Methods-Supercharging with Supercharging Units-Charger Pressure–Volume Flow Map-Displacement Compressor.

UNIT II THERMODYNAMICS OF SUPERCHARGING L - 9

Energy Balance of the Supercharged Engines Work Process - Engine High-Pressure Process, Gas Exchange Cycle Low-Pressure Processes, Utilization of Exhaust Gas Energy- Efficiency Increase by Supercharging - Characteristic Values for the Description of the Gas Exchange and Engine Efficiencies - Influencing the Engine's Total Efficiency Value via Supercharging.

UNIT III TURBOCHARGING L - 9

Objectives and Applications for Exhaust Gas Turbocharging - Turbocharging Requirements - Principles of Operation of Turbo Machines - Basic Fluid Mechanics of Turbocharger Components - Energy Transfer in Turbo Machines, Compressors, Turbines- Energy Balance of the Charging System.

UNIT IV TURBOCHARGING SYSTEM DEVELOPMENTS L – 9

Exhaust Waste Gate - Variable Geometry Systems - Turbo Compounding - Variable Geometry and Compound Systems - Exhaust Gas Recirculation - Electric Drive Turbocharger -Two-Stage or Series Turbo Charging - Sequential Turbo Charging - Complex, Hyper Bar Systems.

UNIT V MATCHING OF THE TURBOCHARGERAND CHARGE AIR COOLING L - 9

Matching of the Turbocharger - Possibilities for the Use of Exhaust Energy and the Resulting Exhaust System Design - Turbine Design and Control - Compressor Design and Control - Charge Air Coolers and Charge Air Cooling Systems: Basics and Characteristics -Charge Air

Cooling Systems - Design Variants of Charge Air Coolers - Water-Cooled Charge Air Coolers, Air-to-Air Charge Air Coolers,.

Reference Books:

1. K. Kollmann and H. P. Lenz, 'Charging the Internal Combustion Engine', Springer Wien NewYork, 2007.
2. N. Watson and M. S. Janota,'Turbochargingthe Internal CombustionEngine',The Macmillan Press LtdLondon, 1982.
3. Obert E.F, 'Internal Combustion Engines and Air Pollution', Intext Educational New York, 1980.
4. Richard Stone, 'Internal Combustion Engines', SAE, 1992.

	EXPERIMENTAL METHODS AND OPTIMIZATION TECHNIQUES	L	T	P	C
		3	0	0	3

Course Category: ProgramElective

Course Outcomes

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

CO Nos.	Course Outcomes	Level of learning domain (Based on revised Bloom's)
CO1	Apply the experimental design and analysis of variance for solving design problems using one-way, two-way and three-way classifications with the statistical methods CRD, RBD and LSD	K3
CO2	Understand the experimental design problems for two-factor experiments and also learn Taguchi approach for robust design	K2
CO3	Apply the classical optimization techniques for single variable and multi-variable optimization problems using Calculus	K3
CO4	Apply the numerical optimization techniques for unconstrained optimization problems for single-variable and multi-variable optimization problems	K3
CO5	Understandthe constrained nonlinear programming problems with equality and inequality constraints using numerical optimization methods	K2

UNIT I ANALYSIS OF VARIANCE L - 9

Analysis of Variance (ANOVA) – one-way classification– two-way classification – basic principles of design of experiments – replication, randomization and local control – Completely Randomized Design (CRD) – Randomized Block Design (RBD) – Latin Square Design (LSD).

UNIT II DESIGN OF EXPERIMENTS L - 9

Factorial experiments and their need – $2^2, 2^3$and 3^2 Factorial Experimental Designs without confounding (Theory and Problem only, no derivation expected) – Applications of $2^2, 2^3$and 3^2 Factorial Experimental Designs– Taguchi Approach – Parameter Design – Robust Design

UNIT IIICLASSICAL OPTIMIZATION TECHNIQUES L - 9

Optimal problem formulation - Single-variable optimization – First Derivative Test – Second Derivative Test – Multi-variable optimization – Gradient Test – Hessian Matrix – Constrained Optimization Problems using Equality Constraints – Direct Method

UNIT IV NUMERICAL OPTIMIZATION TECHNIQUES L - 9

Single-variable optimization – Bracketing methods – Fibonacci search method – Golden section search method – Newton-Raphson method – Multi-variable optimization – Gradient methods – Newton's method –Cauchy's steepest descent method – Powell's conjugate direction method

UNIT V NONLINEAR PROGRAMMING L - 9

Constrained optimization – Equality and inequality constraints - Lagrange multiplier method for nonlinear programming – Kuhn-Trucker conditions – Penalty function method – Frank-Wolfe method – Generalized projection method

TOTAL: 45 Periods

Reference Books:

1. R. Panneerselvam, 'Design and Analysis of Experiments', PHI Learning Private Limited, New Delhi, 2012.
2. K. Deb, 'Optimization for Engineering Design', PHI Learning Private Limited, New Delhi, 2012.
3. D.C. Montgomery, `Design and Analysis of Experiments', Wiley, New Jersey, 1984.
4. S.S. Rao, `Optimization Theory and Applications', Wiley, New Jersey, 1984.
5. M.S. Phadke, `Quality Engineering using Robust Design', Prentice Hall, New Jersey, 1989.

	VEHICLE DYNAMICS	L	T	P	C
		3	0	0	3

Course Category: Specialization Elective / PTE

Self-learning Content:
Basic of vibrations, tires and chassis Components….

Course Outcomes

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

CO Nos.	Course Outcomes	Level of learning domain (Based on revised Bloom's)
CO1	Classify the tyre dynamics with respect to force, friction & moments.	K2
CO2	Predict the various vehicle stability in all drives.	K3
CO3	Demonstrate the aerodynamic forces, moments and its performance.	K3
CO4	Analyze the effect on the steering dynamic and stability of the vehicle.	K3
CO5	Compute the effective suspension and parameters and its properties.	K3

UNIT I MECHANICS OF PNEUMATIC TIRE L - 9

Tyre forces and moments, rolling resistance of tyres, coefficient of friction in different road conditions, Tractive effort and longitudinal slip, cornering properties of tyres, performance of tyres on wet surfaces, Ride properties of tyres, Estimation of tire road friction. Test on various road surfaces. Tire vibration.

UNIT II STABILITY OF VEHICLES L-9

Load distribution for three wheeler and four wheeler. Stability of vehicle running on slope, banked road and during turn, calculation of Tractive effort, maximum acceleration and reaction forces for different drives.

UNIT III PERFORMANCE CHARACTERISTICS OF ROAD VEHICLES L - 9

Equation of motion and maximum tractive effort, Aerodynamic forces and moments, vehicle power plant and transmission characteristics, prediction of vehicle performance, operating fuel economy, engine and transmission matching, braking performance.

UNIT IV HANDLING CHARACTERISTICS OF ROAD VEHICLES L - 9

Steering geometry, Steady state handling characteristics, Steady state response to steering input. Testing of handling characteristics. Transient response characteristics, Directional stability.

UNIT V RIDE CHARACTERISTICS OF VEHICLES L - 9

Human response to vibration, vehicle ride models, introduction to random vibration, active and semi active suspensions, Roll center, Roll axis and Vehicle under side forces. Influence of suspension stiffness, suspension damping, and tire stiffness. Air suspension system and their properties.

Reference Books:

1. N.K Giri,Automobile mechanics, khanna publishers, 2010.
2. Wong. J. Y., "Theory of Ground Vehicles", 3rd Edition, Wiley-Interscience, 2001
3. Singiresu S. Rao, "Mechanical Vibrations", 5 th Edition, Prentice Hall, 2010
4. Rajesh Rajamani, "Vehicle Dynamics and Control", 1st edition, Springer, 2005
5. Thomas D. Gillespie, "Fundamentals of Vehicle Dynamics", Society of Automotive Engineers Inc, 1992.

Sample Assessment Questions:

UNIT-1	**Theory:** 1. Discuss the factors affecting the rolling resistance of tires with neat diagram. 2. Draw a tire axis system. Explain all the forces and moments acting on tyre.
UNIT-2	**Theory:** 1. A motor car with wheel base 275 cm with a centre of gravity 85 cm above the ground and 115 cm behind the front axle has a coefficient of adhesion 0.6 between the tyre and the ground. Calculate the maximum possible acceleration when the vehicle, is. a) driven on four wheels, b) driven on the front wheels only c) driven on the rear wheels only 2. Discuss stability of a four wheeled vehicle taking a turn considering reaction at the wheels due to weight and Reactions at wheels due to centrifugal force and Reaction at the wheels due to gyroscopic effect.
UNIT-3	**Theory:** 1. Derive the equation of motion and maximum tractive effort in road vehicles. 2. Discuss how to predict the vehicle performance based on the (i)Operating fuel economy, (ii) Engine and transmission matching (iii)Braking performance.
UNIT-4	**Theory:** 1. Derive the equation of Steady state handling characteristics of a vehicle. 2. Explain directional stability of (i) Over steer iii)Under steer (ii) Neutral steer
UNIT-5	**Theory:**

	1. Write short notes on (i) Influence of suspension stiffness (ii) Suspension damping (iii) Tire stiffness 2. Derive the equation of Roll center, Roll axis and Vehicle under side forces.

	ENGINE MATERIALS AND MANUFACTURING	L	T	P	C
		3	0	0	3

Course Category: Specialization Elective/PTE

UNIT I MATERIALS **L - 9**

Selection – types of Materials – Ferrous – Carbon and Low Alloy steels, High Alloy Steels, Cast Irons – Non Ferrous – Aluminum, Magnesium, Titanium, Copper and Nickel alloys.

UNIT II ENGINE COMPONENTS **L - 9**

Cylinder Block, Cylinder Head, Crankcase and Manifolds, Piston Assembly, Connecting Rod, Crankshaft, Camshaft and Valve Train - Production methods – Casting, Forging, Powder Metallurgy – Machining – Testing Methods.

UNIT III ENGINE AUXILIARIES **L - 9**

Carburetors, fuel injection system components, radiators, fans, coolant pumps, Ignition System.

UNIT IV COMPUTER INTEGRATED MANUFACTURING **L - 9**

Integration of CAD, CAM and CIM- Networking, CNC programming for machining of Engine Components.

UNIT V QUALITY AND TESTING **L - 9**

TS 16949, BIS codes for testing. Instrumentation, computer aided engine testing, metrology for manufacturing Engine Components.

Reference Books:

1. M. F. Ashby, H. Shercliff, D. Cubon, Materials Engineering Science, Processing and Design, Butterworth Publications, 2007
2. C. Brian, G. Patrick and J. Colin, Automotive Engineering: Light Weight, Functional and Novel Materials, Taylor & Francis, 2007
3. M. P. Groover, Fundamentals of Modern Manufacturing: Materials, Processes, and Systems, 2nd edition, John Wiley & Sons, 2005

	TRIBOLOGY	**L**	**T**	**P**	**C**
		3	**0**	**0**	**3**

Course Category: Specialization Elective/PTE

Course Outcomes:

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

CO Nos.	**Course Outcomes**	**Level of learning domain (Based on revised Bloom's)**
CO1	Understand the importance of surface treatment and wear mechanisms	K2
CO2	Describe the theory of lubrication of different phases	K2
CO3	Comprehend the necessity of contact surface and load transfer	K2
CO4	Identify and able to measure the surface wear using the instruments	K2
CO5	Assess the technical knowledge for designing engine components	K2

UNIT I SURFACES, FRICTION AND WEAR L - 9

Topography Of The Surfaces - Surface Features Of Metal And Composites - Surface Interaction - Theories Of Friction - Sliding And Rolling Friction, Friction Properties Of Metallic And Non-Metallic Materials - Friction In Extreme Conditions – Wear- Types Of Wear - Mechanism Of Wear - Wear Resistance Materials - Surface Treatment - Surface Modifications – Surface Coatings, Failure Analysis, New Trends In Friction And Wears.

List of Demonstration:

1. Scratch Test
2. Wore down parts of long run machines

UNIT II LUBRICATION THEORY L - 9

Lubricants And Their Physical Properties Lubricants Standards - Lubrication Regimes Hydrodynamic Lubrication - Reynolds Equation, Thermal, Inertia,And Turbulent Effects - Elasto Hydrodynamic And Plasto Hydrodynamic And Magneto Hydrodynamic Lubrication - Hydro Static Lubrication - Gas Lubrication. – Stir Back Diagram, design And Performance Analysis of thrust and Journal Bearings – Slide Bearing - Full, Partial, Fixed and Pivoted Journal Bearings Design - Lubricant Flow And Delivery - Power Loss, Heat And Temperature Rotating Loads And Dynamic Loads In Journal Bearings - Special Bearings - Hydrostatic Bearing Design.

List of Demonstration:

1. Types of Lubricants
2. Effect of Lubricants on Machinery

UNIT III ROLLING ELEMENT BEARINGS L - 9

Geometry And Kinematics - Materials And Manufacturing Processes - Contact Stresses - Hertzian Stress Equation - Load Divisions - Stresses And Deflection - Axial Loads And Rotational Effects, Bearing Life Capacity And Variable Loads - Iso Standards - Oil Films And Their Effects - Rolling Bearings Failures, Needle bearing.

List of Demonstration:

1. Bearing Elements (Ball/Roller/Cones)

2. Identification and Selection of bearings based on application

UNIT IV TRIBO MEASUREMENT IN INSTRUMENTATION L - 9

Wear Measurement Principle - Surface Topography Measurements – Surface Texture Measurement and Assessment Statically Methods -Scanning Electron Microscope & Friction and Wear Measurements - Laser Method - Instrumentation - International Standards - Bearings Performance Measurements - Bearing Vibration Measurement, Lubricate Monitoring Soap, Ferographyand other Rapid Testing Methods for Lubrication Catenation

List of Demonstration:

1. Lubricity Measurement
2. Friction & Wear Measurement
3. Fatigue Testing

UNIT V APPLICATION OF TRIBOLOGY IN ENGINE COMPONENTS AND VISCOSITY L - 9

Components Like Piston, Bearings, Piston Rings, Value Train, Drive Train, Reciprocating Components, Engine Friction, Spytter Coated Bearing etc Basic Definition for Viscosity, Convention, Dynamic Viscosity, Measurement, Variation With Temperature, ASTM Charts, Grade Of Oil.

List of Demonstration:

1. Identification of Stress Locations
2. Identification of Failure Locations
3. Importance of Bearing & Lubrication in Engine

Reference Books:

1. Bowden, F.P. & Tabor, D., “Friction And Lubrication Of Solids”, Oxford University Press 1986.
2. Ernest Rabinowiez z, “Friction And Wear Of Materials” Inter science Publishers, 1995.
3. Neale, M.J., Tribology – Hand Book, Butterworth, 1995.
4. Fuller D.D., Theory And Practice Of Lubrication Of Engineers: John Wiley Sons, 1984
5. Cameron, A. "Basic Lubrication Theory", Ellis Herward Ltd. Uk, 1981.
6. Hulling, J. (Editor) --"Principles Of Tribology", Macmillan, 1984.
7. Williams J.A. "Engineering Tribology", Oxford Univ. Press, 1994.
8. Neale M.J, "Tribology Hand Book ", Butterworth Heinemann, 1995.
9. Bhushan. B. “Modern Tribology Handbook”, Volumes 1 & 2. - Boca Raton A.O.: Crc Press, 2000. – 1760 P.

	MATERIALS FOR AUTOMOBILE	L	T	P	C
		3	0	0	3

Course Category: Program Electives

UNIT –I ENGINEERING ALLOYS **L - 9**

Cast iron, steels, alloy steels - significance of iron – iron carbide equilibrium diagram in design steels and cast irons, stainless steels –, types, specific applications, effect of alloying elements, Aluminum, Magnesium and Ti wrought and cast alloys used in automotive applications and its types. Modern materials- Light weight materials & implications on vehicle design, high strength low alloy steel (HSLA) – High strength Steels (HSS), Advanced High Strength Steels (AHSS), Ultra high strength Steels (UHSS) for automotive components.

UNIT –II POLYMERS **L - 9**

Engineering plastics, polymers in electrical and electronics application, electro conducting polymers polymer batteries – electrets - polymers with piezoelectric, pyro electric and ferroelectric properties-photo conducting polymers. Unit II Polymers for high temperature applications, Polymers for high temperature resistance– fluoro polymers – aromatic polymers– heterocyclic polymers.

UNIT – III CERAMICS **L - 9**

Heat engine ceramics, turbine blade ceramics, heat exchanger ceramics, heat shield ceramics, electronic ceramics, ferroelectrics, electrical insulators, smart ceramics, piezo electrics, ferrite metalized ceramics, superconducting ceramics, structural ceramics, carbides, nitrides, oxides, sialon , borides silicides, Nano ceramics- properties of nano ceramics- advanced nano ceramics carbon nano tubes, fibres, nanosilica-nano alumina- nano titania and zinc oxide applications.

UNIT- IV COMPOSITES **L - 9**

Composites in Automotive Environment: Need for composites, Properties of engineering composites and their limitations, Significance of Polymer, Metal and Ceramic matrix composite systems, Property correlation with reinforcement shape and distribution, Processing and application of different composites for automotive components. Nano composites and its Importance - thermoplastic based, thermosets based and elastomer based- influence of size, shape and role of interface in composites applications.

UNIT – V MODERN MATERIALS AND ALLOYS **L - 9**

Natural fibers, Refractory metals, SMART Materials - shape memory alloys (SMA), Piezo-electric materials, MEMS materials, Metallic glass-Quasi crystal and Nano crystalline materials, metal foams, syntactic foams and composites.

REFERENCES

1. Tai – Ran Hsu, MEMS and Microsystems Design and Manufacture, Tata-McGraw Hill, New Delhi, 2002.
2. Charles P Poole, Frank J Owens, Introduction to Nano technology, John Wiley and Sons, 2003.

	FINITE ELEMENT ANALYSIS	L	T	P	C
		3	0	2	4

Course Category: Specialization Elective/PTE

UNIT I INTRODUCTION **L -9**

Historical Background – Mathematical modeling of field problems in Engineering – Governing Equations – Discrete and Continuous models – Boundary, Initial and Eigen value problems – Weighted Residual methods – Variational formulation of Boundary Value problems – Ritz Technique – Basic concepts of the finite element method.

UNIT II ONE DIMENSIONAL PROBLEMS **L - 9**

One Dimensional second order Equations - Discretization – Element types – Linear and Higher order Elements – Derivation of Shape functions and stiffness matrices and force vectors – Assembly of matrices – Longitudinal vibration frequencies and mode shapes – Transverse deflections and Natural frequencies of beams

UNIT III TWO-DIMENSIONAL SCALAR VARIABLE PROBLEMS **L - 9**

Second Order 2D Equations involving Scalar Variable Functions – Variational formulation – Finite element formulation – Triangular Elements, Application to Field problems – Thermal problems – Quadrilateral Elements, Higher order elements.

UNIT IV TWO-DIMENSIONAL VECTOR VARIABLE PROBLEMS

Equations of elasticity – Plane stress, Plane strain and axis symmetric problems – Body forces and Temperature Effects – Stress calculations- Plate and Shell elements.

UNIT V ISOPARAMETRIC FORMULATION

Natural co-ordinate systems – Isoparametric elements – Shape functions for iso parametric elements – serendipity elements – Matrix solution techniques – Solution techniques to Dynamic problems – Introduction to Analysis software.

Reference Books:

1. Ibrahim Zeid CAD/CAM Theory & Practice", TMH, 2010
2. Belagundu&Chandrupatla,"Finite Element Method", New Age Int. Pub. 2012

List of Experiments

1. Stress analysis of plate with circular hole in its center.
2. For the simple stepped bar as shown in figure. Determine the displacements, stresses and reactions.
3. Consider the tapered bar shown in fig. below. Determine the nodal displacement, stress in each element. Reaction Forces.
4. Thermal analysis of composite wall structure
5. Thermal analysis of Heat sink.
6. Modal analysis of cantilever beam for natural frequency determination. Modulus of elasticity = 200GPa , density = 7800 Kg/m^3

7. Determine the nodal deflections, reactions forces, and stress for the truss system shown below E=200Gpa , A= 3250mm^2
8. Compute the shear force and bending moment diagrams for the beam shown and find the maximum deflection. Assume rectangular c/s area of 100 mm * 100mm , Youngs modulus of 240 MPa. Poisons ratio 0.27.
9. Buckling analysis of 3D rectangular beam
10. CFD analysis in Laminar flow in 3D circular pipe

	COMPUTATIONAL FLUID DYNAMICS	L	T	P	C
		3	0	2	4

Course Category: Specialization Elective/PTE

UNIT I FUNDAMENTALS OF FLUID FLOW & DISCRETISATION METHOD L - 9

Basic conservation equations for fluid flow and heat transfer, classification of the partial differential equations, Initial and Boundary conditions – Initial and Boundary Value problems – Common methods of discretization: an overview of finite difference, finite element and finite volume methods. Numerical solution of parabolic partial differential equations using finite-difference and finite-volume methods: explicit and implicit schemes, consistency, stability and convergence. Uniform and non-uniform Grids, Numerical Errors, Grid generation, Grid Independence Test.

UNIT II CONDUCTION HEAT TRANSFER L - 9

Conduction equation- Grid layout- discretization - Stability and convergence- nonlinear sources- nonlinear coefficients- under relaxation-boundary conditions- solution by Gauss-Seidal method- solution by Tridiagonal matrix method. Solution of discretized equations using point and line iterations, strongly implicit methods and pre-conditioned conjugate gradient methods.

UNIT III CONVECTION-CONDUCTION PROBLEMS L - 9

Convection-conduction problems: Central difference, upwind, exponential, hybrid and power-law schemes, comparison of exact solution, CDS and UDS- false conductivity- total variation diminishing scheme - Stability of the unsteady conduction-convection equation.
Note: Tutorials/One –dimensional code should be written by the student & submit

UNIT IV NAVIER-STOKES EQUATIONS L - 9

Numerical solution of the Navier-Stokes system for incompressible flows: stream-function, vorticity and artificial compressibility methods, requirement of a staggered grid. MAC, SIMPLE, SIMPLEC and SIMPLER algorithms.

UNIT V ANALYSIS USING SOFTWARE L - 9

Flow through manifolds; air motion in engines; turbulence and its modeling; phase-change problems, interface/free-surface tracking methods; engine processes with and without chemical reactions.

Reference Books:

1. Chung, T. J.: Computational Fluid Dynamics, Cambridge University Press, 2002.
2. Date, A. W.: Introduction to Computational Fluid Dynamics, Cambridge University Press, 2005.
3. Ferziger, J. H. and M. Peric: Computational methods for Fluid Dynamics, Second Edition Springer, 1999.
4. Fletcher, C. A. J.: Computational Techniques for Fluid Dynamics, Vol. 1, Second Edition, Springer, 1991.
5. Muralidhar, K., Sundarajan, T.: Computational Fluid Flow and Heat Transfer, Narosa Publishing House, New Delhi, 1997.
6. Shaw, C. T.: Computational Fluid Dynamics, Prentice Hall, 1992.

List of Experiments

1. Simulation of flow around external vehicle
2. Computational analysis of flow around external vehicle
3. Computational analysis of gasoline engine exhaust pipe
4. Computational analysis of catalytic converter
5. Analysis of gasoline engine exhaust pipe

SPECIALIZATION ELECTIVES

FOR

ELECTRIC & HYBRID VEHICLES

	AUTOMOTIVE EMBEDDED SYSTEM	L	T	P	C
		3	0	0	3

Course Category: Specialization Elective/EHV

UNIT I: AUTOMOTIVE EMBEDDED SYSTEM OVERVIEW **L - 9**

Automotive Embedded System Technology, Overview of Embedded System Categories, Various Embedded Sub Systems like Chassis, Body, Driveline, Engine, Fuel, Emission, Brakes, Suspension, Emission, Brakes, Suspension, Doors, Safety & Security, Comfort & Multimedia, Communication & Lighting and Future Trends in Automotive Embedded Systems: X by Wire technologies.

UNIT II: AUTOMOTIVE HARDWARE MODULE **L - 9**

Concept to Market: Understanding Automotive Product Design Cycle, Microcontroller, architecture, Memory map, I/O map, Building Blocks of Automotive Electronic Product: Actuators, Sensors, Semiconductor Components, Devices, Integrated Circuits (ICs), Relay, Stepper motor, PCBs etc.

UNIT III: AUTOMOTIVE SENSORS **L - 9**

Automotive Sensors and Transducers: Temperature, Force, Oxygen Sensor, LAMBDA Sensor, Proximity Distance Sensors, Speed, Engine Knock Sensor, Resistive Potentiometer & Flow. Typical Sensors Specifications & Microcontroller Interfacing, Signal Processing circuit, Sensor Calibration.

UNIT IV: AUTOMOTIVE SOFTWARE **L - 9**

Structure of embedded program, infinite loop, and compiling, linking and locating, downloading and debugging, Intra processor Communication Protocols: I2C & I2S, SPI & USB, LIN and CAN. Coding Standards and Guidelines: MISHRA C & Automotive Operating System: OSEK/VDX, AUTOSAR.

UNIT V: VERIFICATION & VALIDATION **L - 9**

The Validation and Verification Process, Introduction to NI Lab VIEW for Automotive, Test Categories like Functional Test, Black Box Test, Boundary level Test & Test Case Development, Reliability and Certifications Tests: EMI / EMC Tests as per AIS 004 standard, Environmental Test, Vibration Tests, Protection against Dust, Water Ingress and IP Standards Vehicle Diagnostic Interface like OBD, OBD - II.

Reference Books:

1. MiroslawStaron, “Automotive Software Architectures: An Introduction”, Springer, 2017. (ISBN: 978-3-319-58609-0)
2. Nicolas Navet and Francoise Simonot-Lion, “Automotive Embedded Systems Handbook”, CRC Press, 2009. (ISBN: 978-0-8493-8026-6)
3. Ronald K. Jurgen, “Distributed Automotive Embedded Systems”, SAE International, 2007. (ISBN: 978-0-7680-1966-7)
4. Ronald K. Jurgen, “Automotive Software”, SAE International, 2006. (ISBN: 978-0-7680-1714-4).

	AUTOMOTIVE THERMAL SYSTEM	L	T	P	C
		3	0	0	3

Course Category: Program Elective/EHV

Fundamental Concept of Thermodynamics, Path and Point Functions, Reversible and Irreversible Processes, Concept of Temperature and Thermal Equilibrium, First Law and Second Law of Thermodynamics, Refrigeration, Steady and Unsteady Heat Conduction.

Course Outcomes

CO Nos.	Course Outcomes	Level of learning domain (Based on revised Bloom's)
C01	Understand the fundamental concept of thermodynamics and solve the problem of closed and open systems and steady flow processes	K2
C02	Calculate the change entropy at Closed and open system and understand the Available and Unavailable Energy.	K3
C03	Apply the general thermodynamic property relations and standards to solve problems	K3
C04	Explain the different gas power cycles and application in internal combustion engine and air conditioning	K2
C05	Describe the different heat transfer principles of different automotive applications.	K2

UNIT I BASIC CONCEPTS AND FIRST LAW L- 9

Basic concepts - Concept of continuum, comparison of microscopic and macroscopic approach-Intensive and extensive properties- thermodynamics System and their types- Quasi-static- Heat and work transfer, displacement work and other modes of work- Zeroth law of thermodynamics –, application to closed and open systems and steady flow processes.

UNIT II SECOND LAW, ENTROPY AND AVAILABILITY L- 9

Heat Reservoir, source and sink- Heat Engine, Refrigerator and Heat pump- Statements of second law and its corollaries- Carnot cycle, reversed Carnot cycle, Performance- Clausius inequality- Concept of entropy, T-s diagram, Tds Equations, Entropy Changes for a Closed and open system- Third Law of Thermodynamics, principle of increase in entropy- Available and Unavailable Energy.

UNIT III IDEAL, REAL GASES AND THERMODYNAMIC RELATIONS L- 9

Properties of Ideal gas- Ideal and real gas comparison- Equations of state for ideal and real gases- Reduced properties- Mole and Mass fraction, Dalton's and Amagat's Law, Properties of gas mixture – Molar mass, gas constant, density, change in internal energy -Maxwell relations, Tds Equations, Difference and ratio of heat capacities- Joule-Thomson Coefficient, Clausius Clapeyron equation.

UNIT IV REFRIGERATION AND AIR CONDITIONING L- 9

Refrigerants, classification of refrigerants - Elements of refrigeration systems, Vapour compression refrigeration cycle, factors affecting the performance of a vapour compression system - Vapour absorption system and working principle, comparison between vapour

compression and vapour absorption systems - Air conditioning system, types and working principles.

List of Demonstration:

- Determination of COP of a refrigeration system
- Demonstration on Psychrometric processes

UNIT V CONDUCTION, CONVECTION AND RADIATION L- 9

General Differential equation of heat conduction– Cartesian and Polar Coordinates – One dimensional steady state heat conduction –– plane and Composite Systems-Free and Forced Convection-Heat Exchanger Types - Overall Heat Transfer Coefficient-Black Body Radiation – Grey body radiation - Shape Factor-Radiation Shields.

List of Demonstration:

- Demonstration on Natural convection-vertical cylinder
- Explain the forced convection inside tube

Reference Books:

1. Y.A. Cengel, Heat Transfer – A practical Approach, Tata McGraw-Hill, 2003.
2. M.N. Ozisik, Heat transfer, McGraw Hill (1985).
3. Bejan, Advanced Engineering Thermodynamics, John Wiley and Son, 1998.
4. S.R.Turns, Thermodynamics - concepts and Application, Cambridge UniversityPress, 2008.
5. Van Wylen& Sonntag , Thermodynamics, John Wiley & Sons 1991
6. J. M. Smith and H.C Van Ness. Introduction to Chemical Engineering Thermodynamics, McGraw-Hill Inc., 1987.
7. F.P. Incropera and Dewitt D.P, Fundamentals of Heat and Mass transfer, John Willey& Sons (1996).

	ELECTRIC DRIVES AND CONTROL	L	T	P	C
		3	0	0	3

Course Category: Program Elective/EHV

UNIT I: MOTORS FUNDAMENTALS AND MECHANICAL SYSTEMS L - 9

DC motor - Types, induced emf, speed-torque relations; Speed control – Armature and field control; Ward Leonard control – Constant torque and constant horse power operations. Review of Induction Motor operation – Equivalent circuit – Performance of the machine with variable voltage, rotor resistance variation, pole changing and cascaded induction machines, slip power recovery – Static Kramer Drive. Synchronous, Brushless DC and Switched Reluctance Drives.

UNIT II: CONVERTER AND CHOPPER CONTROL L - 9

Principle of phase control – Series and separately excited DC motor with single phase and three phase converters – waveforms, performance parameters, performance characteristics - Operation with freewheeling diode schemes; Drive employing dual converter. Introduction to time ratio control and frequency modulation; Class A, B, C, D and E chopper controlled DC motor – performance analysis, multi-quadrant control.

UNIT III: VSI AND CSI FED INDUCTION MOTOR CONTROL L - 9

AC voltage controller fed induction machine operation – Energy conservation issues – V/f operation theory – requirement for slip and stator voltage compensation. CSI fed induction machine – Operation and characteristics - PWM controls.

UNIT IV: FIELD ORIENTED CONTROL L - 9

Field oriented control of induction machines – Theory – DC drive analogy – Direct or Feedback vector control - Indirect or Feed forward vector control – Flux vector estimation - Space Vector Modulation control.

UNIT V: DIRECT TORQUE CONTROL L - 9

Direct torque control of Induction Machines – Torque expression with stator and rotor fluxes, DTC control strategy – optimum switching vector selection – reduction of torque ripple methods.

Reference Books:

1. Vedam Subramanyam, “Electric Drives – Concepts and Applications”, Tata McGraw Hill, 2000.
2. R.Krishnan, “Electric Motor Drives – Modeling, Analysis and Control”, Prentice- Hall of India Pvt. Ltd., New Delhi, 2003.
3 Austin Hughes, “Electric Motors and Drives – Fundamentals, Types and Applications”, Elsevier – a division of Reed Elsevier India private Limited, New Delhi, 2006.

	AUTOMOTIVE DIAGNOSTICS	L	T	P	C
		3	0	0	3

Course Category: Program Elective/EHV

Course Outcomes

Upon the successful completion of the course, studentwill be able to

CO Nos.	Course Outcomes	Level of learning domain (Based on revised Bloom's)
CO1	Understand the working principle of Networking protocols and ECU	K2
CO2	Illustrate the knowledge on Fault codes and Diagnostics of ECU	K2
CO3	Illustrate the knowledge on Diagnostics Tools	K2
CO4	Explain the approach techniques to resolve the issues flagged	K2
CO5	Illuminate the understanding of the OBD, its tools and techniques	K3

UNIT-I: THE COMPUTER ECM **L - 9**

Fundamental parts of a computer, practical automotive computer system, Principles of operation, Computer data, Computer interfaces, Control of output devices, Computer memories, Fault codes, Adaptive operating strategy of the ECM, Networking of computers, Vehicle network systems, Prototype network systems.

List of Demonstration:

1. Communication Protocols
2. Parts and Interfaces of the ECU

UNIT-II: SELF DIAGNOSIS AND FAULT CODES **L - 9**

Access to Diagnostic trouble codes (DTC), Developments in self-diagnosis, Diagnostic equipment and limitations of DTCs, Diagnostic equipment and limitations of DTCs.

List of Demonstration:

1. Identify DTCs

UNIT-III: DIAGNOSTIC TOOLS AND EQUIPMENT **L - 9**

Breakout boxes, Diagnostic tools that connect to ECM, The digital multimeter, Portable flat screen oscilloscopes, Diagnostic tool and oscilloscope combined, Pressure gauges, Calibrating test instruments, Location charts and wiring diagrams, Sources of diagnostic data ,Exhaust gas emissions and emission system testing.

List of Demonstration:

1. Use of Tools to read Data from the ECU

UNIT-IV: DIAGNOSTIC TECHNIQUES **L - 9**

Circuit testing, Vehicle specific details, six-steps approach, Skills required for effective diagnosis, An approach to fault finding, Emissions related testing, Ignition system tests, Diesel injection, Sensor tests on other systems, Intermittent faults.

List of Demonstration:

1. Error solving by resolving the identified DTCs

UNIT-V: ON-BOARD DIAGNOSTICS **L - 9**

On-board diagnostics – a first perspective, Petrol/gasoline on-board diagnostic monitors, On-board diagnostics – a second perspective, OBD for Engine systems, chassis systems, electrical systems, transmission systems.

List of Demonstration:

1. Read data from Vehicle using OBD and identify the causes and rectification

Reference Books:

1. Allan W. M. Bonnick, Automotive Computer Controlled Systems Diagnostic tools and techniques, Butterworth-Heinemann, 2011.
2. Tom Denton,Advanced Automotive Fault Diagnosis,Second Edition,2006.

	MICRO ELECTRO MECHANICAL SYSTEMS	L	T	P	C
		3	0	0	3

Course Category: Program Elective/EHV

Aims & Objectives:

This course enables understanding the concept of MEMS and Microsystems. Helps to understand the diverse technological and functional approaches and applications and provides an insight of micro sensors, actuators and micro fluidics. Gain the knowledge about microfabrication, micromachining and micro packaging.

Course Outcomes

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

CO Nos.	Course Outcomes	Level of learning domain (Based on revised Bloom's)
CO1	Attain a broad range of the knowledge required to grow in the evolving field of MEMS and microsystem.	K2
CO2	Familiar with the principle and operation of microsensor and microactuator.	K2
CO3	Select and assess suitable materials for manufacturing MEMS and microsystem.	K2
CO4	Describe the different microfabrication and micromachining process.	K2
CO5	Describe the different stages of microsystems packaging and packaging materials.	K2

UNIT I: OVERVIEW OF MEMS AND MICROSYSTEMS L - 9

MEMS and Microsystems–MEMS as micro sensors and micro actuators- MEMS and Microsystem products– Evolution of Microfabrication, Microsystems and Microelectronics-Comparison of Microsystems and microelectronics-Multidisciplinary nature of Microsystems-Microsystems and miniaturization- Applications of Microsystems in various industries.

UNIT II: MICRO SENSORS AND ACTUATORS L - 9

Micro sensors- Bio sensors, Chemical sensors, Optical sensors, Pressure sensors, Thermal sensors – thermopiles, thermistors. Microactuator - Micro actuation principles-Micro gripper-Micro motors-Micro valves-Micro pumps- Micro accelerometers-Micro fluidics.

UNIT III: MATERIALS FOR MEMS AND MICROSYSTEMS L - 9

Substrates and wafers – Silicon as a substrate material, ideal substrates for MEMS – single crystal Silicon and wafers crystal structure – mechanical properties of Si –Silicon compounds – Gallium arsenide- quartz – piezoelectric crystals – polymers.

UNIT IV: MICROFABRICATION AND MICRO MACHINING L - 9

Photolithography-Ion Implantation-Diffusion-Chemical vapour deposition (CVD)-Enhanced CVD-Physical vapours deposition (Sputtering)-Etching-chemical etching, plasma etching-Bulk Micro Machining -Surface Micro Machining -LIGA process.

UNIT V: MICROSYSTEM PACKAGING L - 9

General considerations in packaging - Levels of Microsystem packaging – die level, device level and system level – Essential packaging technologies – die preparation, surface bonding, wire bonding and sealing - Three-dimensional packaging, assembly of Microsystems – selection of packaging materials.

Text Books

1. Tai-Ran Hsu, MEMS and Microsystems Design and Manufacture, Tata McGraw Hill, New Delhi, 2017.
2. Mahalik, N. P, MEMS, Tata McGraw Hill, New Delhi, 2007.

Reference Books

3. Julian W. Gardner, Florin Udrea, *Microsensors: Principles and Applications*, Wiley, 2015.
4. Michael Kraft and Neil M. White, MEMS for automotive and aerospace applications, Woodhead Publishing Limited, 2013.
5. Chang Liu, “Foundations of MEMS”, Pearson International Edition, 2006.
6. Marc F Madou, *Fundamentals of Micro Fabrication*, CRC Press, 2nd Edition, 2002

	IN-VEHICLE NETWORKING	L	T	P	C
		3	0	0	3

Course Category: Program Elective/EHV

Self-Learning Content: Basic working principles of analog and digital communication.

Course Outcomes

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

CO Nos.	Course Outcomes	Level of learning domain (Based on revised Bloom's)
CO1	Describe about in –vehicle networking.	K2
CO2	Explain the different network and communication protocol.	K2
CO3	Understand the higher layer protocols.	K2
CO4	Describe the flexray protocol.	K2
CO5	Describe the latest trends in in–vehicle networking.	K2

UNIT I BASICS OF IN-VEHICLE NETWORKING L - 9

Overview of Data communication and networking –need for In-Vehicle networking – layers of OSI reference model –multiplexing and de-multiplexing concepts –vehicle buses.

List of Demonstration:

1. Different types of communication between two-microcontrollers.

UNIT II NETWORKS AND PROTOCOLS L – 9 Overview of general-purpose networks and protocols -Ethernet, TCP, UDP, IP,ARP,RARP - LIN standard overview –workflow concept-applications –LIN protocol specification –signals - Frame transfer –Frame types –Schedule tables –Task behaviour model –Network management –status management - overview of CAN –fundamentals –Message transfer – frame types-Error handling –fault confinement-Bit time requirements.

List of Demonstration:

1. CAN communication between two-microcontrollers.

UNIT III HIGHER LAYER PROTOCOL L – 9

Introduction to CAN open –TTCAN –Device net -SAE J1939 - overview of data channels – control channel-synchronous channel – asynchronous channel –Logical device model – functions-methods-properties-protocol basics- Network section-data transport –Blocks – frames –Preamble-boundary descriptor

List of Demonstration:

1. Diagnosis tool for CAN communication between two-microcontrollers.

UNIT IV FLEXRAY PROTOCOL L – 9 Introduction –network topology –ECUs and bus interfaces –controller host interface and protocol operation controls –media access control and frame and symbol processing – coding/decoding unit –FlexRay scheduling

UNIT V LATEST TRENDS L - 9

Car networking protocols – Networking future trends –Roadmaps –Competitive advantage

Reference Books:

1. J.Gabrielleen,"Automotive In-Vehicle Networks", John Wiley & Sons, Limited, 2008
2. Robert Bosch," Bosch Automotive Networking", Bentley publishers, 2007
3. Society of Automotive Engineers, "In-Vehicle Networks", 2002.
4. Ronald K Jurgen, "Automotive Electronics Handbook", McGraw-Hill Inc. 1999.
5. Indra Widjaja, Alberto Leon-Garcia, "Communication Networks: Fundamental Concepts and Key Architectures", McGraw-Hill College; 1st edition, 2000.
6. Konrad Etschberger, "Controller Area Network, IXXAT Automation", August 22, 2001.
7. Olaf Pfeiffer, Andrew Ayre, Christian Keydel, "Embedded Networking with CAN and CANopen", Annabooks/Rtc Books, 2003

	INTELLIGENT TRANSPORT SYSTEMS	L	T	P	C
		3	0	0	3

Course Category: Program Elective/EHV

Self-Learning Content: Fundamentals of sensors, navigation and wireless communication.

Course Outcomes

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

CO Nos.	Course Outcomes	Level of learning domain (Based on revised Bloom's)
CO1	Describe the digital map database module.	K2
CO2	Describe the working of the positioning module.	K2
CO3	Describe the working of the direction module.	K2
CO4	Describe the working of wireless communication module.	K2
CO5	Describe the working autonomous location and navigation.	K2

UNIT I DIGITAL MAP DATABASE MODULE **L - 9**

Introduction to Modern Vehicle Location and Navigation - Basic Representations - Reference Coordinate Systems – Standards - Proprietary Digital Map Databases - Digital Map Compilation.

List of Demonstration:

1. By using Global Positioning System device.

UNIT II POSITIONING MODULE **L –**

9Introduction-Dead Reckoning-Global Positioning System - Sensor fusion - Conventional map matching - Fuzzy logic Based Map matching - Other Map matching algorithms - Map aided Sensor calibration

List of Demonstration:

2. By using Global Positioning System device with digital map.

UNIT III DIRECTION MODULE **L - 9**

Shortest Path - Heuristic Search - Bidirectional Search - Hierarchical search - other algorithms - Guidance while En Route - Guidance while off Route - Guidance with dynamic information.

List of Demonstration:

1. By using directional sensors data on digital map.

UNIT IV WIRELESS COMMUNICATION MODULE **L –**

9Introduction - Communication Subsystem Attributes - Existing Communication Technologies - Communication Subsystem Integration.

List of Demonstration:

1. By using Mobile communication, Bluetooth & Wi-Fi communication.

UNIT V AUTONOMOUS LOCATION AND NAVIGATION **L –**

9Introduction – Vehicle Location: Standalone Technologies - Radio Technologies - Satellite Technologies - Vehicle Navigation: Coping with complex requirements - Dual use navigation and entertainment components - Centralized location and Navigation Introduction -

Automatic Vehicle Location: Centralized and Distributed Approach- Dynamic Navigation :Centralized and Distributed.

Reference Books:

1. "Intelligent Vehicle Technologies Theory and Applications"– L Vlacic, M Parent, F Harashima- Butterworth Heinemann
2. "Vehicle location and Navigation Systems" – Yilin Zhao – Artech House Inc.
3. Sussman Joseph, "Perspectives on Intelligent Transportation Systems (ITS)", New York, NY: Springer, 2010.
4. Mashrur A. Chowdhury, and Adel Sadek, "Fundamentals of Intelligent Transportation Systems Planning", Artech House, Inc., 2003.

	AUTOMOTIVE SAFETY	L	T	P	C
		3	0	0	3

Course Category: Program Elective/EHV

UNIT I INTRODUCTION VEHICLE SAFETY, STRUCTURAL CRASHWORTHINESS AND CRASH TESTING L – 9

Automotive Safety-Active and passive safety, Driver assistance systems in automobiles, Definitions and terminology. Balance of stiffness and toughness characteristics and energy absorption characteristics of vehicle structures, Design of crash crumple zones, Modeling and simulation studies, Optimization of vehicle structures for crash worthiness, Types of impacts, and Impact with rebound, movable barrier tests, Analysis and simulation of vehicle in barrier impacts, Roll over crash tests, Behavior of specific body structures in crash testing, Photographic analysis of impact tests.

UNIT II ERGONOMICS AND HUMAN RESPONSE TO IMPACT L – 9

Importance of Ergonomics in Automotive safety, Locations of controls, Anthropometry, Human impact tolerance Determination of Injury thresholds, Severity Index, Study of comparative tolerance, Application of Trauma for analysis of crash injuries. Injury criteria's and relation with crash and modeling and simulation studies in dummy.

UNIT III VEHICLE SAFETY SYSTEMS L – 9

Survival space requirements, Restraints systems used automobiles, Types of safety belts, Head restraints, Air bags used in automobiles, Use of energy absorbing systems in automobiles, Impact protection from steering controls, Design of seats for safety, types of seats used in automobiles. Importance of Bumpers in automobiles, Damageability criteria in bumper designs. Introduction to the types of safety glass and their requirements and rearward field of vision in automobiles, Types of rear view mirrors and their assessment. Warning devices, Hinges and latches etc. Active safety.

UNIT IV FUNDAMENTALS OF LIGHT, VISION AND COLOUR L – 9

Electromagnetic radiation and light, Propagation of light, Spectral sensitivity of light, Measures of radiation and light, standard elements for optical control. Illuminant calculations, Derivation of luminous flux from luminous intensity, flux transfer and inter reflection, luminance calculations, discomfort glare, eyes as an optical system visual processing, lighting for results, modes of appearance, Pointers for lighting devices. Nature of the color Tri-chromatic Colorimetry, Surface color, color spaces and color solids, color rendering.

UNIT V LIGHT MEASUREMENTS, TESTING EQUIPMENT, CALIBRATION AND PHOTOMETRIC PRACTICE L – 9

Basics of standards and detectors, spectral measurements and Colorimetry, illuminant meters and luminance meters, colorimeters. Fundamentals of equipment used for light measurement in Automotive field; Gonio- Photometer, Reflecto-meter, Colorimeter, Integrating sphere, types, application, coordinates system, Types of sensors and working principle, construction, characteristics etc. used in different equipment. National and international Regulations, test requirements and testing procedure.

Reference Books:

1. Jullian Happian-Smith 'An Introduction to Modern Vehicle Design' SAE, 2002
2. Johnson, W., and Mamalis, A.G., "Crashworthiness of Vehicles, MEP, London, 1995
3. Edward .A, Lamps and Lighting, Hodder & Stoughton, London, 1993.
4. Bosch –automotive -handbook ,edition 5-SAE Publication-2000
5. Rollover Prevention, Crash Avoidance, Crashworthiness, Ergonomics and Human Factors", SAE Special Publication, November 2003.

	PLUG-IN ELECTRIC VEHICLES IN SMART GRID	L	T	P	C
		3	0	0	3

Course Category: Program Elective/EHV

Self-Learning Content: Fundamentals of power system, power grid, smart grid and battery charging.

Course Outcomes

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

CO Nos.	Course Outcomes	Level of learning domain (Based on revised Bloom's)
CO1	Describe about vehicle electrification and impact of charging strategies.	K2
CO2	Describe the influence of EVs on power system.	K2
CO3	Describe the frequency control and voltage reserve from EVs.	K2
CO4	Describe the ICT solutions to support EV deployment.	K2
CO5	Describe the EV charging and facility planning.	K2

UNIT I VEHICLE ELECTRIFICATION & IMPACT OF CHARGING STRATEGIES L - 9

Introduction, Impact of charging strategies, EV charging options and infrastructure, energy, economic and environmental considerations, Impact of EV charging on power grid, effect of EV charging on generation and load profile, Smart charging technologies, Impact on investment.

List of Demonstration:

1. Demonstration of EV Charging.

UNIT II INFLUENCE OF EVS ON POWER SYSTEM L - 9

Introduction, identification of EV demand, EV penetration level for different scenarios, classification based on penetration level, EV impacts on system demand: dumb charging, multiple tariff charging, smart charging, case studies.

List of Demonstration:

1. Demonstration the influence of EVs on power system using simulation model.

UNIT III FREQUENCY CONTROL RESERVES & VOLTAGE SUPPORT FROM EVS L - 9

Introduction, power system ancillary services, electric vehicles to support wind power integration, electric vehicle as frequency control reserves and tertiary reserves, voltage support and electric vehicle integration, properties of frequency regulation reserves, control strategies for EVs to support frequency regulation.

List of Demonstration:

1. Demonstration the frequency regulation by EVs.
2. Demonstration the voltage regulation by EVs.

UNIT IV ICT SOLUTIONS TO SUPPORT EV DEPLOYMENT L - 9

Introduction, Architecture and model for smart grid & EV, ICT players in smart grid, smart metering, information & communication models, functional and logical models, technology and solution for smart grid: interoperability, communication technologies.

UNIT V EV CHARGING FACILITY PLANNING **L - 9**

Energy generation scheduling, different power sources, fluctuant electricity, centralized charging schemes, decentralized charging schemes, energy storage integration into Microgrid, Design of V2G Aggregator.

Reference Books:

1. SumedhaRajakaruna, FarhadShahnia and Arindam Ghosh, “Plug In Electric Vehicles in Smart Grids-Integration Techniques”, Springer Science + Business Media Singapore Pte Ltd., 2015.
2. Canbing Li, Yijia Cao, YonghongKuang and Bin Zhou, “Influences of Electric Vehicles on Power System and Key Technologies of Vehicle-to-Grid”, Springer-Verlag Berlin Heidelberg, 2016.
3. Qiuwei Wu, “GRID INTEGRATION OF ELECTRIC VEHICLES IN OPEN ELECTRICITY MARKETS”, John Wiley & Sons, Ltd, 2013.

	TESTING AND CERTIFICATION OF ELECTRIC AND HYBRID VEHICLES	L	T	P	C
		3	0	0	3

Course Category: Program Elective

UNIT I: INTRODUCTION **L - 9**

Specification & Classification of Vehicles (including M, N and O layout), Homologation & its Types, Regulations overview (EEC, ECE, FMVSS, AIS, CMVR), Type approval Scheme, Homologation for export, Conformity of Production, various Parameters, Instruments and Types of test tracks, Hardware in The Loop (HIL) concepts for EV/HEVs.

UNIT II: STATIC TESTING OF VEHICLE **L - 9**

Photographs, CMVR physical verification, Tyre Tread Depth Test, Vehicle Weightment, Horn installation, Rear view mirror installation, Tell Tales, External Projection, Wheel Guard, Arrangement of Foot Controls for M1 Vehicle, Angle & Dimensions Measurement of Vehicle, The Requirement of Temporary Cabin For Drive– Away – Chassis, Electric vehicle – Safety Norms, Energy consumption and Power test.

UNIT III: DYNAMICS TESTING OF VEHICLE **L - 9**

Hood Latch, Gradeability, Pass-by Noise, Interior Noise, Turning Circle Diameter & Turning Clearance Circle Diameter, Steering Effort, Constant Speed Fuel Consumption, Cooling Performance, Speedo-meter Calibration, Range Test, Maximum Speed, Acceleration Test, Coast-down test, Brakes Performance ABS Test, Broad band / Narrow band EMI Test, Electric vehicle – Range Test.

UNIT IV: VEHICLE COMPONENT TESTING **L - 9**

Horn Testing, Safety Glasses Test: Windscreen laminated and toughened safety glass, Rear View Mirror Test, Hydraulic Brakes Hoses Fuel Tank Test: Metallic & Plastic, Hinges and Latches Test, Tyre & Wheel Rim Test, Bumper Impact Test, Side Door Intrusion, Crash test with dummies, Demist test, Defrost Test, Interior Fittings, Steering Impact test (GVW<1500 kg), Body block test, Head form test, Driver Field Of Vision, Safety belt assemblies, Safety belt anchorages, Seat anchorages & head restraints test, Airbag Test, Accelerator Control System, Motor power, Safety Requirements of Traction Batteries, EMI-EMC (CI, BCI, RE,RI and CTE).

UNIT V: TESTS FOR HYBRID ELECTRIC VEHICLES, RETRO-FITMENT AND CHARGING STATION **L - 9**

Hybrid Electric Vehicles Tests (M and N category), Tests for Hybrid Electric System Intended for Retro-fitment on Vehicles of M and N Category (GVW < 3500 kg), Test for Electric Propulsion kit intended for Conversion, Test for Electric Vehicle Conductive AC Charging System, and Test for Electric vehicle conductive DC charging system.

Reference Books:

1. "Vehicle Inspection Handbook", American Association of Motor Vehicle Administrators
2. Michael Plint& Anthony Martyr, "Engine Testing & Practice", Butterworth Heinmenn, 3rd ed, 2007
3. Proceedings- Automotive Testing & Certification held on 20th to 24th July 2010 at ARAI PUNE
4. Bosch Automotive Handbook, Robert Bosch, 7th Edition, 2007