Savitribai Phule Pune University
Faculty of Science & Technology

Curriculum/Syllabus
For
Final Year
Bachelor of Engineering
(Choice Based Credit System)
Automobile Engineering
(2019 Course)
Board of Studies – Mechanical and Automobile Engineering
(With Effect from Academic Year 2022-23)

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Automobile Engineering (2019 pattern)

Course Code	Course Name	Teaching Scheme (Hrs./week)			Examination Scheme and Marks						Credit			
		TH	PR	TUT	ISE	ESE	TW	PR	OR	TOTAL	TH	PR	TUT	TOTAL
Semester-VII														
416481	Automotive Testing and Certification	3	2	-	30	70	-	-	25	125	3	1	-	4
416482	Machine and Vehicle Dynamics	3	2	-	30	70	-	-	25	125	3	1	-	4
416483	Industrial Engineering*	2	-	-	-	50	-	-	-	50	2	-	-	2
416484	Elective – III	3	-	-	30	70	-		-	100	3	-	-	3
416485	Elective - IV	3	2	-	30	70	-	50	-	150	3	1	-	4
416486	Vehicle Maintenance and Service Practices	-	2	-	-	-	50	-	-	50	-	1	-	1
416487	Project (Stage - I)	-	4	-	-	-	50	-	50	100	-	2	-	2
416488	Audit course$	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total	**14**	**12**		**120**	**330**	**100**	**50**	**100**	**700**	**14**	**6**	**-**	**20**
Semester-VIII														
416489	Hybrid and Electric Vehicle	3	2	-	30	70	25	-	25	150	3	1	-	4
416490	Automotive System Design	3	2	-	30	70	25	-	25	150	3	1	-	4
416491	Elective - V	3	-	-	30	70	-	-	-	100	3	-	-	3
416492	Elective - VI	3	-	-	30	70	-	-	-	100	3	-	-	3
416493	Automotive Systems Analysis and Simulation Laboratory	-	2	-	-	-	25	-	25	50	-	1	-	1
416494	Project (Stage - II)	-	10	-	-	-	100	-	50	150	-	5	-	5
		12	**16**	**-**	**120**	**280**	**175**	**-**	**125**	**700**	**12**	**8**	**-**	**20**

Elective-III		Elective-V	
416484A	Artificial Intelligence and Machine Learning	416491A	Alternative Fuels and Emission control
416484B	Automotive Control Systems	416491B	Renewable Energy
402044E	Internet of Things**		
Elective-IV		**Elective-VI**	
416485A	Finite Elements Analysis	416492A	Transport Management and Automobile Industry
416485B	Computational Fluid Dynamics	416492B	Automotive Safety
		416492C	Process Planning and Cost Estimation

Abbreviations: TH: Theory, **PR**: Practical, **TUT**: Tutorial, **ISE**: In-Semester Exam, **ESE**: End-Semester Exam, **TW**: Term Work, **OR**: Oral

- Student can select any elective subjects from the list given as per his/her choice. However, it is advised to select the subjects from within a group identified for specialization.

Instructions:

- Practical/Tutorial must be conducted in **FOUR batches per division** only.
- Minimum number of Experiments/Assignments in PR/Tutorial shall be carried out **as mentionedin the syllabi** of respective courses.
- Assessment of tutorial work has to be carried out similar to term-work. The Grade cum marks forTutorial and Term-work shall be awarded on the basis of **continuous evaluation.**
- ***** Marked Course (Industrial Engineering) End semester examination will be 2 hr only.
- ******Marked Course (Internet of Things) is common with BE (Mechanical Engineering) 2019 Course.
- $ Audit course is mandatory but it is non-credit course. Examination has to be conducted at the end of Semesters for award of grade at institute level. Grade awarded for audit course shall not be calculated for grade point & CGPA.

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416481: Automotive Testing and Certification					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30 Marks**
Practical	**2 Hrs./Week**	**Practical**	**1**	**End-Semester**	**70 Marks**
				Oral	**25 marks**

Prerequisites: Applied Thermodynamics, Automotive Electrical and Electronics, Automotive Chassis and Transmission

Course Objectives:

1. **Understand** types of vehicles, certification and homologation.
2. **Gain** knowledge of vehicle performance parameters.
3. **Describe** the various types of vehicle test methods.
4. **Acquire** the basic knowledge of chassis dynamometer and tests performed on it.
5. **Explain** the different mechanism of noise generation and sources of vehicle noise.
6. **Describe** the different types of vehicle component testing methods.

Course Outcomes:

On successful completion of the course, learner will be able to,

CO1. **CLASSIFY** the vehicle with respect to certification and homologation.
CO2. **DEFINE** key performance parameters of a vehicle.
CO3. **PERFORM** different types of vehicle level tests.
CO4. **DESCRIBE** various methods of vehicle testing on chassis dynamometer.
CO5. **SUMMARIZE** the mechanism of vehicle noise generation and sources of noise.
CO6. **OBTAIN** know-how in testing methodologies for certification of vehicle components testing.

Course Contents

Unit 1	**Vehicle Classification**

Introduction, Specification & Classification of Vehicles (including M, N and O layout), Regulations overview (ECE, EEC, FMVSS, AIS, CMVR, ADR), Homologation & its Types, Type approval and Conformity of Production, Engine and Vehicle specifications, Two Wheeler and 4 Wheeler certification tests.

Unit 2	**Vehicle Performance Parameters**

Vehicle Performance parameters: Fuel economy, acceleration, deceleration, gradability, top speed, handling, comfort, life durability.

Automobile testing instrumentation: Sensors types and selection, instrumentation for functional tests, model test and full scale testing

Unit 3	Vehicle Level Testing

Vehicle Testing: Photographs, CMVR physical verification, Vehicle weightment, free acceleration test, coast down test, pass by noise test, Brake test, ABS, Turning circle diameter test, Steering effort test, Speedometer calibration, External projection test, Gradability test, Endurance test, High speed performance test.

Test tracks: Proving ground testing, high speed track, pavement track, corrugated track, mud track, steering pad, gradient track, Water/salt water wade track, Straight line braking track, split mu track, wet pad, Accelerated fatigue track, External noise test track, comfort track.

Unit 4	Laboratory Testing

Chassis Dynamometer and its types, Testing on chassis dynamometer for emission and performance for BS-VI, Real Drive Emission Test (RDE), Driving Cycles- USA, Japan, Euro and India, Types of World Harmonized Tests, Non-road Transient Cycle (NRTC), accelerated testing, virtual testing, evaporative emission testing, oil consumption testing, Engine power test (petrol & diesel), Indian driving cycles.

Unit 5	Noise Testing

Mechanism of noise generation, Sources of noise and vibration, design features, common problems, pass-by noise requirements, target vehicles and objective targets, Vehicle structure noise, Engine noise, Transmission noise, Exhaust noise, causes and remedies on road shocks, wind noise and measurement.

Unit 6	Vehicle Component Testing

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, Demist test, Defrost Test, Interior Fittings, Steering Impact test (GVW W<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.

Books and other resources

Text Books:

1. Raymond M. Brach and R. Matthew Brach, "Vehicle Accident Analysis and Reconstruction Methods", SAE International, 2011.

References Books:

1. Ulrich Seiffert and LotharWech, “Automotive Safety Handbook”, SAE International, 2007.
2. AIS- Automotive Industry Standards.
3. IS standards
4. CMVR – Central Motor Vehicle Regulations.
5. ECE & EC Regulations/Standards
6. Robert Bosch GmbH, Bosch Automotive Handbook
7. Safety Regulations- Society of Indian Automobile Manufacturers.
8. A.J.Martyr, M.A.Plint, Engine Testing Theory and Practice, SAE International, Third Edition, 2007.

Web References:

1. https://www.araiindia.com/downloads
2. https://dieselnet.com/standards/cycles/index.php

Guidelines for Laboratory Conduction

The student shall complete the following activity as a Term Work.
Oral examination shall be based on the Term work undertaken during the semester.

Practical: (Perform any 9 out of 12 experiments)

1. Estimation of power requirement for vehicle propulsion by taking actual vehicle example.
2. Perform coast down test to find vehicle inertia.
3. Perform On road fuel consumption test at different speeds.
4. Perform Brake efficiency measurement test.
5. Perform pass- by noise test.
6. Perform free acceleration test.
7. Perform Real Drive Emission (RDE) test as per BS-VI norms.
8. Perform Vibration measurement in passenger compartment.
9. Laboratory testing of vehicle on chassis dynamometer for measurement of performance.
10. Laboratory testing of vehicle on chassis dynamometer for measurement of emission.
11. Report based on visit to vehicle testing and research organization.
12. On road emission testing of petrol and diesel vehicles as per PUC/RTO guidelines.

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Board of Studies - Mechanical and Automobile Engineering

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416482: Machine and Vehicle Dynamics					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30 Marks**
Practical	**2 Hrs./Week**	**Practical**	**1**	**End-Semester**	**70 Marks**
				Oral	**25 Marks**

Pre-requisites: Kinematics of Machinery, Design of Machine Elements, Design of Engine Components, Automotive Chassis & Transmissions.

Course Objectives:

1. Implement & Analyze the balancing of rotating masses, reciprocating masses and concept of static and dynamic balancing.
2. Learn the basic concept of vibrations, types of vibrations, undamped and damped vibration, also different types of damping.
3. Familiarize with the concepts of force vibration, transmissibility, resonance phenomenon and phase difference.
4. Acquaint with the fundamentals of vehicle dynamics through different equations of motions.
5. Understand the performance characteristics of road vehicle during acceleration & braking.
6. Learn the fundamental conditions of handling & ride performance of vehicle.

Course Outcomes:

On completion of the course, students will be able to -

CO1. **APPLY** balancing technique for static and dynamic balancing of rotating masses, multi cylinder inline and radial engines.

CO2. **ANALYZE** the natural frequency of system for undamped and damped free vibrations.

CO3. **INTERPRET** the implications of forced vibrations on the systems.

CO4. **ANALYZE** effect of different forces acting on vehicle through equations of motion.

CO5. **ANALYZE** the acceleration and braking characteristics of vehicle.

CO6. **ANALYZE** the ride and handling characteristics in vehicle design.

Unit 1	**Balancing**

Balancing of rotating masses in one and several planes, balancing of reciprocating masses in single and multi-cylinder engines: in-line, radial and V-type, primary and secondary balancing analysis, concept of direct and reverse cranks method.

Unit 2	Single Degree of Freedom Systems - Free Vibrations

Fundamentals of Vibration: Elements of a vibratory system, S.H.M., degrees of freedom, modeling of a system, concept of linear and non-linear systems, equivalent spring, linear and torsional systems. **Undamped free vibrations:** Natural frequency by equilibrium and energy methods for longitudinal and torsional vibrations.

Damped free vibrations: Different types of damping, equivalent viscous damping, free vibrations with viscous damping - over damped, critically damped and under damped systems, initial conditions, logarithmic decrement, dry friction or coulomb damping - frequency and rate of decay of oscillations.

Unit 3	Single Degree of Freedom Systems – Forced Vibrations

Forced vibrations of longitudinal and torsional systems, Frequency Response Functions - Simple harmonic excitation, excitation due to reciprocating unbalance, base excitation, magnification factor, transmissibility, resonance phenomenon and phase difference, Quality Factor, Vibration Isolation, Force and Motion transmissibility.

Introduction to free vibration of 2-DOF system and mode shape.

Unit 4	Introduction of Vehicle Dynamics

Vehicle as lumped mass, Vehicle coordinate system, earth fixed coordinate system, Various external forces acting on vehicle with road loads: Rolling resistance of tire, gradability, Aerodynamics resistance, and drawbar pull, Nature of the forces and factors affecting the forces, Dynamic axle loading in different cases, Traction and Tractive effort, equation of motion for maximum tractive effort, weight distribution of vehicle, stability of vehicle on slope.

Unit 5	Acceleration and Braking Characteristics

Acceleration - Power limited acceleration: Engines, Power Train and Automatic Transmission. Traction Limited, Transverse Weight Shift due to drive torque, Numerical Treatment.

Braking – Constant Deceleration, Stopping distance and time, Braking Sources, Brake Factor, Braking Efficiency, Braking Applied To Rear Wheels, Front Wheels And All Four Wheels, On Straight And Curved Path.

Unit 6	Handling and Ride Mode

Handling Mode: Mathematical model of handling, Fundamental condition for true Rolling Steady State Handling: Slip angle, cornering power, Neutral steer, under steer and over steer, Steady state response, Yaw velocity, Lateral Acceleration, Curvature response and Directional stability.

Testing of Handling characteristics: constant speed test, constant steer angle test, Constant radius test.

Ride performance criteria: Vehicle ride model, 2-DOF vehicle model of sprung & unsprung mass, 2-DOF vehicle model for pitch & Bounce, oscillation centers, active and semi active suspension.

Books

Textbook:

1. VP Singh, "Mechanical Vibrations", Dhanpat Rai and Sons, New Delhi
2. G. K. Grover, and S. P. Nigam,, "Mechanical Vibrations", Nemchand and Brothers, Roorkee, U.K, India

References:

1. S. S. Rao ,"Mechanical Vibrations", Pearson Education
2. Kewal Pujara and R.S. Pujara, "Vibration and Noise for Engineers", Dhanpat Rai and Sons, Delhi
3. Gillespie Thomas, "Fundamentals of Vehicle Dynamics", SAE USA 1992.
4. John Wiley and Sons J Wong , "Theory of Ground Vehicles", New York, 1978
5. Ham B, Pacejka, "Tyre and Vehicle Dynamics", SAE Publication – 2002
6. Popp, K. and Schiehlen,W, "Ground Vehicle Dynamics" Springer, 1993.
7. Reza N. Jazar, "Vehicle Dynamics: Theory and Application" Springer, 2008.

Web References:

1. https://www.youtube.com/watch?v=bX_m53Xexvk&list=PLAC668A0566953FB5
2. https://www.youtube.com/watch?v=IRfWDBMN4yU&list=PLbRMhDVUMngdM3vvYapHCEPTiEvoATCHS
3. https://www.youtube.com/watch?v=9CPA6WG6mRo&t=836s
4. https://www.youtube.com/watch?v=LZ82iANWBL0&list=PLbMVogVj5nJTW50jj9_gvJmdwFWHaqR5J
5. https://www.youtube.com/watch?v=Cg0L_HZYxP4&list=PLW3FM5Kyc2_4PGkumkAHNXzWtgHhaYe1d
6. https://www.youtube.com/playlist?list=PLEzzQIuBvBkoqJOP2IL3Elt6Ra8j4zFL3

Virtual Lab links:

1. https://dom-nitk.vlabs.ac.in/exp/multiple-mass-in-single-plane/
2. https://dom-nitk.vlabs.ac.in/exp/muliple-mass-in-multiple-plane/
3. https://mdmv-nitk.vlabs.ac.in/exp/exp-rotating-unbalance-nitk/
4. https://mdmv-nitk.vlabs.ac.in/exp/exp-cantilever-beam-nitk/
5. https://mdmv-nitk.vlabs.ac.in/exp/exp-simply-supported-beam-nitk/
6. https://mdmv-nitk.vlabs.ac.in/exp/exp-fixed-beam-nitk/
7. https://mdmv-nitk.vlabs.ac.in/exp/exp-sdof-system-nitk/
8. https://mdmv-nitk.vlabs.ac.in/exp/exp-base-excitation-nitk/
9. https://mdmv-nitk.vlabs.ac.in/exp/exp-forced-vibration-nitk/
10. https://mdmv-nitk.vlabs.ac.in/exp/exp-dynamic-vibration-absorber-nitk/
11. http://vlabs.iitkgp.ernet.in/rtvlas/exp8/index.html
12. http://vlabs.iitkgp.ernet.in/rtvlas/exp7/index.html

Term Work

The Term Work shall consist of :-
Any eight experiments from following list (with experiment no.6 compulsory)

OR

Any seven experiments from following list (with experiment no.6 compulsory) & any one from virtual lab.

1. Experimental verification of dynamic balancing of rotating masses.
2. Determination of the natural frequency of damped vibration of single degree freedom system and to find it's damping coefficient.
3. Determination of critical speed of single rotor system.
4. Determination of resonance frequency of transverse vibration of beam.
5. Determination of the frequency response curve under different damping conditions for single degree freedom system of vibration.
6. Multi body simulation of steering and suspension components using any of the following mentioned FEA and MBD software's. (Compulsory)
7. Study of shock absorber and to plot transmissibility curve.
8. Measurement of vibration parameters like frequency, amplitude, acceleration of any vibrating system or vehicle by using vibration measuring instruments.
9. Study of low speed maneuverability parameters of a vehicle.
10. Analysis of machine vibration signature using any analysis software. Software's: Ansys, Abaqus, MSC-Nastran, MSC Adams, Motion Solve, AMESim, CarSim, and Matlab
11. Verification of natural frequency of torsional vibration of two rotor system and position of node.

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Automobile Engineering (2019 pattern)

416483: Industrial Engineering					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**2 Hrs./week**	**Theory**	**2**	**In-Semester**	**-**
				End-Semester*	**50 marks**

Prerequisites: Basic concepts of Mathematics and Mechanical Engineering, Industrial Orientation, Quality Control, Human Psychology, Basic Finance, Passion for Continual Improvement.

Course Objectives:

1. To introduce the concepts, principles, and framework of Industrial Engineering and Productivity enhancement approaches.
2. To familiarize the students with different time study and work measurement techniques for productivity improvement.
3. To introduce various aspects of facility design.
4. To acquaint the students with various components and functions of Production Planning and inventory Control.

Course Outcomes

Learner will be able to:

CO1. **EVALUATE** the productivity and **IMPLEMENT** various productivity improvement techniques.

CO2. **APPLY** work study techniques and **UNDERSTANDS** its importance for better productivity.

CO3. **DEMONSTRATE** the ability to **SELECT** plant location, appropriate layout and material handling equipment.

CO4. **USE** of Production planning and control tools for effective planning, scheduling and managing the shop floor control and **PLAN** inventory requirements.

Course Contents

Unit 1 **Introduction to Industrial Engineering and Productivity**

Introduction to Industrial Engineering, Historical background and scope, Contribution of Taylor, Gilbreth, Gantt, Maynard, Ford, Deming and Ohno. Importance of Industrial engineering. Introduction to Work system design

Productivity: Definition of productivity, Measures of Productivity, Total Productivity Model, Need for Productivity Evaluation, Productivity measurement models, Productivity improvement approaches, Principles, Productivity Improvement techniques – Technology based, Material based, Employee based, Product based techniques, Overall Equipment Effectiveness and efficiency, Introduction of Lean Manufacturing, Lean Enterprise

Unit 2	Work Study

Method Study: Introduction and objectives, Areas of application of work study in industry, Selection and Basic procedure. Recording techniques, Operations Process Chart, Flow Process Chart (Man, Machine & Material) Multiple Activity Chart, Two Handed process chart, Flow Diagram, String Diagram and Travel Chart, Cycle and chronocycle graphs, SIMO chart, Therbligs, Micro motion and macro-motion study: Principles of motion economy, Normal work areas and work place design.

Work Measurement: Techniques, time study, steps, work sampling, Determination of time standards. Observed time, basic time, normal time, rating factors, allowances, standard time, and standard time determination, standardized work, 7 wastages, Kaizen concept in work study

Introduction to a line of balance, assembly line balancing, and progress control

Introduction to PMTS, MTM, and MOST and Kaizen

Unit 3	Production Facility Design

Plant Location: Introduction, Factors affecting location decisions, Multi-facility location

Plant Layout: Principles of Plant layout and Types, factors affecting layout, methods, factors governing flow pattern, travel chart for flow analysis, analytical tools of plant layout, layout of manufacturing shop floor, repair shop, services sectors, and process plant. Layout planning, Quantitative methods of Plant layout and relationship diagrams, Area per Square meter metric. Dynamic plant layout

Material Handling: Objectives and benefits of Material handling, Relationship between layout and Material handling, Equipment selection

Introduction of Value Stream Mapping

Unit 4	Production Planning and Control

Types and methods of Production, and their Characteristics, functions and objectives of Production Planning and Control, Steps: Process planning, Loading, Scheduling, Dispatching and Expediting with illustrative examples, Capacity Planning, Aggregate production planning and Master production scheduling. **Inventory Control**: Introduction to inventory, types of inventory, EOQ (Numericals), concepts, type of Inventory models-deterministic and probabilistic, Selective inventory control, Fundamental of Material Requirement Planning (MRP-I), Manufacturing Resource Planning (MRP-II), Enterprise Resource Planning (ERP), Just-in-Time system (JIT), PUSH and PULL system, Kanban, Inventory analysis methods– ABC, XYZ, HLM, ABC-XYZ blend and Supply Chain Management (SCM),

Books and other resources

Text Books:

1. O. P. Khanna, Industrial engineering and management, Dhanpat Rai publication
2. M Mahajan, Industrial Engineering and Production Management, Dhanpat Rai and Co.
3. Martend Telsang, Industrial Engineering, S. Chand Publication.
4. Banga and Sharma, Industrial Organization& Engineering Economics, Khanna publication.

References Books:

1. Askin, Design and Analysis of Lean Production System, Wiley, India
2. Introduction to Work Study by ILO, ISBN 978-81-204-1718-2, Oxford & IBH Publishing Company, New Delhi, Second Indian Adaptation, 2008.
3. H. B. Maynard, K Jell, Maynard's Industrial Engineering Hand Book, McGraw Hill Education.
4. Zandin K.B., Most Work Measurement Systems, ISBN 0824709535, CRCPress,2002
5. Martin Murry, SAP ERP: Functionality and Technical Configuration, SAP Press.
6. Barnes, Motion and time Study design and Measurement of Work, Wiley India

7. Sumanth, D.J, “Productivity Engineering and Management”, TMH, New Delhi, 1990.
8. Edosomwan, J.A, “Organizational Transformation and Process re- Engineering”, British Cataloging in publications, 1996.
9. Prem Vrat, Sardana, G.D. and Sahay, B.S, “Productivity Management - A systems approach”, Narosa Publications, New Delhi, 1998.
10. Francis, R.L., and White, J.A, “Facilities layout and Location”, Prentice Hall of India, 2002.
11. James A. Tompkins, John A. White, “Facilities Planning”, Wiley, 2013
12. Richard L. Francis, Leon F Mc Ginnes and John A. White, “Facility Layout and Location- An Analytical Approach”, PHI, 1993

Web References:

1. https://archive.nptel.ac.in/courses/112/107/112107143/#
2. https://nptel.ac.in/courses/112107249
3. https://onlinecourses.nptel.ac.in/noc22_me04/preview
4. https://nptel.ac.in/courses/112107292
5. https://nptel.ac.in/courses/112107142

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Board of Studies - Mechanical and Automobile Engineering

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416484A: Artificial Intelligence & Machine Learning					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30 Marks**
				End-Semester	**70 Marks**

Prerequisites: Programming and Problem Solving, Linear Algebra, Probability, Statistics, Logical Reasoning, Automobile Engineering Systems, Numerical and Optimization Methods

Course Objectives:

1. Acquaint with fundamentals of artificial intelligence and machine learning.
2. Learn feature extraction and selection techniques for processing data set.
3. Understand basic algorithms used in classification and regression problems.
4. Outline steps involved in development of machine learning model.
5. Familiarize with concepts of reinforced and deep learning.
6. Implement and Analyze machine learning model in automobile engineering problems.

Course Outcomes:

On completion of the course the learner will be able to;

CO1. **DEMONSTRATE** fundamentals of artificial intelligence and machine learning.
CO2. **APPLY** feature extraction and selection techniques.
CO3. **APPLY** machine learning algorithms for classification and regression problems.
CO4. **DEVISE AND DEVELOP** a machine learning model using various steps.
CO5. **EXPLAIN** concepts of reinforced and deep learning.
CO6. **SIMULATE** machine learning model in automobile engineering problems.

Course Contents

Unit 1	**Introduction to AI & ML**

History of AI, Comparison of AI with Data Science, Need of AI in Mechanical Engineering, Introduction to Machine Learning. Basics: Reasoning, problem solving, Knowledge representation, Planning, Learning, Perception, Motion and manipulation.

Approaches to AI: Cybernetics and brain simulation, Symbolic, Sub-symbolic, Statistical.

Approaches to ML: Supervised learning, Unsupervised learning, Reinforcement learning.

Unit 2	Feature Extraction and Selection
Feature extraction: Statistical features, Principal Component Analysis. **Feature selection:** Ranking, Decision tree - Entropy reduction and information gain, Exhaustive, best first, Greedy forward & backward, Applications of feature extraction and selection algorithms in automobile Engineering.	
Unit 3	**Classification & Regression**
Classification: Decision tree, Random forest, Naive Bayes, Support vector machine. **Regression:** Logistic Regression, Support Vector Regression. **Regression trees:** Decision tree, random forest, K-Means, K-Nearest Neighbor (KNN). Applications of classification and regression algorithms in automobile Engineering.	
Unit 4	**Development of ML Model**
Problem identification: classification, clustering, regression, ranking. Steps in ML modeling, Data Collection, Data pre-processing, Model Selection, Model training (Training, Testing, K-fold Cross Validation), Model evaluation (understanding and interpretation of confusion matrix, Accuracy, Precision, Recall, True positive, false positive etc.), Hyper parameter Tuning, Predictions.	
Unit 5	**Reinforced and Deep Learning**
Characteristics of reinforced learning: Algorithms, Value Based, Policy Based, Model Based; Positive v/s Negative Reinforced Learning; Models: Markov Decision Process, Q Learning. Characteristics of Deep Learning, Artificial Neural Network, Convolution Neural Network. Application of Reinforced and Deep Learning in automobile Engineering.	
Unit 6	**Applications**
Role of AIML in: Autonomous Vehicles (Avs), Electric Vehicles (Evs), Automatic Guided Vehicles (Agvs), Connected Vehicles (Cvs), Motorsports, Vehicle Health Diagnostics, Predictive Vehicle Maintenance, Enhancing Manufacturing, Boosting Sales, Access Control Using Facial Recognition, Auto Parts Design Using Digital Twins, Route Optimization, Computer Vision	

Books and other resources

Text Books:

1. Deisenroth, Faisal, Ong, Mathematics for Machine Learning, Cambridge University Press, 2020.
2. B Joshi, Machine Learning and Artificial Intelligence, Springer, 2020.
3. Parag Kulkarni and Prachi Joshi, "Artificial Intelligence – Building Intelligent Systems", PHI learning Pvt. Ltd., ISBN – 978-81-203-5046-5, 2015
4. Stuart Russell and Peter Norvig (1995), "Artificial Intelligence: A Modern Approach," Third edition, Pearson, 2003.
5. Eliot, L., & Eliot, M. (2017). Autonomous vehicle driverless self-driving cars and artificial intelligence: Practical advances in AI and machine learning. LBE Press Publishing.
6. Fernández-López, A., Fernández-Castro, B., & García-Coego, D. (2022). ML & AI Application for the Automotive Industry. In Machine Learning and Artificial Intelligence with Industrial Applications (pp. 79-102). Springer, Cham.
7. Ranjan, S., & Senthamilarasu, S. (2020). Applied Deep Learning and Computer Vision for Self-Driving Cars: Build autonomous vehicles using deep neural networks and behavior-cloning techniques. Packt Publishing Ltd.

References Books:

1. Solanki, Kumar, Nayyar, Emerging Trends and Applications of Machine Learning, IGI Global, 2018.
2. Mohri, Rostamizdeh, Talwalkar, Foundations of Machine Learning, MIT Press, 2018.
3. Kumar, Zindani, Davim, Artificial Intelligence in Mechanical and Industrial Engineering, CRC Press, 2021.
4. Zsolt Nagy - Artificial Intelligence and Machine Learning Fundamentals-Apress (2018)
5. Artificial Intelligence by Elaine Rich, Kevin Knight and Nair, TMH

Web References:

1. http://nptel.ac.in/courses/111101003/
2. https://nptel.ac.in/courses/106/106/106106202/
3. https://nptel.ac.in/courses/112/103/112103280/
4. https://www.analyticsvidhya.com/

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Undergraduate Program – Final Year Automobile Engineering (2019 pattern)

<table>
<tr><th colspan="6">416484B: Automotive Control Systems</th></tr>
<tr><th colspan="2">Teaching Scheme</th><th colspan="2">Credits</th><th colspan="2">Examination Scheme</th></tr>
<tr><td>Theory</td><td>3 Hrs./Week</td><td>Theory</td><td>3</td><td>In-Semester</td><td>30 Marks</td></tr>
<tr><td></td><td></td><td></td><td></td><td>End-Semester</td><td>70 Marks</td></tr>
<tr><td colspan="6">Prerequisites: Systems in Mechanical Engineering, Programming and Problem Solving, Basic Electronics Engineering, Electrical and Electronics Engineering, Automobile Electrical and Electronics</td></tr>
<tr><td colspan="6">Course Objectives:
1. The students can learn basic knowledge about control system and automotive systems.
2. The students able to impart the response of a system and its stability concepts.
3. The students can know the modeling of physical systems.
4. The student will be well versed in the recent trends of automotive systems</td></tr>
<tr><td colspan="6">Course Outcomes:
On completion of the course the learner will be able to;
CO1. IMPART basic knowledge about the open loop and close system and modeling of a system
CO2. ACQUIRE the different order of a system with response and its stability concepts.
CO3. ANALYZE the PID controller and design a system with lead and lag compensator
CO4. DEVELOP the state space model for automotive systems
CO5. ANALYZE the model of vehicle control system
CO6. UNDERSTAND modern automotive systems and its requirements.</td></tr>
<tr><td colspan="6">Course Contents</td></tr>
<tr><td>Unit 1</td><td colspan="5">Introduction</td></tr>
<tr><td colspan="6">Open loop and closed loop systems-Transfer function of elements - Modeling of physical systems - Mechanical systems - Translational and Rotational systems - Thermal systems - Introduction to Block Diagrams - Signal Flow Graphs.</td></tr>
<tr><td>Unit 2</td><td colspan="5">System Response</td></tr>
<tr><td colspan="6">First order, Second order control system response for Step, Ramp and Impulse inputs - Characteristic Equation, Poles and Zeroes concept.</td></tr>
<tr><td>Unit 3</td><td colspan="5">Stability Analysis</td></tr>
<tr><td colspan="6">Stability analysis- Routh Hurwitz stability criteria – stability in the frequency domain –gain and phase margins</td></tr>
</table>

Unit 4	Control System Design
Proportional, Integral, Derivative controllers, P, PI, and PID control - Design in the frequency domain- lead, lag compensator design	
Unit 5	**Modeling of Physical Systems**
Fundamentals of State Space representation - State Models .Modeling of Suspension System Power steering System	
Unit 6	**Vehicle Control System**
ABS control systems –control of yaw dynamics – engine model for lambda control - knock control	

Books and other resources

Text Books:

1. Uwe Kiencke and Lars Nielsen, "Automotive Control Systems: For Engine, Driveline, and Vehicle", 2nd Edition, Springer, 2010

References Books:

1. I.J. Nagrath and M. Gopal, "Control Systems Engineering", 4th Edition, New Age International (P) Limited, 2006
2. Norman S. Nise, "Control Systems Engineering", 6th Edition, Wiley, 2010
3. Katsuhiko Ogata, "Modern Control Engineering", 5th Edition, Prentice Hall, 2009

402044E: Internet of Things**					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30 Marks**
				End-Semester	**70 Marks**

Prerequisites: Systems in Mechanical Engineering**,** Programming and Problem Solving, Basic Electronics Engineering, Solid Mechanics, Solid Modeling and Drafting, Electrical and Electronics Engineering, Mechatronics, Measurement Laboratory, Fluid Power & Control Laboratory

Course Objectives:

5. Introduction to IoT, Overview of IoT Building Blocks
6. Build small applications in IoT for Mechanical Engineering Applications using Sensors, Actuators, Microcontrollers and Cloud
7. Learn commonly used IoT Simulation Hardware platforms
8. Understand different Communication Technologies used in IoT
9. Development of application level protocol and Security of IoT Ecosystem
10. Understand IoT applications in different domains

Course Outcomes:

On completion of the course the learner will be able to;

CO1. **EXPLAIN** the Applications/Devices, Protocols and Communication Models of IoT
CO2. **DEMONSTARTE** small Mechanical Engineering IoT oriented applications using Sensors, Actuators, Microcontrollers and Cloud
CO3. **SELECT** commonly used IoT Simulation Hardware platforms
CO4. **APPLICATION** of Interfacing and Communication Technologies for IoT
CO5. **ILLUSTRATE** IoT Application Development and Security of IoT Ecosystem
CO6. **EVALUATE** Present and Future Domain specific Applications of IoT Ecosystem

Course Contents

Unit 1	**Introduction to the Internet of Things (IoT)**

Overview, History, Definition and Characteristics, Connectivity Terminologies, Building blocks, Types of technologies used in IoT System, Baseline Technologies (Machine-to-Machine (M_2M) communications, Cyber-Physical-Systems (CPS)), IoT Vs M_2M, IoT enabled Technologies, IoT Levels and Templates, Design Methodology, The Physical Design Vs Logical Design of IoT, Functional blocks of IoT and Communication Models/Technologies, Development Tools used in IoT, IoT Architecture and Protocols, Various Platforms for IoT, Real time Examples of IoT, Challenges in IoT, The process flow of an IoT application, Evolution of Connected Devices,

Applications of IoT, IoT Enablers, Overview of Governance, Privacy and Security Issues.	
Unit 2	**Sensors, Actuators and Microcontrollers**
Measuring physical and virtual quantities in digital world, Overview of Sensors working,Analog Vs Digital Sensors, Wired Vs Wireless Sensors, Types of Sensors, Types of Converters Types of Transducers and Actuator, Controlling Hardware, Types of Controller, Role of microcontroller as gateway to interfacing sensors and actuators, Microcontroller Vs Microprocessor, Type of microcontrollers in embedded System	
Unit 3	**IoT Simulation Environment Hardware platforms and Endpoint Interfacing**
IoT supported Hardware platforms: Introduction to IoT Simulation Environment and Devices (Raspberry Pi, Espressif Processors, Arduino), Architecture, Setup, IDE, Installation, Interfaces (serial, SPI, I_2C), Programming with focus on interfacing for reading input from pins,connecting external gadgets/sensors/actuators, Controlling and Displaying Output, Libraries, Basics of Embedded C programming **Interfacing:** Interfacing Input, Intermediate, Output and Display Sensors, Converters, Actuators, Controlling Hardware, Controllers and Network Devices, **IoT Architecture:** Building architecture and Open source architecture (OIC), Main design principles and needed capabilities, An IoT architecture outline, Standards Considerations	
Unit 4	**Interfacing and Communication for Building IoT Applications**
Communication: Overview and Working of Controlled Systems, Connectivity models - TCP/IP Vs OSI model, IoT Communication Models, IoT Communication APIs, Serial Vs Parallel Communication, Wires Vs Wireless Communication, their Technologies and Hardware **IoT Communication Protocols:** Protocol Standardization for IoT, Role of M_2M in IoT, M_2M Value Chains, IoT Value Chains, M_2M and WSN Protocols (SCADA and RFID) **Physical Servers and Cloud Platforms:** Web server, Posting sensor(s) data to web server, Introduction to Cloud Storage models and Communication APIs Webserver, API Virtualization concepts and Cloud Architecture, Advantages and limitations of Cloud computing, IoT Cloud platforms, Cloud services	
Unit 5	**IoT Application Development and Security of IoT Ecosystem**
Application Protocols: MQTT, REST/HTTP, SQL Back-end Application Designing (Designing with Apache, MySQL, HTML, CSS), Non SQL Back-end Application Designing (MongoDB Object Type Database, jQuery for UI Designing), JSON lib for data processing **Security:** Need of security in IoT, Security & Privacy during development, Privacy for IoT	

enabled devices, IoT security for consumer devices, Security levels, protecting IoT devices, Security, Privacy and Trust in IoT-Data-Platforms

Unit 6	**Present and Future Domain specific Applications of IoT Ecosystem**

IoT applications for industry: Future Factory Concepts, Brownfield IoT, Smart Objects, Smart Applications. Study of existing IoT platforms /middleware, Business, Manufacturing, Smart Homes/Home automation, Surveillance applications, Connected Vehicles, Agriculture, Healthcare, Activity Monitoring, Retail, Logistics, Security, Health and Lifestyle, Legal challenges, IoT in Environmental Protection Modern Day IoT Applications, Smart Grid, Smart Cities - Security,Privacy and Trust in IoT-Data-Platforms for Smart Cities, First Steps Towards a Secure Platform, Smartie Approach. Data Aggregation for the IoT in Smart Cities

Future: Future IoT ecosystem, Need of powerful core for building secure algorithms, Examples for new trends (AI, ML penetration to IoT)

Books and other resources

Text Books:

1. Bahga, A. and Madisetti, V., (2015), "Internet of Things - A Hands-on Approach," Universities Press, ISBN: 9788173719547
2. Hajjaj, S S H. and Gsangaya, K. R., (2022), "The Internet of Mechanical Things: The IoT Framework for Mechanical Engineers," CRC Press, ISBN: 9781032110950
3. Raj, P. and Raman, A. C., (2017), "The Internet of Things: Enabling Technologies, Platforms, and Use Cases," Auerbach Publications/CRC Press, ISBN: 9781498761284
4. Adrian McEwen, A. and Cassimally, H., (2013), "Designing the Internet of Things," John Wiley and Sons, ISBN:
5. Veneri, G., Capasso, A., (2018), "Hands-On Industrial Internet of Things: Create a powerful Industrial IoT infrastructure using Industry 4.0," Packt Publishing, ISBN: 9781789537222
6. Hersent, O, Boswarthick, D., Elloumi, O., (2012), "The Internet of Things: Key Applications and Protocols", Wiley, ISBN: 9781119994350
7. Uckelmann, D., Harrison, M., Michahelles, F., (2011), "Architecting the Internet of Things," Springer, ISBN: 9781119994350

References Books:

1. daCosta, F., (2013), "Rethinking the Internet of Things: A Scalable Approach to Connecting Everything", Apress Publications, ISBN: 9781430257417
2. Waher, P., (2015), "Learning Internet of Things," Packt Publishing, ISBN: 9781783553532
3. Ovidiu, V. and Friess, P., (2014), "Internet of Things - From Research and Innovation to Market Deployment," River Publishers, ISBN: 9788793102941, https://www.riverpublishers.com/pdf/ebook/RP_E9788793102958.pdf
4. Ida, N., (2020), "Sensors, Actuators and Their Interfaces," SciTech Publishers, ISBN: 9781785618352
5. Pfister, C., (2011), "Getting Started with the Internet of Things," O'Reilly Media, ISBN:

9781449393571
6. Wallace, S., Richardson, M., Wolfram Donat, W., (2021), "Getting Started With Raspberry Pi: Getting to Know the Inexpensive ARM-Powered Linux Computer," Make Community, LLC, ISBN: 9781680456998
7. Elangovan, U., (2019), "Smart Automation to Smart Manufacturing: Industrial Internet of Things," Momentum Press, ISBN: 9781949449266
8. Jha, S., Tariq, U., Joshi, G. P., Solanki, V. K., (2022), "Industrial Internet of Things: Technologies, Design, and Applications," CRC Press, ISBN: 9780367607777
9. Schwartz, M., (2016), "Internet of Things with Arduino Cookbook," Packt Publishing, ISBN: 9781785286582
10. Kurniawan, A., (2019), "Internet of Things Projects with ESP32: Build exiting and powerful IoT projects using the all-new Expresif ESP32," Packt Publishing, ISBN: 9781789956870

Web References:

1. https://nptel.ac.in/courses/106105166
2. https://www.udemy.com/internet-of-things-iot-for-beginners-getting-started/
3. http://playground.arduino.cc/Projects/Ideas
4. http://www.megunolink.com/articles/arduino-garage-door-opener
5. http://www.willward1.com/arduino-wifi-tutorial
6. http://www.toptechboy.com/arduino-lessons
7. https://www.eprolabs.com
8. http://www.makeuseof.com/tag/pi-overdose-heres-5-raspberry-pi-alternatives

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Automobile Engineering (2019 pattern)

416485A: Finite Element Analysis					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30**
Practical	**2 Hrs./Week**	**Practical**	**1**	**End-Semester**	**70**
				Practical	**50**

Prerequisites: Solid Mechanics, Numerical and Optimization Methods, Engineering Mathematics, Manufacturing Processes, Fluid Mechanics, Heat and Mass Transfer.

Course Objectives:

1. To understand the basic concepts and working of finite element analysis
2. To nurture students about the discretization process and criteria for quality mesh.
3. To understand the approaches of Finite Element Method (FEM) and to find displacement and stresses over the body.
4. To develop the knowledge and skills needed to effectively evaluate the results using Finite Element Analysis (FEA).
5. To apply computational technique to solve complex solid mechanics problems and its loading states.
6. To study the applications of FEA in the various domains of the Mechanical Engineering.

Course Outcomes:

On completion of the course, learner will be able to

CO1: **EXPLAIN** the working of finite element analysis.

CO2: **APPLY** material properties and boundary condition to **SOLVE** 1D- stiffness matrices to obtain nodal or elemental solution.

CO3: **APPLY** material properties and boundary condition to **SOLVE** 2-D element stiffness matrices to obtain nodal or elemental solution.

CO4: **ANALYZE** the results obtained and Factors influencing the results

CO5: **EXPLAIN** the fundamentals of non-linear analysis

CO6: **EVALUTE** Thermal and Dynamic Analysis problems

Course Contents

Unit 1	**Introduction of FEA**

Review of Solid Mechanics: Stress- strain at a point, Differential Equations of Equilibrium, Stress-strain equations, strain-displacement equations

Introduction of FEA: Brief History of FEM, general fem procedure, applications of fem in various field, advantages and disadvantages of fem, difference between FEM and FDM consistent units system, approximate methods of solving differential equations, weighted residual method (Galerkin method, least square method, collocation and subdomain method), variation method (Ritz method).

Unit 2	**1D Elements**

Introduction to different approaches used in FEA such as direct approach, variational approach, weighted residual (Galerkin) for 1D elements. Types of 1D element. Displacement function, Global and local coordinate systems, Order of element, primary and secondary variables, shape functions and its properties. **Bar, Beam and Truss Element** - Element stiffness matrix, Assembling stiffness Equation, Load vector, and stress and reaction forces calculations.	
Unit 3	**2D Elements**
Types of 2D elements, Plane Stress, Plane Strain, axi-symmetric problems in 2D elasticity. Constant Strain Triangle (CST) - Element Stiffness matrix, Assembling stiffness equation, Load vector, Stress and reaction forces calculations. Shape function of Linear Strain Triangle (LSR) and Linear Strain Rectangle (LSR), compression of 2D elements.	
Unit 4	**Meshing and Result Refinement**
Modelling techniques**,** 1D, 2D, 3D, axisymmetric elements, Element selection criteria, Meshing- Effect of mesh density, Refining Mesh, Element Quality Criterion:-Jacobian, Aspect ratio, Warpage, Minimum and Maximum angles, Average element size, Minimum Length, skewness, Tetra Collapse etc., priori and posteriori error estimate, adaptive mesh refinement, Convergence of solution.	
Unit 5	**Introduction to Non-Linear analysis**
Non-Linear Analysis: Introduction to Nonlinear Problems, Comparison of Linear and Nonlinear analysis, Types of Nonlinearities, Stress-strain measures for Nonlinear analysis, Analysis of Geometric, Material Nonlinearity Nonlinear equation solving procedure - direct iteration, Newton- Raphson method, modified Newton-Raphson method, incremental techniques.	
Unit 6	**Thermal and Dynamic Analysis problems**
1D Steady State Heat Transfer Problems: Introduction, Governing differential equation, steady-state heat transfer formulation of 1D element for conduction and convection problem, boundary conditions and solving for temperature distribution. **Dynamic Analysis:** General dynamic equation of motion, point and distributed mass, lumped and Consistent mass, Mass matrices formulation of bar element, natural frequency of Undamped-free vibration	

Books

Text Books:

1. S. S. Bhavikatti, Finite Element Analysis, New Age International Publishers, Third Edition, 2015.
2. Chandrupatla T. R. and Belegunda A. D., Introduction to Finite Elements in Engineering, Prentice Hall India, 2002.
3. G Lakshmi Narasaiah, Finite Element Analysis, BS Publications / BSP Books, 2nd edition, 2020.
4. J. N. Reddy, An Introduction to the Finite Element Method, Mcgraw Hill Series in Mechanical, 2005.
5. P. Seshu, Text book of Finite Element Analysis, PHI Learning Private Limited, New Delhi, 10th Printing, 2012.
6. Daryl L. Logan , 'A First Course in the Finite Element Method', Cengage Learning

References Books:

1. K. J. Bathe, Finite Element Procedure, Prentice-Hall of India (P) Ltd., New Delhi, 1996.
2. Cook R. D., Finite Element Modeling for Stress Analysis, John Wiley and Sons Inc, 1995.
3. G.R. Liu S. S. Quek, The Finite Element Method- A Practical Course, Butterworth Heinemann, 2013.
4. Fagan M. J., Finite Element Analysis Theory and Practice, Harlow Pearson/Prentice Hall, 2012.
5. S. Moaveni, Finite element analysis, theory and application with Ansys, Pearson, Third Edition, 2011.
6. David V. Hutton, Fundamental of Finite Element Analysis, Tata McGraw-Hill, 2017.
7. Mukhopadhyay M and Sheikh A. H., Matrix and Finite Element Analyses of Structures, Ane Books Pvt. Ltd., 2009
8. Daryl L. Logan, A First Course in the Finite Element Method, Fourth Edition, Thomson Canada Limited, 2007.
9. O.C. Zienkiewicz, The Finite Element Method: Its Basis and Fundamentals, Sixth Edition, Elsevier Butterworth-Heinemann, 2005.
10. J. N. Reddy, An Introduction to Nonlinear Finite Element, Oxford University Press-New Delhi, 2014

Web References:

- **https://nptel.ac.in/courses/112/104/112104116/-**for Basics of Finite Element Analysis by Prof.Nachiketa Tiwari, IIT Kanpur
- **https://nptel.ac.in/courses/112/106/112106130/**for Advanced Finite Element Analysis by Dr. R. Krishnakumar, Department of Mechanical Engineering, IIT Madras
- **https://nptel.ac.in/courses/112/103/112103299/**for Finite Element Analysis for Welding Analysis by Prof. Swarup Bag, Department of Mechanical Engineering, IIT Guwahati.

Guidelines for Laboratory Conduction
• The student shall complete the following Practical using any commercial/open-source software • The student shall complete any 8 experiments from 1 to 10 • Practical examination shall be based on the practical undertaken during the semester. 1. 1D Bar Element – Structural Linear Analysis 2. Truss Analysis using 1D Element 3. 2D Structural Linear of any Engineering Problem 4. Comparison of FEA results of 2D analysis with varied number of elements and types of elements 5. Static thermal Analysis 6. Coupled Analysis- (Structural + Thermal) 7. Analysis of Machine Component using 3D Elements 8. Non-Linear Analysis of Assembly using Contact Elements 9. Modal Analysis – Spring -Mass system, simply supported/Cantilever beam, etc. 10. Demonstration on advanced applications of FEA, NVH, CFD, Crash, Fatigue, Manufacturing, etc.

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Automobile Engineering (2019 pattern)

416485B: Computational Fluid Dynamics					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30 Marks**
Practical	**2 Hrs./Week**	**Practical**	**1**	**End-Semester**	**70 Marks**
				Practical	**50Marks**

Prerequisites: Mathematics, Physics, Systems in Mechanical Engineering, Engineering Thermodynamics, Applied Thermodynamics, Fluid Mechanics, Numerical & Statistical Methods, Heat & Mass Transfer, Computer Aided Engineering

Course Objectives:

This course "Fundamentals of Computational Fluid Dynamics" is designed with the following objectives in mind:

1. Students should be able to model fluid / heat transfer problems and apply fundamental conservation principles.
2. Students should be able to discretize the governing differential equations and domain by Finite Difference Method.
3. Students should be able to solve basic convection and diffusion equations and understands the role in fluid flow and heat transfer.
4. To prepare the students for career in industry in CAE through use of software tools.
5. To prepare the students for research leading to higher studies

Course Outcomes:

On completion of the course the learner will be able to;

CO1. **DISTINGUISH** and **ANALYSE** the governing equations of fluid mechanics and heat

CO2. **EXPLAIN** different types of Discretization Techniques

CO3. **ANALYZE** and **MODEL** the 2D heat conduction problem

CO4. **APPLY** the numerical method to solve Convection – Diffusion system

CO5. **EVALUATE** the Incompressible fluid flow problem using Navier-Stoke's equation

CO6. **USE** a CFD tool effectively for practical problems and research.

Course Contents	
Unit 1	**Introduction to Computational Fluid Dynamics**
Introduction to Computational Fluid Dynamics, CFD as a research and design tool, Applications in various branches of Engineering, Derivation and physical interpretation of governing equations (conservation of mass, momentum and energy) in differential form, Concept of substantial derivative, divergence and curl of velocity, Mathematical behavior of Governing Equations and boundary conditions, Discretization methods for the CFD (FDM, FVM, FEM, Hybrid Methods), Intro to Meshless Methods, Meshed Vs Meshless Methods	
Unit 2	**Basic Discretization Techniques**
Introduction to grid generation (Types of grids such as structured, unstructured, hybrid, multiblock, Cartesian, body fitted and polyhedral etc.), Need to discretize the domain and governing equations, Finite difference approximation using Taylor series, for first order (Forward Difference Approximation, Backward Difference Approximation, Centraldifference Approximation) and second order (based on 3 node, 4 node and 5 node points),explicit and Implicit approachesapplied to 1D transient conduction equation, Couette flow equation ($\partial p/\partial x = 0$) using FTCS and Crank Nicholson's Method, Stability Criteria concept and physical interpretation, Thomas Tri-diagonal matrix solver	
Unit 3	**Two Dimensional Steady and unsteady heat conduction**
Solution of two dimensional steady and unsteady heat conduction equation with Dirichlet, Neumann, robbins and mixedboundary condition – solution by Explicit and Alternating Direction Implicit method (ADI Method), Approach for irregular boundary for 2D heat conduction problems.	
Unit 4	**Application of Numerical Methods to Convection – Diffusion system**
Convection: first order wave equation solution with upwind, Lax–Wendroff, Mac Cormack scheme, Stability Criteria concept and physical interpretation Convection –Diffusion: 1D and 2D steady Convection Diffusion system – Central difference approach, Peclet Number, stability criteria, upwind difference approach, 1 D transient convection-diffusion system	
Unit 5	**Incompressible fluid flow**
Solution of Navier-Stoke's equation for incompressible flow using SIMPLE algorithms and its variation (SIMPLER), Application to flow through pipe, Introduction to finite volume method.	
Unit 6	**CFD as Practical approach**
Introduction to any CFD tool, steps in pre-processing, geometry creation, mesh generation, selection of physics and material properties, specifying boundary condition, Physical Boundary condition types such as no slip, free slip, rotating wall, symmetry and periodic, wall roughness, initializing and solution control for the solver Residuals, analyzing the plots of various parameters (Scalar and Vector contours such as streamlines, velocity vector plots and animation). Introduction to turbulence models. Reynolds Averaged Navier-Stokes equations (RANS), k-ϵ, k-ω. Simple problems likeflow inside a 2-D square lid driven cavity flow through the nozzle.	

Books and other resources

Text Books:

1. Ghoshdastidar, P. S. (2017), "Computational Fluid Dynamics and Heat Transfer," Cengage learning, ISBN: 9788131533079
2. Atul Sharma, A., (2016), "Introduction to Computational Fluid Dynamics: Development, Application and Analysis," Wiley, ISBN: 9781119002994
3. Versteeg, H. K., Malalasekhara, W., (2007), "An Introduction to Computational Fluid Dynamics: The Finite Volume Method," PHI, ISBN: 9780131274983
4. Muralidharan, K., Sundarajan , T., (2009), "Computational Fluid Flow and Heat Transfer," Narosa Pub, ISBN: 9788173195228
5. Rao, J.S., (2017), "Simulation Based Engineering in Fluid Flow Design," Springer, ISBN: 9783319463810
6. Anderson, Jr., D. A. A (2017), "Computational Fluid Dynamics - the Basics with Applications," , McGraw Hill Education, ISBN: 9781259025969
7. Jaiman, R. K. and Joshi, V., (2022), "Computational Mechanics of Fluid-Structure Interaction: Computational Methods for Coupled Fluid-Structure Analysis," Springer, ISBN: 9789811653544

References Books:

1. Thompson, J. F., Soni, B. K., Weatherill, N. P., (1998), "Handbook of Grid Generation," CRC Press, ISBN: 9780849326875
2. Ferziger, J. H., Perić, M., Street, R. L., (2019), "Computational Methods for Fluid Dynamics,"Springer, ISBN: 9783319996912
3. Pletcher, R.H., Tannehill, J.C., Anderson, D.A., (2012), "Computational Fluid Mechanics and Heat Transfer," CRC Press, ISBN: 9781591690375
4. Patankar, S. V., (2017), "Numerical Heat Transfer and Fluid Flow," CRC Press, ISBN: 9781138564695
5. Chung, T. J., (2014), "Computational Fluid Dynamics," Cambridge University Press, ISBN: 9781107425255
6. Tu, J., Yeoh, G-H. and Liu, C., (2018), "Computational Fluid Dynamics: A practical approach," Butterworth-Heinemann, ISBN: 9780081011270
7. Date, A. W., (2005), "Introduction to Computational Fluid Dynamics," Cambridge University Press, ISBN: 9780521685337
8. Schlichting, H., Gersten, K., (2016), "Boundary-Layer Theory," Springer, ISBN: 9783662529171
9. Tennekes, H. and Lumley, J. L., (2018), "A First Course in Turbulence," The MIT Press, ISBN: 9780262536301
10. Wilcox, D.C., (1998), "Turbulence Modeling for CFD," DCW Industries, ISBN: 9780963605153
11. Paidoussis M. P., Price, S. and de Langre, E., (2011), "Fluid-Structure Interactions: Cross-Flow-Induced Instabilities," Cambridge University Press, ISBN: 9780521119429
12. Bungartz, H-J. and Schäfer, M., (2006), "Fluid-Structure Interaction: Modelling, Simulation, Optimization," Springer, ISBN: 9783540345954

Web References:

1. Singh, K. M., (2019), "Computational Fluid Dynamics," IIT Roorkee, https://nptel.ac.in/courses/112107080
2. Ramakrishna, M., (2019), "Introduction to CFD," IIT Madras, https://archive.nptel.ac.in/courses/101/106/101106045/
3. Roy, A., (2019), "Introduction to CFD," IIT Kharagpur, https://archive.nptel.ac.in/courses/101/105/101105085/
4. Chakraborty, S., (2020), "Computational Fluid Dynamics," IIT Kharagpur, https://archive.nptel.ac.in/courses/112/105/112105254/
5. Chandrasekaran, S., (2019), "Advanced Marine Structures," IIT Madras, https://nptel.ac.in/courses/114106037

Guidelines for Laboratory Conduction

- The student shall complete the following Practical using any commercial/open-source software
- The student shall complete any 8 experiments from 1 to 10
- Practical examination shall be based on the practical undertaken during the semester.

1. Generation of different meshes
   a. Structured mesh
   b. Unstructured mesh,
   c. Multiblock, etc.
2. 1D transient heat conduction by FTCS OR Crank Nicholson scheme
3. 1-D (first order)wave equation by Upwind scheme and study the impact of CFL number on the stability and solution .
4. 2D Transient Conduction equation / 2D Convection-Diffusion Equation
5. Numerical simulation and analysis of boundary layer over a flat plate (Blausius Equation) are using any CFD software or computer programming.
6. Numerical simulation and analysis of boundary layer for
   a). Developing flow through a pipe
   b) Fully developed flow through a pipe.
7. Numerical simulation and analysis of 2D square lid driven cavity using any CFD software. Effect of Reynolds number on the vorticity patterns.
8. CFD Analysis of external flow: Circular Cylinder or Aerofoil (NACA 0012)
9. CFD analysis of heat transfer in pin fin.
10. Mini project on any practical application. Students should take a problem of their choice and verify the CFD solution with experimental data / research paper

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Automobile Engineering (2019 pattern)

416486: Vehicle Maintenance and Service Practice					
Teaching Scheme		**Credits**		**Examination Scheme**	
Practical	**2 Hrs.**	**Practical**	**1**	**Term Work**	**50**

Prerequisites: Applied Thermodynamics, Automotive Electrical and Electronics, Automotive Chassis and Transmission.

Course Objectives:

1. **Understand** basics of wheel alignment and wheel balancing .
2. **Gain** knowledge of tuning procedure of petrol and diesel engins.
3. **Describe** the various methods of wear measurements of engine compoents.
4. **Acquire** the basic knowledge of CNG/LPG kit.
5. **Understand** importance of overhauling.

Course Outcomes:

On successful completion of the course, learner will be able to,

CO1. **CHECK** Wheel Balancing and Wheel Alignment

CO2. **EXAMINE** problems occurred in engine and identify critical inspection parameters by performing engine tune up and overhaul.

CO3. **CARRY** out wear measurement of engine components and engine compression and vacuum testing.

CO4. **DEMONSTRATE** working of CNG/LPG kit.

CO5. **EXECUTE** overhauling of Clutch, Gearbox, differential, axle and braking system.

Course Contents

The student shall complete the following activity as a Term Work.

Practical: (From below list of experiments, Sr. No 01 to 07 & 12 is compulsory and any 2 experiments from Sr. No 08 to 11)

1. Check and adjust wheel alignment by using computerized wheel alignment machine.
2. Check and adjust wheel balancing by using computerized wheel balancing machine.
3. Demonstration and hands on practice of Petrol / Diesel engine tune up.
4. Demonstration and hands on practice of Engine top overhaul
5. Inspection & wear measurement of engine components.
6. Engine cylinder compression & vacuum testing.
7. Demonstration of CNG/LPG kit.
8. Demonstration and hands on practice of Overhauling of clutch.
9. Demonstration and hands on practice of Overhauling of gear box.
10. Demonstration and hands on practice of Overhauling of differential & axle.
11. Demonstration and hands on practice of Overhauling of braking system.
12. Visit to fuel injection pump & injector testing station.

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<table>
<tr><th colspan="6">416487: Project (Stage I)</th></tr>
<tr><th colspan="2">Teaching Scheme</th><th colspan="2">Credits</th><th colspan="2">Examination Scheme</th></tr>
<tr><td>Practical</td><td>4 Hrs./Week</td><td>Practical</td><td>2</td><td>Term Work</td><td>50 Marks</td></tr>
<tr><td></td><td></td><td></td><td></td><td>Oral</td><td>50 Marks</td></tr>
<tr><td colspan="6">Prerequisites: Project Based Learning, Internship/Mini Project, Laboratory works, Audit Courses</td></tr>
<tr><td colspan="6">Course Objectives:
1. To provide an opportunity of designing and building complete system or subsystems based on areas where the student likes to acquire specialized skills.
2. To obtain hands-on experience in converting a small novel idea / technique into a working model / prototype involving multi-disciplinary skills.
3. To embed the skill in a group of students to work independently on a topic/ problem/ experimentation selected by them and encourage them to think independently on their own to bring out the conclusion under the given circumstances of the curriculum period in the budget provided with the guidance of the faculty.
4. To encourage creative thinking processes to help them to get confidence by planning and carrying out the work plan of the project and to successfully complete the same, through observations, discussions and decision making process.
5. To get visibility in industry to Project and Project group</td></tr>
<tr><td colspan="6">Course Outcomes:
On completion of the course the learner will be able to;
CO1. Implement systems approach.
CO2. To conceptualize a novel idea / technique into a product.
CO3. To think in terms of a multi-disciplinary environment.
CO4. To take on the challenges of teamwork, and document all aspects of design work.
CO5. To understand the management techniques of implementing a project.</td></tr>
<tr><td colspan="6">Course Contents</td></tr>
<tr><td colspan="6">Project work in the seventh semester is an integral part of the TW work. The project work shall be based on the knowledge acquired by the student during the graduation and preferably it should meet and contribute towards the needs of the society.
Project work shall be based on any of the following:
1. Fabrication of product/ testing setup of an experimentation unit/ apparatus/ small equipment, in a group.
2. Experimental verification of principles used in Mechanical Engineering Applications.
3. Projects having valid database, data flow, algorithm, and output reports, preferably software based.</td></tr>
</table>

4. Study projects are strictly allowed.

Project Lab

1. There has to be a **Project Lab** in the department.
   a. It consists of necessary tools required to do a project.
   b. Previous projects and their components.
   c. Common measuring instruments.
   d. Previous years' project reports.
   e. Project related books and Publications.
   f. Proper linkage with central workshop and various laboratories.
   g. Safety measures.

2.All the project activities must be handled with a digital platform which is developed in the department according to the policies laid down by the institution. Respective authority levels created to maintain the transparency and confidentiality.

Books and other resources

References Books:

- Dissertations and Project Reports: A Step by Step Guide by Dr Stella Cottrell.

Web References:

1. SWAYAM-NPTEL Course.
2. MOOCs' Courses.

Guidelines for Project Execution:

At the end of the 6th Semester

1. Students will make groups according to their suitability.
2. Department faculty will float prospective Project Titles through Project Coordinator.
3. Department will take care of a list of titles at least two times of the groups.
4. Students will interact with guides for scope and outline of the project.
5. Maximum of two groups will be given to a guide.
6. Guide and Project groups will be finalized at the end of sixth semester so that project work can be started at the start of Seventh semester.

During the 7th Semester

1. Project work is expected to be done in the Project Lab.
2. Projects must be executed in association with industrial experts/facilities.
3. Progress of project work is monitored regularly on weekly project slots/project day.
4. Regular interval presentations are to be arranged to review and assess the work.
5. Project work is monitored and continuous assessment is done by guide and authorities.

Term Work:

- The student shall prepare the duly certified final report of project work in standard format for satisfactory completion of the work by the concerned guide and head of the Department/Institute.
- Recommended performance measure parameters may Include-Problem definition and scope

of the project, Literature Survey, Appropriate Engineering approach used, Exhaustive and Rational Requirement Analysis,

- Comprehensive Implementation - Design, modeling, documentation, Usability, Optimization considerations (Time, Resources, Costing), Thorough Testing, Project Presentation and Demonstration (ease of use and usability), Social and environment aspects.
- The term work under project submitted by students shall include

1. Work Diary: Work Diary maintained by group and countersigned by the guide weekly. The contents of work diary shall reflect the efforts taken by project group for

a. Searching suitable project work
b. Brief report preferably on journals/ research or conference papers/ books or literature surveyed to select and bring up the project.
c. Brief report of feasibility studies carried to implement the conclusion.
d. Rough Sketches/ Design Calculations
e. Synopsis

- The group should submit the synopsis in the following form.

i. Title of Project
ii. Names of Students
iii. Name of Guide
iv. Relevance
v. Present Theory and Practices
vi. Proposed work
vii. Expenditure
viii. References

- The synopsis shall be signed by each student in the group, approved by the guide (along with external guide in case of sponsored projects) and endorsed by the Head of the Department
- Presentation: The group has to make a presentation in front of the faculty of department at the end of semester.

Examination Scheme:

- During university examination internal examiner (preferably the guide) and External examiners jointly, evaluate the project work.
- During the process of monitoring and continuous assessment & evaluation the individual and team performance is to be measured.
- The project term work shall be evaluated on the basis of reviews. In first semester two reviews are to be taken and evaluated for total 30 marks (15 marks each)
- Review 1 and 2 will be based on synopsis submission (team members, Title of the Project Work, abstract, Problem Definition, work done earlier, Objectives of the Project,Methodology of the Project, Application / Significance of the Project, Duration of theProject, Individual Role of the Student, References, sponsored etc.)
- The final presentation shall be taken in front of external examiner and to be evaluated for 40 marks
  - 10 marks for presentation for group,
  - 15 marks for quality of the project work.
  - 15 marks for quality of the project report

Project Report
• Stage I report shall be in the booklet form. • Plagiarism check is must, and certificate shall be attached in the report.
References: • References format MUST BE STANDARD – ASME, SAE or IEEE,AIS

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416488: Audit Course VII				
Teaching Scheme		**Credits**	**Examination Scheme**	
		Non- Credit		

GUIDELINES FOR CONDUCTION OF AUDIT COURSE

Faculty mentor shall be allotted for individual courses and he/she shall monitor the progress for successful accomplishment of the course. Such monitoring is necessary for ensuring that the concept of self-learning is being pursued by the students 'in true letter and spirit'

- If any of the following listed course is selected through Swayam/ NPTEL/ virtual platform, the minimum duration shall be of 8 weeks.
- However if any of the course duration is less than the desired (8 weeks) the mentor shall ensure that other activities in form of assignments, quizzes, group discussion etc. (allied with the course) for the balance duration should be undertaken.
- Students can join any online platform or can participate any online/offline workshop to complete the Audit course with prior-permission of mentor.

In addition to credits courses, it is mandatory that there should be an audit course (non-credit course) from Final year of Engineering. The student will be awarded grade as AP on successful completion of the audit course. The student may opt for any one of the audit courses in each semester. Such audit courses can help the student to get awareness of different issues which make an impact on human lives and enhance their skill sets to improve their employability. List of audit courses offered in the semester is provided in the curriculum. Students can choose one of the audit courses from the list of courses mentioned. Evaluation of the audit course will be done at institute level. The student registered for audit course shall be awarded the grade AP and shall be included such grade in the Semester grade report for that course, provided student has the minimum attendance as prescribed by the Savitribai Phule Pune University and satisfactory in-semester performance and secured a passing grade in that audit course. No grade points are associated with this 'AP' grade and performance in these courses is not considered in the calculation of the performance indices SGPA and CGPA. Evaluation of the audit course will be done at institute level itself

List of Courses to be opted (Any one) under Audit Course VII
A. Yoga Practices **B. Stress Management** **C. Indian Philosophy** Note:-The title indicated above are subject to change in time to come and such an alteration (if any) should be brought to the notice of the BoS.
Using NPTEL Platform: (preferable)
NPTEL is an initiative by MHRD to enhance learning effectiveness in the field of technical education by developing curriculum based video courses and web based e-courses. The details of NPTEL courses are available on its official website www.nptel.ac.in • Students can select any one of the courses mentioned above and has to register for the corresponding online course available on the NPTEL platform as an Audit course. • Once the course is completed the student can appear for the examination as per the guidelines on the NPTEL portal. • After clearing the examination successfully; student will be awarded with a certificate.
Assessment of an Audit Course
• The assessment of the course will be done at the institute level. The institute has to maintain the record of the various audit courses opted by the students. The audit course opted by the students could be interdisciplinary • During the course students will be submitting the online assignments/report/course completion certificate etc. A copy of the same can be submitted as a part of term work for the corresponding Audit course. • On the satisfactory submission of assignments/report/course completion certificate etc., the institute can mark as "Present" and the student will be awarded the grade AP on the mark-sheet.

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416489: Hybrid and Electric Vehicle					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30 Marks**
Practical	**2 Hrs./Week**	**Practical**	**1**	**End-Semester**	**70 Marks**
				Term Work	**25 Marks**
				Oral	**25 Marks**

Prerequisites: Applied Thermodynamics, Automotive Electrical and Electronics, Automotive Chassis and Transmission, Automotive Testing and Certification.

Course Objectives:

1. Understand types of hybrid and electric vehicles.
2. Gain knowledge of hybrid electric vehicle.
3. Describe the various methods of electric vehicle propulsion.
4. Acquire the basic knowledge of various energy storage devices.
5. Explain the importance of selecting proper electric drive.
6. Memorize the different types of energy management systems

Course Outcomes:

On completion of the course the learner will be able to; On successful completion of the course, learner will be able to,

CO1. **DESCRIBE** the vehicle with respect to certification and homologation.
CO2. **CLASSIFY** the different hybrid electric vehicle.
CO3. **IDENTIFY** and **EVALUATE** the Prime Movers, Energy Storage and Controllers
CO4. **DESCRIBE** the various methods of energy storage.
CO5. **SELECT** the size of electric drive for particular application
CO6. **OBTAIN** knowledge of energy management systems.

Course Contents

Unit 1 **Introduction to Hybrid and Electric Vehicle**

History and evolution of Electric Vehicles, Comparison of Electric with Internal Combustion Engine Vehicles, Limitations of IC Engine Vehicles (ICEV), Exhaust Emission and Global warming, Environmental importance of Hybrid and Electric Vehicles, Overview of EV Challenges, Classification, Overview of EV Technologies, Advantages and Disadvantages, Economic and Environmental impacts of using Electrical Vehicles, Emerging Technologies for Electric Vehicle Drives, Case Studies of Two-Wheeler, Three-Wheeler, and Four-Wheeler Electric Vehicles.
Brief introduction to Autonomous and self-driving Vehicles

Unit 2	Hybrid Electric Vehicle

Classification of HEV - Architecture, Construction, Working, Advantages and Limitations of Conventional and Gridable HEV, Classification of Conventional HEV, Types of Gridable HEV, Tractive force, Power and Energy requirements for standard drive cycles of HEV

Hybrid Electric Drive-Trains - Basic concept of Hybrid Traction, introduction to various hybrid Drive-Train Topologies, Power flow Control in Hybrid Drive-Train Topologies, Fuel Efficiency Analysis

Control Strategy - Supervisory Control, Selection of Modes

Unit 3	Electric Propulsion

Introduction to electric components used in hybrid and electric vehicles, Configuration and control of DC Motor drives, Configuration and control of Induction Motor drives, configuration and control of Permanent Magnet Motor drives, Configuration and control of Switch Reluctance Motor drives, drive system efficiency

Unit 4	Energy Storage

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

Unit 5	Sizing the Electric Drive

Matching the electric machine and the internal combustion engine (ICE), Sizing the propulsion motor, sizing the power electronics, selecting the energy storage technology, Communications, supporting subsystems.

Unit 6	Energy Management Strategies

Introduction to energy management strategies used in hybrid and electric vehicles, classification of different energy management strategies, comparison of different energy management strategies, implementation issues of energy management strategies, Battery Thermal Management Systems and its types, working and comparison.

Case Studies: Design of a Hybrid Electric Vehicle (HEV), Design of a Battery Electric Vehicle (BEV).

Books and other resources

Text Books:

1. Iqbal Hussein, (2021), "Electric and Hybrid Vehicles: Design Fundamentals," CRC Press, ISBN: 9780367693930
2. Denton, Tom, (2020), "Electric and Hybrid Vehicles," 2nd Ed., Routledge, ISBN:9780367273248
3. John Lowry, James Larminie, (2012), "Electric Vehicle Technology Explained," Wiley, ISBN: 9781119942733
4. Knowles, Don, (2011), "Automotive Suspension & Steering Systems," Cengage learning,ISBN: 9781435481152
5. Malen, Donald E., (2011), "Fundamentals of Automobile Body Structure Design," SAE International, ISBN: 9780768021691
6. R. Krishnan, (2001), "Electric Motor Drives: Modeling, Analysis, and Control," Pearson,ISBN: 9780130910141
7. Mohammad Saad Alam, Reji Kumar Pillai, N. Murugesan, (2021), "Developing Charging Infrastructure and Technologies for Electric Vehicles," IGI Global/ Business Science Reference, ISBN: 9781799868583

References Books:

1. Mehrdad Ehsani, Yimi Gao, Sefano Longo, Kambiz Ebrahimi, (2019), "Modern Electric, Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design," CRC Press, ISBN: 9780367137465AIS- Automotive Industry Standards.
2. Tariq Muneer, Mohan Kolhe, Aisling Doyle, (2017), "Electric Vehicles: Prospects and Challenges," Electric Vehicles: Prospects and Challenges, ISBN: 9780128030219CMVR – Central Motor Vehicle Regulations.
3. Sandeep Dhameja, (2001), "Electric Vehicle Battery Systems,", Newnes, ISBN: 9780750699167Robert Bosch GmbH, Bosch Automotive Handbook
4. Bruno Scrosati, Jürgen Garche, Werner Tillmetz, (2015), "Advances in Battery Technologies for Electric Vehicles," Woodhead Publishing, ISBN: 9781782423775A.J.Martyr, M.A.Plint, Engine Testing Theory and Practice, SAE International, Third Edition, 2007.
5. Shunli Wang, Carlos Fernandez, Yu Chunmei, Yongcun Fan, Cao Wen, Daniel-Ioan Stroe, Zonghai Chen, (2021), "Battery System Modeling," Elsevier, ISBN: 9780323904728
6. Andrea, Davide, (2010), "Battery management systems for large lithium battery packs,"Artech House Publishers, ISBN: 9781608071043

Web References:

1. https://archive.nptel.ac.in/courses/108/103/108103009/
2. https://archive.nptel.ac.in/courses/108/106/108106170/
3. https://archive.nptel.ac.in/courses/108/102/108102121/
4. https://archive.nptel.ac.in/courses/108/106/108106182/

Guidelines for Laboratory Conduction

- The student shall complete the following Practical as a term work
- The student shall complete any 9 experiments from 1 to 12

1. Study of basic components of e-vehicles.
2. Study of basic components of hybrid vehicles.
3. Battery capacity calculations for specific application using any simulation/mathematical tool.
4. Study and verification active and passive cell balancing (using suitable simulation).
5. Battery connections for discharge system (using suitable simulation).
6. Experiment/Simulation for AC-DC, DC-DC, Speed Control using electric motor.
7. Battery pack performance characteristics (To know the variation of time with various battery working parameters).
8. Determination of suitable wire size for specific capacity of motor.
9. Study of different wire harnessing for e-vehicle.
10. Study of Battery Management System.
11. Study of Battery Thermal Management System.
12. Case study of 2/3/4 wheeler e-vehicle/hybrid vehicle.

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416490: Automotive System Design					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30 Marks**
Practical	**2 Hrs./Week**	**Practical**	**1**	**End-Semester**	**70 Marks**
				Term Work	**25 Marks**
				Oral	**25 Marks**

Prerequisites: Engineering Mathematics, Engineering Graphics, Solid Mechanics, Engineering Materials, Automotive Chassis and Transmission.

Course Objectives:

Course Objectives:- This course "Automotive System Design" is designed with the following objectives in mind:

1. The Students shall be able to select proper material for automotive components as per application.
2. The student shall gain appreciation and understand the design function in Automobile Engineering, steps involved in designing of various parts like clutch, gearbox, propeller shaft, axles, suspension etc.
3. The Students shall be able to choose proper materials for different vehicle components depending on their physical and mechanical properties

Course Outcomes:

CO1. **ANALYZE** the vehicle design requirements of various components and system.
CO2. **EVALUATE** the design equations based on strength criteria for different automotive components.
CO3. **DECIDE** optimum design parameters for automotive systems.
CO4. **DESIGN** Automotive Components and Automotive systems.
CO5. **ENHANCEMENT** of proficiency in manual as well as computer aided drafting, design & analysis.

Course Contents

Unit 1	**Design of Clutch**

Material selection for Clutch lining, material property, Design requirements of friction clutches, selection criterion, torque transmission capacity, Design of single plate clutch, multi-plate clutch and centrifugal clutch, Advances in Automotive Clutch.

Unit 2	Design of Gearbox
Selection of material for gears and gearbox housing, material properties and specification, Selection of gear ratios and final drive ratio, numerical on 3- speed and 4- speed gearbox, Epicycle gear box, and numerical treatment on epicycle gearbox	
Unit 3	**Design of Propeller Shafts and Axles**
Material selection for propeller shaft, universal joint and final drive, Design of propeller shafts for bending, torsion and rigidity, Design of universal joints and slip joints, final drive, Design of live and dead axles.	
Unit 4	**Design of braking systems**
Material selection for brake lining material, brake oil properties, Design of hydraulic braking system, internal expanding shoe brake and disc brake, design of master and wheel cylinder and piping design, braking force calculation, Hand brake.	
Unit 5	**Design of Suspension and Steering System**
General design considerations of suspension system, Material selection for leaf spring and helical spring, design of helical and leaf springs for automobile suspension system, design considerations of Belleville springs, elastomeric springs, design considerations of steering system and vehicle frame design.	
Unit 6	**Statistical Consideration in Design and Optimization**
Ergonomics and aesthetic design, statistics in design, design for natural tolerances, statistical analysis, and mechanical reliability, introduction to design optimization of mechanical elements, adequate and optimum design, methods of optimization, Johnson's method of optimum design-simple problems in optimum design like axially loaded members.	

Books and other resources

References Books:

1. S.P. Patil, "Mechanical System Design", 2nd Edition, Jaico Publishing house, Mumbai
2. N. K. Giri, "Automobile Mechanics", 8th Edition, Khanna Publishers, Delhi.
3. R. B. Gupta, "Auto Design", (2016) Satya Prakashan, New Delhi.
4. V.B. Bhandari., "Design of Machine Elements", 3rd Edition Tata McGraw-Hill Publishing Company Ltd., New Delhi.
5. R.C. Johnson ,"Optimum Design of Mechanical Elements", 2nd Edition, John Wiley & Sons Ltd., New York.
6. J.S. Arora, "Introduction to Optimum Design", 4th Edition, McGraw-Hill Book Company Ltd
7. M. F. Spotts and T.E. Shoup, "Design of machine Elements", 7th Edition, Pearson Education.
8. Julian Happian "An Introduction to Modern Vehicle Design", – Smith, Butterworth Heinemann
9. Joseph E. Shigley and Larry D. "Mechanical Engineering Design", Mitchell, Fourth Edition, McGraw-Hill.
10. Callister W.D. "Material Science and Engineering- An introduction", (2006) , Wiley –Eastern.
11. Raghavan, V., "Physical Metallurgy", (2003) ,Prentice Hall of India.
12. Michael F. Ashby, "Materials Selection in Mechanical Design", Butterworth Heinemann,2005.

Design Data Books:

1. P.S. G. College of Technology, Coimbatore, "Design Data Handbook"
2. K. Mahadevan, K. Balveera Reddy, "Design Data Handbook"

Term Work

Practical Contents:-

(1) Design of automotive clutch assembly and component drawing (Two full imperial sheets along with design calculations report) consists of:

a. Functional design of clutch
b. Design of clutch shaft, hub and flange
c. Design of damper springs
d. Design of sectors, rivets etc.
e. Design of pressure plate assembly
f. Design for linkage mechanism
g. Details and assembly drawing each on full empirical sheet (Manual Drafting)
h. Details and assembly drawing using any drafting software (Drafting by using CAD software)

OR

h. Prepare solid model of each part and assemble them by using any solid modeling software package. Extract three views of assembly on one sheet. Also, extract at least two views of every part on other sheet.

(2) Design of automotive gear box along with reverse gear (Two full imperial sheets along with design calculations report) consists of:

a. Calculation of gear ratios
b. Determination of number of teeth on gear pair
c. Determination of gear reductions
d. Design of gear pairs
e. Design of shafts
f. Selection of bearings
g. Details and assembly drawing

OR

g. Prepare solid model of each part and assemble them by using any solid modeling software package. Extract three views of assembly on one sheet. Also, extract at least two views of every part on other sheet.

(3) Design of suspension spring and its analysis using any analysis software. Also, verify analysis results (Maximum Shear Stress and Maximum Deflection) by using Analytical Method.

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<table>
<tr><th colspan="6">416491A: Alternative Fuels and Emission Control</th></tr>
<tr><th colspan="2">Teaching Scheme</th><th colspan="2">Credits</th><th colspan="2">Examination Scheme</th></tr>
<tr><td>Theory</td><td>3 Hrs./Week</td><td>Theory</td><td>3</td><td>In-Semester</td><td>30 Marks</td></tr>
<tr><td></td><td></td><td></td><td></td><td>End-Semester</td><td>70 Marks</td></tr>
<tr><td colspan="6">Pre requisites: Basic Engineering Science - Physics, Chemistry, Material Science, Engineering Metallurgy, Manufacturing processes Etc.</td></tr>
<tr><td colspan="6">Course Objectives:
1. To acquire complete knowledge on availability of possible alternate fuels and their properties to use as fuel in CI and SI engines.
2. To develop knowledge all, the possible way of using alcohols and Hydrogen as a fuel IN IC engines.
3. To understand the challenges and difficulties in using vegetable oil and natural acquiring gases as an alternative fuel in internal combustion engines.
4. To analyse the formation of major pollutants like UBHC, CO, NOx, particulate matter and smoke also discuss the harmful effects.
5. To demonstrate the various devices used to measure pollutants and deliberate the Emission standards followed in various nations
6. To design various control techniques to reduce pollutants in combustion and various after treatment process to minimize emissions</td></tr>
<tr><td colspan="6">Course Outcomes:
On completion of the course the learner will be able to;
CO1. ACQUIRE complete knowledge on availability of possible alternate fuels and their properties to use as fuel in CI and SI engines.
CO2. UNDERSTAND the challenges and difficulties in using vegetable oil as an alternative fuel in internal combustion engines.
CO3. IDENTIFY the uses of hydrogen as fuel in IC engines as an alternative for fossil fuels.
CO4. RECOGNIZE the usefulness of natural acquiring gases towards IC engines
CO5. EXPLAIN Various refinery processes
CO6. EVALUATE fuel ratings, additive mechanisms of fuels</td></tr>
<tr><td colspan="6">Course Contents</td></tr>
<tr><td>Unit 1</td><td colspan="5">Alternative Fuels, Properties And Testing Methods of Fuels</td></tr>
<tr><td colspan="6">Need for alternative fuels. World and Indian energy scenario on alternative fuels. Production technologies for biofuels for internal combustion engines- Pyrolysis, gasification, digestion.</td></tr>
</table>

Unit 2	Alcohols, Hydrogen As Fuels

Production methods of alcohols. Properties of alcohols as fuels. Methods of using alcohols in CI and SI engines. Performance emission and combustion characteristics in CI and SI engines.

Production methods of hydrogen. Combustive properties of hydrogen. Problems associated with hydrogen as fuel and solutions. Different methods of using hydrogen in SI and CI engines. Hydrogen storage - safety aspects of hydrogen.

Unit 3	Vegetable Oils As Fuels

Various vegetable oils and their important properties. Different methods of using vegetable oils engines – Blending, preheating Transesterification and emulsification of Vegetable oils. Role of Nanofluids, additives and cetane improvers for performance improvement of vegetable oils as fuel.

Unit 4	Biogas, Lpg And Natural Gas As Fuels

Production methods of Biogas, Natural gas and LPG. Properties studies. CO2 and H2S scrubbing in Biogas. Modification required to use in SI and CI Engines- Performance and emission characteristics of Biogas, NG and LPG in SI and CI engines.

Unit 5	Emission From Automobiles, Test Procedures And Emission Measurements

Sources of Pollution. Various emissions from Automobiles — Formation — Effects of pollutants on environment human beings. Emission control techniques – Emission standards.

Constant Volume Sampling I and 3 (CVSI &CVS3) Systems- Sampling Procedures — Chassis dyno - Seven mode and thirteen mode cycles for Emission Sampling — Sampling problems — Emission analyzers —NDIR, FID, Chemilum inesecent, Smoke meters, Dilution Tunnel, SHED Test, Sound level meters.

Unit 6	Emission From SI and CI Engine and Its Control

Emission formation in SI Engines, Effects of design and operating variables on emission formation , Catalytic converters — Charcoal Canister — Positive Crankcase ventilation system, Secondary air injection, thermal reactor, Laser Assisted Combustion. Formation of White, Blue, and Black Smokes, NOx, soot, sulphur particulate and Intermediate Compounds , Significance Effect of Operating variables on Emission formation — Fumigation, EGR, HCCI, Particulate Traps, SCR — Cetane number Effect.

Text Books:

1. Ganesan.V., "Internal Combustion Engines", Tata McGraw-Hill Publishing Co., New Delhi, 2017
2. George E. Totten, Editor, Fuels and Lubricants Handbook: Technology, Properties, Performance, and Testing, ASTM International.
3. B.P Pundir , Engine Emissions, Narosa publications 2nd edition 2017
4. D.J.Patterson and N.A.Henin, 'Emission from Combustion Engine and their Control', Anna Arbor Science Publication,1985.
5. G.P.Springer and D.J.Patterson, Engine Emissions, Pollutant formation, Plenum Press, New York, 1986.

References Books:

1) Paul Richards "Automotive fuels reference book" SAE International, Third edition 2014
2) Roger Frederick Haycock, John Hillier, Arthur J. Caines "Automotive lubricants Reference book", SAE International, Second edition 2004
3) Wilfrid Francis– Fuels and Fuel Technology, Vol. I & II
4) A.Alexander, J.P.Barde, C.lomure and F.J. Langdon, 'Road traffic noise', Applied science publisher ltd., London,1987.
5) Crouse and Anglin, 'Automotive Emission Control', McGraw Hill company., New York 1993.
6) C.Duerson, 'Noise Abatement', Butterworths ltd., London1990.
7) LL Beranek, 'Noise Reduction', McGraw-Hill Company., New York 1993.

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416492B: Renewable Energy					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30**
				End-Semester	**70**

Prerequisites: Systems in mechanical engineering, Applied Thermodynamics, Fluid mechanics, Heat transfer and Energy Engineering

Course Objectives:

1. To understand fundamentals, needs and scopes of renewable energy technologies.
2. To design and applications of solar thermal conversion systems.
3. To design wind energy systems
4. To study different aspects of geothermal energy.
5. To study different sources of bio-energy.
6. To describe ocean energy systems.

Course Outcomes:

On completion of the course the learner will be able to;

1. **DESCRIBE** fundaments, needs and scopes of renewable energy systems.
2. **APPLY** Installation practices of Solar Photovoltaic Systems.
3. **DESIGN AND ANALYSIS** of wind energy conversion system.
4. **ANALYZE** performance aspects of geothermal energy systems
5. **DETERMINE** performance parameters of bio-energy conversion systems.
6. **EXPLAIN** fundaments of ocean energy systems.

Course Content

Unit 1 **Introduction to Renewable Energy Technologies**

Scenario of Renewable Energy Generation: Energy (and power) policies in the country, Energy supply and renewable energy programme during different plan periods. Renewable energy use and target in India.

Solar Energy Fundamentals: Solar Radiation and Measurement, Solar constant, Solar angles, day length, angle of incidence on tilted surface, Extra-terrestrial characteristic, Effect of earth atmosphere, Measurement and estimation on horizontal and tilted surfaces (numerical treatment on Solar angles and Measurements).

Solar thermal collectors: Flat plate collectors.

Solar Concentrating Collectors: types- line and point concentrator, tracking systems, theory of Concentrating collectors, parabolic trough collector, parabolic dish collector, Central receiver systems, concentrated Fresnel linear receiver (CFLR).

Unit 2	Solar Thermal Systems and Applications

Solar Photovoltaic Systems: Principle and V-I characteristics of PV Cell , efficiency of solar cell , configuration of solar PV panel, Trends of PV collectors, large solar PV systems, Solar PV diesel electric hybrid.

Solar thermal Applications: Solar energy thermal storage, heating and cooling of buildings, solar pumping, solar cooker, solar still, solar drier, solar refrigeration and air conditioning, solar pond, solar green house, solar furnaces, Solar thermal power generation. Binary cycle solar thermal power plant.

Unit 3	Wind Energy Systems

Wind Energy Fundamentals: Nature of wind, Power in wind, forces on blades, Wind turbine efficiency, wind velocity duration curve.

Types of Wind turbines, Horizontal axis and vertical axis wind turbines.

Wind energy farms, Wind energy conversion systems. Solar-wind hybrid system. Control and monitoring of a wind farm.

Unit 4	Geothermal Energy

Geothermal Energy resources, geothermal gradients, Hydrothermal resources, Geopressured resources. Geothermal Electric Power Plants: Vapour dominated, Liquid dominated, Binary cycle liquid dominated geothermal power plant. Hybrid conventional and geothermal power plant. Prime movers for geothermal energy conversion.

Unit 5	Biomass Energy and MHD

Biomass: Sources and Characteristics; Biomass conversion technologies. Wet biogas plants ; Biomass gasifiers: Classification and Operating characteristics; Biogas generation, classification of biogas plant. Urban waste to energy by Incineration process: Schematic of a Waste Incineration energy plant. Fluidized bed combustion boiler(FBCB).

Magneto hydrodynamic power generation (MHD): Principle of MHD power generation, MHD systems.

Unit 6	Ocean Energy And Technology

Ocean Energy resources, Off shore and on-shore ocean energy conversion technologies. Advantages and limitations of Ocean Energy.

Ocean Thermal Electricity Conversion (OTEC): Principle of OTEC, Ocean surface temperature, deep water temperature. Open cycle OTEC system, Modified Open cycle OTEC plant. Closed cycle OTEC system, Small scale hydroelectric plant- classification and components of small Hydel power plant

Books and other resources

Text Books:

1. Energy technology / S.Rao & Dr. B.B. Parulekar
2. Non-conventional Energy Sources / G.D.Rai.

References Books:

1. Renewable Energy Sources / Twidell & Weir
2. Solar Energy/ Sukhatme
3. Solar power Engineering/ B.S. Magal Frank Kreith & Frank Kreith
4. Principles of Solar Energy / Frank Kreith & John F Kreider
5. Non Conventional Energy / Ashok V Desai / Wiley Eastern
6. Non Conventional Energy Systems / K Mittal / Wheeler

Web Courses:

1. https://nptel.ac.in/courses/103103206
2. https://nptel.ac.in/courses/103103207
3. https://nptel.ac.in/courses/108108078
4. https://nptel.ac.in/courses/102104057

Web References:

1. **https://www.sciencedirect.com/journal/renewable-energy www.ireda.in**
2. **https://mnre.gov.in Ministry of new and renewable energy, Gov't of India**
3. **www.ntpc.co.in**
4. **www.irena.org**
5. **www.ireda.in**

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Automobile Engineering (2019 pattern)

416492A: Transport Management and Automobile Industry					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30 Marks**
				End-Semester	**70 Marks**

Prerequisites: Nil

Course Objectives:

1. Understand the structure of transport organization in India
2. Understand Licensing, Registration, and Permit related acts and rule
3. Understand Construction of MV and Taxation related acts and rule
4. Study the basic laws related to insurances and offences
5. Study the different factors for the Planning of new transport organization
6. Understand the automotive industry standards

Course Outcomes:

On completion of the course the learner will be able to;

CO1. **DESCRIBE** the structure of transport organization in India
CO2. **INTERPRET** Licensing, Registration, and Permit related acts and rule
CO3. **INTERPRET** Construction MV and Taxation related acts and rule
CO4. **ANALYSIS** basic laws related to insurances and offences
CO5. **ANALYSIS** different factors for the Planning of new transport organization
CO6. **EXPLAIN** the automotive industry standards

Course Contents

Unit 1 **Introduction to transport organization**

Introduction of Motor Vehicle Act (MVA) and Central motor vehicle Rule(CMVR), chapters of MVA, CMVR, transport administrative structure at central and state level, role and responsibility, RTO, economics and records working of various state transport organizations.(MSRTC, BEST), role of various research organizations like-central institute of road transport, automotive research association of India, vehicle research, development and establishment, central road research institute and petroleum conservation and research association.

Unit 2	Licensing, Registration, and Permit

Licensing: Rule of licensing to driver, conductor, need for driving test, responsibility of driver, conductor

Registration: Necessity for registration, registration mark, certificate of registration, Transfer of ownership, Certificate of fitness

Permit: Need, types of permits, Procedure in applying for and granting permits

Unit 3	Construction of MV and Taxation

Construction of Motor vehicle: Overall dimension, Size, nature and condition of tyres, Brakes, steering gears, safety glass and windscreen wipers, Signalling devices, direction indicators and stop lights

Taxation: Taxation Objectives, Structure & methods of laving taxation, Onetime tax, Tax exemption & tax renewal Toll tax reasons & operational management. Build Operate Transfer arrangement

Unit 4	Accident & Prevention

Indian road accident scenario, Highway traffic rules, Traffic signs.

Insurance: significance, type of insurance, Comprehensive, Third party insurance, Furnishing of particulars of vehicles involved in accident, MACT (Motor Accident Claims Tribunal), Solatium Fund, Hit & Run case, Duty of driver in case of accident, Surveyor & Loss Assessor, Surveyors report

Offences, Penalties and Procedure

Unit 5	Planning for New Transport Organization

Geographical considerations in transport operation, economic factors, vehicles used, planning of trips, Concept of BRTS operations.
Passenger and goods Transport: Organization of Transport Services: Records and fleet management, vehicles schedule, booking and reservation, statistical records, recording of goods transport, Scheduling of goods transport, Management Information System (MIS) in passenger / goods transport operation, Storage & transportation of petroleum products,
Advanced Techniques in Traffic Management: Traffic navigation, Global positioning system, and management, it's advantages and disadvantages in terms of mass transportation

Unit 6	Automotive industry standards

Key industry quality standards, need, advantages, Cost of quality & value of quality, Indian Standards (IS) and Automotive Industry standards (AIS), Bharat NCAP, Deming‟s cycles & 14 Points, Juran Trilogy approach, Seven Quality Tools, Introduction to N Seven Tools, Quality Circle, 5S, Kaizen, Poka yoke, Kanban, JIT, IATF 16949, ISO14001, Six Sigma, Criteria for Quality Award (National & International)

Books and other resources
References Books: 1. The Motor vehicle Acts, 1988- MoRTH Commercial Law publisher India Pvt Ltd. 2. The Central Motor vehicle rule, 1989- MoRTH Commercial Law publisher India Pvt Ltd. 3. P.G.Patankar, "Road Passenger Transport in India", CIRT, Pune.The elements of transportation - R.J. Eaton 4. Goods vehicle operation - C.S. Dubbar 5. Road transport law - L.D. Kitchen 6. S.L. Bhandarkar, Vehicle Transport Management, DhanpatRai& Co. (Pvt.) Ltd. 7. CIRT Journal of Transport Management 8. S.K. Shrivastava, "Economics of Transport" 3. "Transport Development in India", S. Chand & Co. Pvt. Ltd., New Delhi.
Web References: 1. http://ebook.commerciallawpublishers.com/fa/cmvr/mobile/index.html 2. http://ebook.commerciallawpublishers.com/fa/cmvr/mobile/index.html 3. Rules of Road Regulations https://transport.maharashtra.gov.in/1280/Acts-and-Rules?Doctype=4aedb1bd-9983-4096-baca-05ddace272b9 4. AIS slandered https://morth.nic.in/ais 5. https://www.araiindia.com/ 6. http://www.cirtindia.com/ 7. https://www.crridom.gov.in/

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Automobile Engineering (2019 pattern)

416492B: Automotive Safety					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30**
				End-Semester	**70**

Prerequisites: Automotive Body Engineering, and Strength of Materials,

Course Objectives:

1. Fundamental concepts of vehicle safety.
2. Automotive European NCAP-Test.
3. Automotive Crash tests to be carried out for any collision.
4. Evaluation of the comfort level in any vehicle.
5. Automotive dummies to be used for different crash tests.
6. Advanced safety systems and driver assistance systems in a vehicle.

Course Outcomes:

On completion of the course the learner will be able to;

CO1. **EXPLAIN** the fundamental concepts of vehicle safety to modern vehicles.
CO2. **DIFFERENTIATE** various Pedestrian Protection
CO3. **SELECT** appropriate crash test to be carried out for any particular collision.
CO4. **EVALUATE** the level of comfort in any vehicle by developing ergonomics report.
CO5. **PREDICT** appropriate dummy to be used for a specific crash test.
CO6. **EXPLAIN** advanced safety systems and driver assistance systems.

Course Content

Unit 1 **Concept of Automotive Safety**

Classification of Automotive Safety, Active Safety, Passive Safety; Primary Collision, Secondary Collision, Accident Avoidance: Human, Vehicle and Environment; Pre-Crash, Mitigation of Injuries: During Accident and After Accident; Crashworthiness, Crashworthiness tests: component tests, sled tests, and full-scale barrier Tests, Crashworthiness Models Requirements.

Unit 2 **Pedestrian Protection**

Pedestrian Protection, First Contact Points Zone in Vehicle-Pedestrian Collisions, Injury Frequency to Pedestrian Body Regions and Vehicle Collision, Pedestrian Head Contact on Vehicle's Hood with Injury Severity and Collision Speed, Driver's Task during Critical Situation of a Potential Accident, Pedestrian Protection Test Procedures according to EEVC WG17 and Euro NCAP-Pedestrian Test as per EC-Directive 2003/102/EC, 2004/90/EC and Conch Directive 70/156/EC for Headform and Legform of Adult and Child, Pedestrian Protection via Hood Airbags.

Unit 3	Impacts, Collisions and Crash Testing of a Vehicle

Frontal Impact, Side Impact, Lateral Collision, Rear-End Collision, Human Testing: Volunteer Testing, Cadaver Testing, Dummies, Crashworthiness: Deceleration Curves, The Square Wave, Injury Tolerance, Control of Deceleration, Pole Testing, Rear Testing, Side Impact Testing, Rollover Testing Construction vehicle test; Compliance Testing, Component Testing, Competitive Race Testing, Proving-Ground Testing and In-Field Testing.

Unit 4	Ergonomics and Packaging of Occupants

Ergonomics, Role of Occupant Packaging in Car Design, Five Steps of Occupant Package Development Process, Strategies for Improving Occupant Accommodation and Comfort, Vehicle Seating Configuration as per SAE Norms, Strengths and Weaknesses of Methods for Evaluating and Improving Occupant Accommodation Standards, Ergonomic Development of a Vehicle with Human Modelling Predictions.

Unit 5	Biomechanics, Anthropometry and Occupant Simulation & Protection

Injury Tolerance Limits for Fractures and Injury of Organs as per AIS or OAIS, External Injuries for Total Body, Brain, Skull, Fracture, Forehead, Cervical Spine, Thorax, Pelvis-Femur and Tibia and Internal Injuries for Load on the Brain and Cervical Vertebra; Patrick Curve for g-level Time Relationship, Severity Index (SI) and Head Injury Criteria (HIC); Anthropomorphic Test Devices: Hybrid II Dummy Family, Hybrid III Dummy Family, CRABI Infant Dummies, Side Impact Dummies, Rear Impact Dummies; Design of Hybrid III Dummy and Bio-RID as per different percentile statures; Crash Dummy Modelling: Modelling Methodology; Real Human Body Modelling: Anthropometry, Occupant and Restraint System Simulation with Pedestrian Simulation Tests, Restraint Systems for Frontal Impacts, Side Protection by Airbags; Energy Absorbing Systems.

Unit 6	Recent Automotive Advanced Safety Systems

Active Bonnet System, Active Headrests, Active Suspension System, Adaptive Cruise Control, Adaptive Front Lighting System, Adaptive Noise Control, Anti-Lock Brake System, Automotive Collision Avoidance System, Blind Spot Alert System, Electronic Stability Control System, Four-Wheel Steering, Forward Collision Warning System, Intelligent Airbag Sensing System, Inflatable Curtains, SIPS, Lane Departure Warning System, Reverse Sensing Aid, Sensotronic Brake Control, Surround View Camera System, Tyre Pressure Monitoring System and Other Driver Assistance Systems.

Books and other resources

Text Books:

1. Peters, George A. and Peters, Barbara J., "Automotive Vehicle Safety", Taylor & Francis, London, 2002.
2. Seiffert, Ulrich and Wech, Lothar, "Automotive Safety Handbook", SAE International, 2007.
3. Prasad, Priya and Belwafa, Jamel E., "Vehicle Crashworthiness and Occupant Protection", Automotive Applications Committee, American Iron and Steel Institute, Southfield, Michigan, 2004

References Books:

1. Gkikas, Nikolaos, "Automotive Ergonomics: Driver-Vehicle Interaction", CRC Press, Boca Raton, 2013.
2. Bridger, R. S., "Introduction to Ergonomics", Routledge, London, 2003.
3. Happian-Smith, Julian, "An Introduction to Modern Vehicle Design", Butterworth Heinemann, First Edition, Great Britain, 2002.
4. Denton, Tom, "Automobile Electrical & Electronic Systems", Elsevier Butterworth-Heinemann, Third Edition, Burlington, 2004.
5. Erjavec, Jack, "Automotive Technology: A Systems Approach", Delmar-Cengage Learning, Fifth Edition, USA, 2010.

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Automobile Engineering (2019 pattern)

416492C: Process Planning and Cost Estimation					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30**
				End-Semester	**70**

Prerequisites: Industrial Engineering, manufacturing Process, Machine Shop

Course Objectives:

1. To understand principle of Process Planning and Process Planning activities.
2. To memorize principle of Costing and Estimation.
3. To be aware of Indirect Expenses, Depreciation and methods of calculating Depreciation.
4. To estimate the cost of various types of Jobs.
5. To estimate the cost for various machining operation.

Course Outcomes:

CO1. **SELEC**T and evaluate various parameters of process planning.

CO2. **PREPARE** process planning activity chart.

CO3. **EXPLAIN** the concept of cost estimation.

CO4. **EXPLAIN** the concept of indirect expenses and depreciation.

CO5. **COMPUTE** the job order cost for different types of shop floor.

CO6. **CALCULATE** the machining time for various machining operation.

Course Content

Unit 1	**Introduction to Process Planning**

Purpose, concept, objectives and scope of process planning - Types of production-Production planning-Production design-manual, CAPP-Retrieval, generative and semi generative approach- Drawing interpretation.

Unit 2	**Process Planning Activities**

Steps in process selection-production equipment and tooling selection, jigs and fixture selection, selection of quality assurance methods- Set of documents for process planning-Economics of process planning-Case study.

Unit 3	Costing and Estimation

Cost estimating- Cost accounting-Elements of cost- Cost of Product- Labour costing-.--Material costing - Cost estimation procedure- Types and methods of cost estimates- Data requirement and sources of information-Allowances in estimation-Illustrative examples.

Unit 4	Indirect Expenses and Depreciation

Introduction, factory expenses, administrative expenses, selling and distribution expenses, calculation of various overheads- Obsolescence- Interest on capitals-Idleness-Repairs and maintenance-Factors affecting the periodic allocation of depreciation-Method of calculating depreciation-Comparison of SLM, DBM and SYDM method- Depreciation and the concept of mechanical fatigue.

Unit 5	Production Cost Estimation

Estimation of labour , material and overhead cost- Estimation in foundry shop-Pattern cost, foundry losses and steps for costing- Estimation in welding shop- Gas welding and arc welding- forging shop-forging operation and estimation procedure-Illustrative example.

Unit 6	Estimation of Machining Times and Costs

Machine shop operations- Estimation of machining time for Lathe, milling, grinding, drilling, shaping and planning operations- Power consumption in machining, metal removal rate and tool life- Illustrative example.

Books and other resources

Text Books:

1. A Text Book of Industrial Engineering and Management, O.P. Khanna, Dhanpat Rai Publication
2. A Text Book of Industrial Engineering and Production Management, M. Mahajan, Dhanpat Rai Publication.
3. A Text Book of Mechanical Estimating and Costing, Sinha B.P., Tata MC Graw Hill Publishing
4. A Text Book of Mechanical Estimating and Costing, T.R. Banga and S.C. Sharma, Khanna Publishers

References Books:

1. Nanua Singh, System Approach to Computer Integrating Design and Manufacturing, John Wiley and Sons, New York, 1996.
2. Joseph G. Monks, Operations Management, Theory and Problems, McGraw Hill Book Company, New Delhi, 1982.
3. Narang, G.B.S and Kumar, V., Production and Planning, Khanna Publishers, New Delhi, 1995.

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Automobile Engineering (2019 pattern)

416493: Automotive Systems Analysis and Simulation Laboratory					
Teaching Scheme		**Credits**		**Examination Scheme**	
Practical	**02 Hrs.**	**Practical**	**01**	**Term Work**	**25 Marks**
				Oral	**25 Marks**

Prerequisites: Systems in Mechanical Engineering, All Automobile Engineering subjects, Solid Modelling and Drafting, Computer Aided Engineering, Finite Element Analysis, Computational Fluid Dynamics, Project Based Learning -I,-II, Skill Development, Internship/Mini project, All Electives

Course Objectives:

1. Develop an understanding of the Systems Engineering Process and the range of factors that influence the product need, concept development, system's mathematical modelling, analysis, synthesis, simulation, design, validation, redesign, planning, production, evaluation and use of a system using manual calculation, mathematical modelling, computational tools to automate product development process.
2. Understand the concepts of and use the developed skills in last three and half year of engineering studies for the design, construction, fault-finding, diagnosis, performance analysis, maintenance, modification, and control of technological systems.
3. Acquire knowledge of new developments and innovations in technological systems to be carried forward to next stage of employment after passing your Undergraduate Degree Examination.
4. Develop an understanding of how technologies have transformed people's lives and can be used to solve challenges associated with climate change, efficient energy use, security,health, education and transport, which will be coming your ways in the coming future.
5. Gain an awareness of quality and standards, including systems reliability, safety and fitness for the intended purpose.
6. Build yourself to face the challenges of future technologies and their associated Problems.

Course Outcomes:

On completion of the course the learner will be able to;

CO1. **DEVELOP** an understanding of the Systems Engineering Process and the range of factors that influence the product need, problem-specific information collection, Problem Definition, Task Specification, Solution Concept inception, Concept Development, System's Mathematical Modelling, Synthesis, Analysis, final solution Selection, Simulation, Detailed Design, Construction, Prototyping, Testing, fault-finding, Diagnosis, Performance Analysis, and Evaluation, Maintenance, Modification, Validation, Planning, Production, Evaluation and use of a system using manual calculation, computational tools

to automate product development process, redesign from customer feedback and control of technological systems.

CO2. **ILLUSTRATE** the concepts and USE the developed skill-set of use of computational tools (FEA, CFD, MBD, FSI, CAE) to automate the complete product development process.

CO3. **EVALUATE** the knowledge of new developments and innovations in technological systems to carry forward to next stage of employment after passing your Undergraduate Degree Examination.

CO4. **APPRAISE** how technologies have transformed people's lives and can be used to **SOLVE** challenges associated with climate change, efficient energy use, security, health, education and transport, which will be coming your ways in the coming future.

CO5. **PRIORITIZE** the concept of quality and standards, including systems reliability, safety and fitness for the intended purpose.

CO6. **INVENT** yourself to face the challenges of future technologies and their associated Problems.

Course Contents

Preamble:

Engineering is the application of science to develop, design, and produce logical and/or physical objects such as buildings, machines, or a computer program to fulfill a desired need or to achieve an objective. So the object or goal of engineering is a design. So Systems Engineering is the engineering of a system - it is the application of science to design a system.

This lab is intended for developing an analysis skill-set with logical reasoning expected by industries to solve their problems during Product (Hardware, Software and Services) Development Process as a part of Company's System Engineering to survive in the open competitive Market, where there is no Textbook available.

TERM WORK:

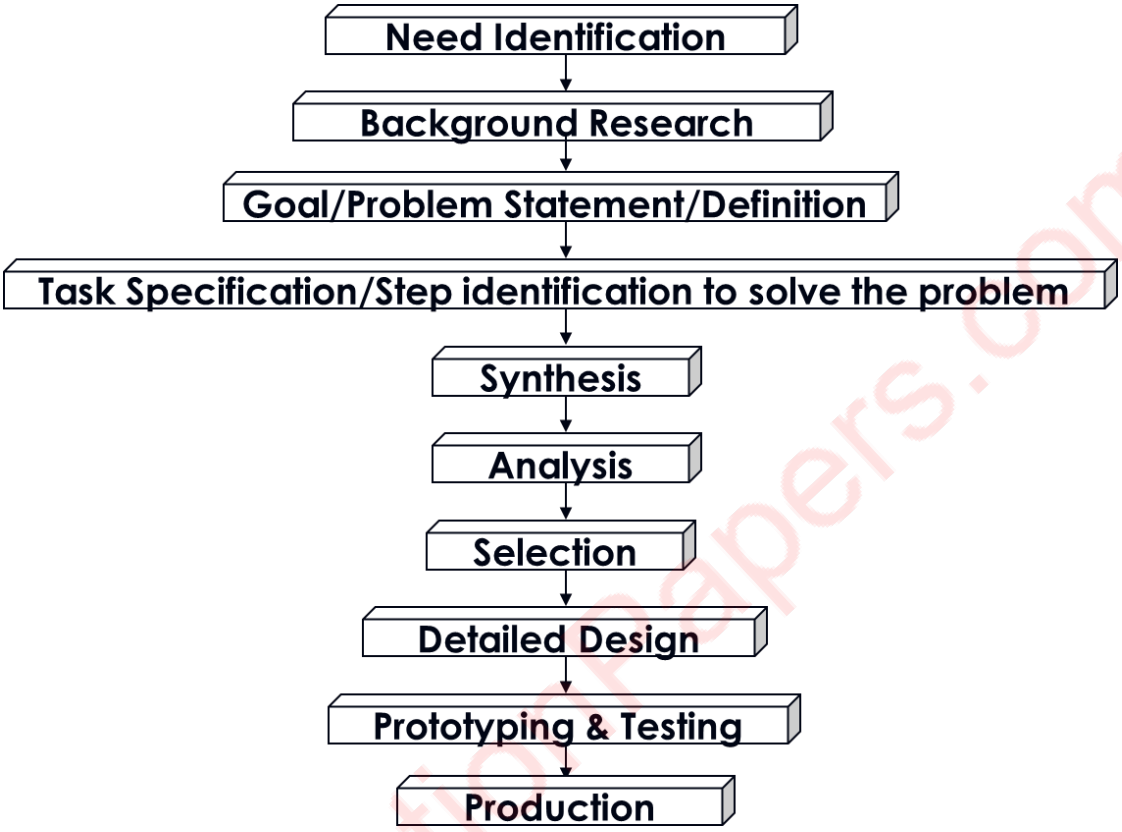
The term work shall consist of following **two parts**, each carry **equal weightage**:

A] Product based Case study

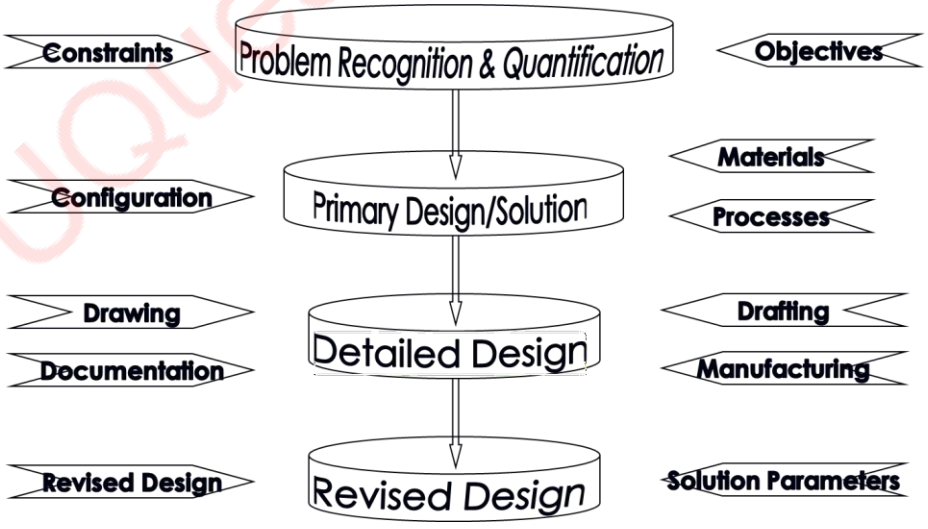
- Group of 2-3 students will take up one product based system analysis activity by consultation with associated faculty and followed by development using available and learned computational tool. It will be in the form of Complete Report.

- The product can be but not limited to: any automobile part, automotive utility products, Hand/Process Tools/Equipments use in automotive related industry, Mass production jigs/fixtures, robotics and automation products, etc.

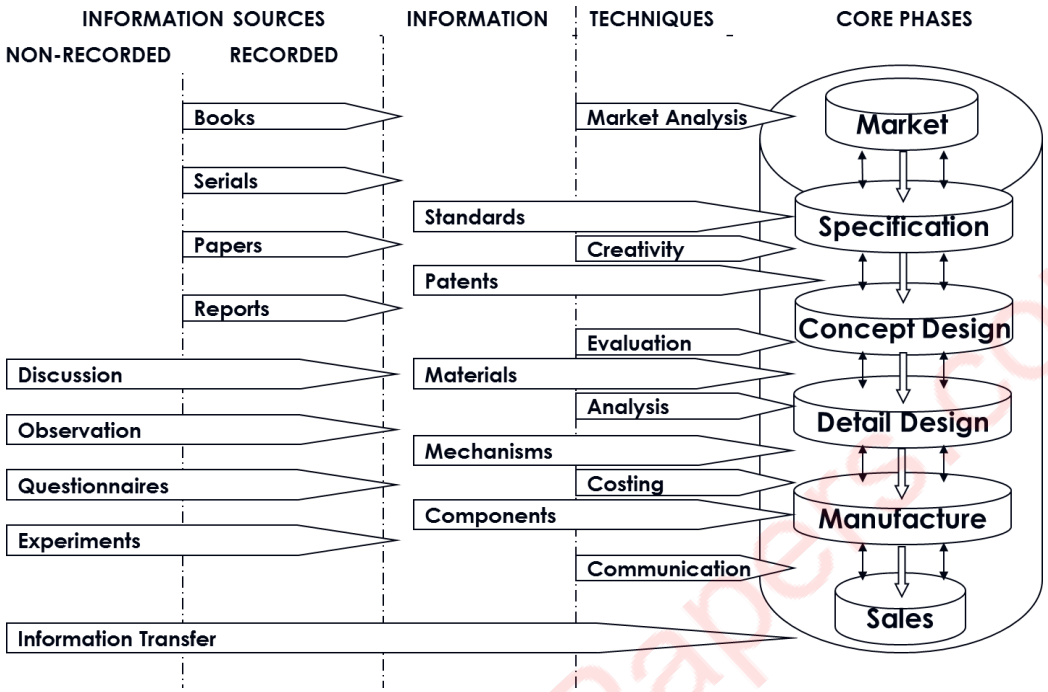
- Product Systems Analysis must follow following approach for developing the final prototype (Hardware, Software and Services).



- The Decision Making Approach with required inputs will be as follows:



- The Resources & flow of Information for System Analysis Activity for Product development must follow:



- **Demonstration by Faculty (guiding role) -** Faculty shall demonstrate complete design, analysis and synthesis of any one automobile system from need to the end use comprising of deployment of appropriate analysis tool for modelling of the prototype. Philosophy must be told and demonstrated by faculty.

NOTE: This work should not be replication of your Project Work

B] List of Assignments (Any three assignment from any category)

- Following Assignment must be completely in a Computer Lab using, Finite element analysis, Computational Fluid Dynamics and Multibody Dynamics Open source or Commercial Software:
- Each Assignment should content details about problem statement, input, boundary condition, solid model, analysis report etc.
- Students can assume the suitable input to conduct the below simulation

B1) **FEA Assignments**

1. Suspension simulation
2. Drop weight simulation
3. Crash Simulation
4. Deep drawing simulation
5. Sheet metal bending simulation
6. Mini project on any practical application. Students should take a problem of their choice and verify the FEA solution with experimental data / research paper.

B2) **CFD Assignments**

1. CFD Simulation of engine Intake Flow
2. CFD Simulation of Exhaust gas flow in Exhaust Manifold
3. Numerical simulation and analysis of boundary layer for a Developing flow through Pipe
4. Fully developed flow through a pipe
5. CFD Simulation of the Air Flow around a Car Model (Ahmed Body)

6. CFD simulation of heat transfer of engine cylinder
7. CFD simulation to calculate the drag force on vehicle body (Ahmed Body)
8. Mini project on any practical application. Students should take a problem of their choice and verify the CFD solution with experimental data / research paper.

B3) **MBD Assignments**

1. Kinematic simulation of the following Multibody Systems:
2. Four bar mechanism/Slider crank mechanism
3. Cam and follower System
4. Serial Robot Manipulators
5. Parallel Robot Manipulators
6. Gera Box simulation
7. Steering assembly simulation
8. Suspension assembly simulation
9. Mini project on any practical application. Students should take a problem of their choice elated to automotive kinematic simulation.

Books and other resources

Text Books:

1. National Aeronautics and Space Administration, (2007), "NASA Systems Engineering Handbook," NASA, ISBN: 9780160797477
2. Space & Missile Systems Center, (2004), "SMC Systems Engineering Primer & Handbook: Concepts, Processes, and Techniques," SMC, U.S. Air Force
3. Oliver, D. W., Kelliher, T. P., Keegan, Jr., J. G., (1997), "Engineering Complex Systems With Models and Objects," McGraw-Hill, ISBN: 978-0070481886
4. Bi, Zhuming (2018), "Finite Element Analysis Applications: A Systematic and Practical Approach, Academic Press, ISBN: 9780128099520

References Books:

1. Rao, J.S., (2017), "Simulation Based Engineering in Fluid Flow Design," Springer, ISBN: 9783319463810
2. Tu, J., Yeoh, G-H. and Liu, C., (2018), "Computational Fluid Dynamics: A practical approach," Butterworth-Heinemann, ISBN: 9780081011270
3. Nikravesh, P.E., (2019), "Planar multibody dynamics: formulation, programming with MATLAB®, and applications," CRC Press, ISBN: 9781138096127
4. Rao, J.S., (2011), "Kinematics of Machinery Through HyperWorks," Springer, ISBN: 9789400711556

<table>
<tr><th colspan="6">416894: Project (Stage II)</th></tr>
<tr><th colspan="2">Teaching Scheme</th><th colspan="2">Credits</th><th colspan="2">Examination Scheme</th></tr>
<tr><td>Practical</td><td>10 Hrs./Week</td><td>Practical</td><td>5</td><td>Term Work</td><td>100 Marks</td></tr>
<tr><td></td><td></td><td></td><td></td><td>Oral</td><td>50 Marks</td></tr>
<tr><td colspan="6">Prerequisites: Project Based Learning, Internship/Mini Project, Project (Stage I)</td></tr>
<tr><td colspan="6">Course Objectives:
1. To provide an opportunity of designing and building complete system or subsystems based on areas where the student likes to acquire specialized skills.
2. To obtain hands-on experience in converting a small novel idea / technique into a working model / prototype involving multi-disciplinary skills.
3. To embed the skill in a group of students to work independently on a topic/ problem/ experimentation selected by them and encourage them to think independently on their own to bring out the conclusion under the given circumstances of the curriculum period in the budget provided with the guidance of the faculty.
4. To encourage creative thinking processes to help them to get confidence by planning and carrying out the work plan of the project and to successfully complete the same, through observations, discussions and decision making process.
5. To get visibility in industry to Project and Project group</td></tr>
<tr><td colspan="6">Course Outcomes:
On completion of the course the learner will be able to;
CO1. Implement systems approach.
CO2. To conceptualize a novel idea / technique into a product.
CO3. To think in terms of a multi-disciplinary environment.
CO4. To take on the challenges of teamwork, and document all aspects of design work.
CO5. To understand the management techniques of implementing a project.</td></tr>
<tr><td colspan="6">Course Contents</td></tr>
<tr><td colspan="6">Extended part of Project Stage I</td></tr>
<tr><td colspan="6">Guidelines for Project Execution</td></tr>
<tr><td colspan="6">1. Refer Project stage I guidelines.</td></tr>
<tr><td colspan="6">Term Work Evaluation</td></tr>
<tr><td colspan="6">1. In Project Stage II, two reviews are to be taken for total 80 marks (40 marks each)
2. Review III shall be based on the approximate end of fabrication / design validation etc. in front of an expert panel from the department.</td></tr>
</table>

3. Review IV will be third party evaluation by Faculty/Student/Industry person/Alumni
4. Evaluation committee will consist of Guide, One Industry person and One Faculty appointed by the Institution.
5. Students shall be encouraged to publish a research paper/patent/technical note. Their credential shall be considered while term work evaluation.

Examination Scheme

1. Examination committee will consist of Guide, (Strictly) One Industry person and One Faculty appointed by the Institution.
2. Well in advance soft copies of the project shall be shared with examination committee.

Presentation of Project Work

Presentation of work in the form of Project Report (s), Understanding individual capacity, Role & involvement in the project, Team Work (Distribution of work, intrateam communication and togetherness), Participation in various contests, Publications and IPR, Manuals (Project Report, Quick reference, System, Installation guide) among other parameters. Team members with guide information shall be added at the end of the report.

Project Report

1. The report shall be both side print hard bound. A hardbound report shall be made after examination and examiner and guide's expected correction, before that report must be loosely bound.
2. Plagiarism check is must, and certificate shall be attached in the report.
3. A group activity shall be presented in report.
4. Report copies shall be submitted in the department, one for university and one for supervisor.
5. For standardization of the project reports the following format shall be strictly followed.
    a. Page size: Trimmed A4
    b. Top Margin: 1.00 Inches
    c. Bottom Margin: 1.32 Inches
    d. Left Margin: 1.5 Inches
    e. Right Margin: 1.0 Inches
    f. Para Text: Times New Roman 12-point font
    g. Line Spacing: 1.15 Lines
    h. Page Numbers: Right aligned at footer. Font 12 point Times New Roman
    i. Headings: Times New Roman, 14 Points, Boldface 10.

Certificate

1. All students should attach a standard format of Certificate as described by the department.
2. Certificates should be awarded to project groups and not individual students of the group.
3. Certificates should have signatures of Guide, External Examiner, Head of Department and Principal.

Index of Report

1. Title Sheet
2. Certificate (Institution)
3. Certificate (Company, if sponsored by company)
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