Savitribai Phule Pune University
Faculty of Science & Technology

Curriculum/Syllabus
For
Fourth Year
Bachelor of Engineering
(Choice Based Credit System)
Mechanical Engineering [Sandwich]
(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 Mechanical Engineering [Sandwich] (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														
402061	Industrial In-plant Training - II	-	14	-	-	-	150	-	100	250	-	7	-	7
402062	Industrial Project#	-	12	-	-	-	100	-	100	200	-	6	-	6
402063	Technical Paper Presentation	-	2	-	-	-	-	-	50	50	-	1	-	1
402064	Energy Engineering and Management (Self-Study - III)**	-	-	-	30*	70	-	-	-	100	3	-	-	3
402065	Industrial Engineering and Organizational Management (Self-Study - IV)**	-	-	-	30*	70	-	-	-	100	3	-	-	3
402054	Audit Course VII$	-	-	-	-	-	-	-	-	-	-	NC		
	Total	**-**	**28**	**-**	**60**	**140**	**250**	**-**	**250**	**700**	**6**	**14**	**-**	**20**
Semester-VIII														
402066	Design of Transmission Elements***	4	2	-	30	70	25	-	25	150	4	1	-	5
402067	Machine Dynamics and Vibration	3	2	-	30	70	-	-	25	125	3	1	-	4
402068	Artificial Intelligence in Mechanical Engineering	3	2	-	30	70	-	-	25	125	3	1	-	4
402069	Elective - I	3	-	-	30	70	-	-	-	100	3	-	-	3
402070	Elective - II	3	-	-	30	70	-	-	-	100	3	-	-	3
402071	Systems Analysis Laboratory	-	2	-	-	-	50	-	50	100	-	1	-	1
402055	Audit Course VIII$	-	-	-	-	-	-	-	-	-	NC			
		16	**8**	**-**	**150**	**350**	**75**	**-**	**125**	**700**	**16**	**4**	**-**	**20**

Elective-I		Elective-II	
402069A	Automobile Engineering	402045A	Product Design and Development
402069B	Refrigeration and Air-Conditioning	402045D	Operations Research
402069C	Fluid Power Control	402051E	Electrical and Hybrid Vehicle
402045C	Additive Manufacturing	402050A	Quality and Reliability Engineering
402051C	Automation and Robotics	402044E	Internet of Things

Audit Courses			
402054A	Yoga Practices	**402054B**	Stress Management
402055A	Managing Innovation	**402055B**	Operations Management

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

Instructions:

- Practical must be conducted in **FOUR batches per division** only.
- Minimum number of Experiments/Assignments in PR/Tutorial shall be carried out **as**

mentioned in the syllabi of respective courses.

- # Preferably Industrial Project shall be done in the same industry of In-Plant Training.
- * In-Semester assessment shall be done at the institute level. Assessment shall be in the form of Assignments. Guidelines are given in the syllabus.
- ** Self Study courses shall be studied independently. However, department shall provide assistance in the form of online / offline way. Expert lectures shall be arranged by the department.
- *** In-Semester and End-Semester Examinations shall be of One and Half hour and Three hour respectively.
- $Audit course is mandatory but 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.

Program Outcomes (POs)

POs are statements that describe what students are expected to know and be able to do upon graduating from the program. These relate to the skills, knowledge, analytical ability attitude and behavior that students acquire through the program.

The POs essentially indicate what the students can do from subject-wise knowledge acquired by them during the program. As such, POs define the professional profile of an engineering graduate.

1. **Engineering Knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

2. **Problem Analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences.

3. **Design/Development of Solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

4. **Conduct Investigations of Complex Problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions for complex problems:

   a. that cannot be solved by straightforward application of knowledge, theories and techniques applicable to the engineering discipline as against problems given at the end of chapters in a typical text book that can be solved using simple engineering theories and techniques;

   b. that may not have a unique solution. For example, a design problem can be solved in many ways and lead to multiple possible solutions;

   c. that require consideration of appropriate constraints / requirements not explicitly given in the problem statement such as cost, power requirement, durability, product life, etc.;

   d. which need to be defined (modelled) within appropriate mathematical framework; and

e. that often require use of modern computational concepts and tools, for example, in the design of an antenna or a DSP filter.

5. **Modern Tool Usage**: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.

6. **The Engineer and Society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

7. **Environment and Sustainability**: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

9. **Individual and Team Work**: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

10. **Communication**: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

11. **Project Management and Finance**: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

12. **Life-long Learning**: Recognize the need for, and have the preparation and ability to engage in independent and lifelong learning in the broadest context of technological change.

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering [Sandwich] (2019 pattern)

402061: Industrial In-plant Training - II					
Teaching Scheme		**Credits**		**Examination Scheme**	
Practical	14 Hrs./Week	PR	7	TW	150 Marks
				OR	100 Marks

Pre-requisites: In-plant Training, Project Based Learning

Course Objectives:

1. To provide platform to students to get feel of the actual working environment and to gain practical knowledge and skills, which in turn will motivate, develop and build their confidence.
2. To provide students the opportunity to test their interest in a particular professional career.
3. To develop skills and techniques in the application of theory to practical work situations.
4. To cultivate student's leadership ability and responsibility to perform or execute the given task.
5. To prepare student for professional work reports and presentations.
6. To make aware student about social and professional responsibilities.

Course Outcomes:

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

CO1. Capability and enthusiasm for self-improvement through continuous professional development and life-long learning
CO2. Knack to be a multi-skilled engineer with good technical knowledge, management, leadership and entrepreneurship skills.
CO3. Capability to acquire and apply fundamental principles of engineering.
CO4. Ability to identify, formulate and model problems and find engineering solution based on a systems approach.
CO5. Awareness of the social, cultural, global and environmental responsibility as an engineer.
CO6. Ability to communicate efficiently.

Course Contents

Students are expected to get familiarized with industrial environment and learn the different industrial practices, techniques and its implementation during their Industrial In-Plant Training II. Student shall undergo industrial training in Large or Medium size Core mechanical industry in various departments,

preferably the same industry where first six months training is completed. During training, students should understand technical and non-technical aspects of industry.

Following are the few industry aspects to be focused during training for the for better understanding and outcome of Industrial training.

Orientation to industry, Departments in Manufacturing Industries, R & D (research and development, quality control, finance, marketing, maintenance, Engineering Projects, Industrial Design and Drawing Practice, Manufacturing processes involved, Machine Tools, Manufacturing Automation, Material Handling, Measurement and Quality Control,

Processes and Operation Planning: 10. Machines, Personal and Plant safety:

Operational Guidelines

1. Duration of training will be full sixth semester (First semester of Final year)
2. It is expected that students work in all the major departments of the industry.
3. The student shall be asked to complete two assignments / case studies based on the problems / scope for improvement identified in the industry.
4. Institute will assign a supervisor faculty to each student for Mentoring and Guidance.
5. Supervisor faculty will guide and monitor student's work progress by visiting the industry on regular basis.
6. Student shall maintain logbook (Diary Notes) during the training

Term Work Guidelines

1. Comprehensive hard bound report based on observations, learning and contributions during training and minimum two case studies/assignments
2. Logbook/diary maintained by student during training

Assignment/case study report should contain subtopics like Introduction, problem/ task identification, Objectives, Methodology, process to be followed/action plan, Observation and solution, Comparison with the earlier status, include graphs wherever necessary, Quantification (the results should be represented in terms of %), Conclusions highlighting major outcome of assignment.

Instructions for In-Plant Training Report

Black hardbound copies of the report of Industrial In-plant Training - II to be submitted to the department. Report should be preferably of 70-90 pages.

Report text should be Times New Roman 12 pt. and both side justified, 1.15-line spacing, double spacing for paragraph.

Report Format

ABSTRACT (Minimum 300 words)

1. Introduction

The purpose of this section is to provide a brief introduction of the work. It should not exceed two pages (2) but should be a minimum of 300 words and should comprise the following topics:

a) **Company Background:** A brief and clear presentation the type of business of the company and the functions of the department(s) in which the student undergone In-Plant Training. Care should be taken that industry profile should not be repeated from IIT-I report.

b) **Training Objectives:** Description of the student's training objective and work accomplishments.

2. Formal Training provided: Description of the training provided. Brief description of each department, machines, equipment, instruments used in the industry is expected.

- Objectives of the training
- Details of machines, equipment, instruments used in the industry
- Tools & Technology Used
- Techniques studied in different Departments
- Software and Tools Used
- Highlights of Training Exposure (area, scope)]

3. Problem Identification/Case Study: (two Assignments) (Discussions and detailing as per instructions given in Term work guidelines)

4. Conclusions and future scope

5. References

Instructions for IIT-II report

Black hardbound copies of the report of Industrial In-plant Training - II to be submitted department. (03 Copies). Report should be preferably of 70 - 90 pages.

Report text should be Times New Roman 12 pt. and both side justified, 1.15-line spacing, double spacing for paragraph, Section titles should be bold with 14 pt typed in all capital letters and should be left aligned. Text should be aligned from both sides (justified).

Use the paper size 8.5" x 11" or A4 (210 x 197 mm). Please follow the margins given bel Top 1", Left

1.5", Bottom 1.25", Right 1". Illustrations (charts, drawings, photographs, figures) are to be in the text. Illustrations must be sharp, clear, black and white. Illustrations from internet are not acceptable.
Examination
Oral shall be based on Term Work completed during training. Oral Examination shall be conducted by appointing one Internal Examiner and one External Examiner from industry.

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering [Sandwich] (2019 pattern)

402062: Industrial Project#					
Teaching Scheme		Credits		Examination Scheme	
Practical	12 Hrs./Week	PR	6	TW	100 Marks
				OR	100 Marks

Prerequisites: Project Based Learning, In-plant Training, Mini Project, Laboratory works, Skill Development, Audit Courses, Industrial Visits

Course Objectives:

1. To apply theory knowledge to solve live industrial problem.
2. To understand the methodology to solve industrial problem in a systematic way.
3. To develop creativity and innovative approach.

Course Outcomes:

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

CO1. Correlate and implement theory knowledge to solve specific industrial problems.
CO2. Develop systematic approach to solve specific industrial problem.
CO3. Competent to face industrial problems.

Course Contents

Student shall decide a suitable project in consultation with the industry authority. The scope of the project shall be such as to complete it within the stipulated training period. Project progress review shall be taken on regular basis by college and industry.

Student shall maintain a project activity book.

Project may be covering following industrial aspects:

1. Manufacturing/Fabrication of a proto-type machine including selection, concept, design, material,
2. Manufacturing of the components, assembly of components. Testing and performance evaluation.
3. Improvement of existing machine/equipment/process.
4. Design and fabrication of Jigs and fixtures, dies, tools, special purpose equipment, inspection gauges,
5. Measuring instruments for automats.
6. Computer aided design, analysis of components such as stress analysis.
7. Problems related to productivity improvements.
8. Problems related to value engineering.
9. Problems related material handling systems.
10. Energy audit of a section in an organization/plant, Industrial waste and its control.

11. Design of a test rig for performance evaluation of machine device.
12. Product design and development.
13. Detail cost estimation of products.
14. Analytical evaluation and experimental verification of any mechanical engineering problems encountered.
15. Quality systems and management.
16. Low cost automation.

Student shall prepare and submit a detailed report based on project work.

Examination

The oral examination shall be based on the Project work. The examination shall be conducted by an internal and an external examiner (External Examiner shall be from industry).

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering [Sandwich] (2019 pattern)

402063: Technical Paper Presentation					
Teaching Scheme		**Credits**		**Examination Scheme**	
Practical	2 Hrs./Week	PR	1	OR	50 Marks

Prerequisites: Seminar, Audit courses, Soft skill, Project based learning

Course Objectives:

1. CREATE interest in Research and advanced technologies
2. SYNTHESIZE the self-learned and searched information

Course Outcomes:

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

CO1: DEVELOP self-learning skills
CO2: IDENTIFY new trends in engineering research
CO3: SUMMARIZE the understanding research in different areas of engineering
CO4: DEMONSTRATE communication and presentation skills

Course Contents

The Technical Paper Presentation (TPP) is expected to be on the state-of-the-art technical topic related to Mechanical Engineering but beyond/outside the syllabus. The Report and the Presentation should be based on the literature, mainly collected and analyzed from the latest research papers from reputed national and international technical journals (minimum 3 research papers are to be submitted along with the report)

The TPP must be approved by the College Guide and finalize the report's index within the first month of the semester's start, and students must elevate the seminar to the level of a research article that can be published as a review article, research/review paper or technical notes in a reputed national or international journal. The concluding section of the TPP report must include information about pertinent research findings from publications that have undergone peer review and been published in either national or international journals.

Report	Report should consist of: i) Title page (in college format/template) ii) Certificate iii) Acknowledgement iv) Contents sheet v) List of Tables/Figures/Graphs etc. or Nomenclature and Symbols vi) Abstract vii) Background and Introduction viii) Analyzed contents ix) Results and Discussions x) Conclusion (in the words of, and as understood by the student from at least 3 research papers) xi) Future scope xii) References Note: Point no. vi to ix should be of 15 to 20 pages and printed on both the sides of paper.
Text	Font: 12, Times New Roman, spacing 1.5
Binding	Spiral bound
Paper	A4 Size
Internal assessment	One mid-term presentation by the student on the chosen topic
Examination	Power-point Presentation – max.10 mins Questions and Answers – max. 5 mins
Marks	Equally divided between the Report and the Presentation
Examiner	Two – 1 Internal & 1 External (Academic/Research Institute)

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering [Sandwich] (2019 pattern)

402064: Energy Engineering and Management (Self-Study-III)**					
Teaching Scheme		**Credits**		**Examination Scheme**	
-	**-**	**TH**	**3**	**In-Semester**	**30* Marks**
Self-Study, In-Semester Examination at Institute Level				**End-Semester**	**70 Marks**

Prerequisites: Thermodynamics, Systems in Mechanical Engineering

Course Objectives:

1. To understand the layout, construction and working of thermal power plant and observe environmental impact of energy system.
2. To study the layout, construction and working of hydel Energy and Nuclear Energy plants.
3. To understand construction, principle of working of various Renewable Energy Systems.
4. To study the energy need and role of Energy management
5. To learn various Energy audit techniques applied to an organization/Industry.
6. To study the cost of electrical power generation and consumption and to learn about construction and working of various waste heat recovery systems.

Course Outcomes:

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

CO1.**ANALYZE** working of thermal power plant and observe environmental impact of energy system.

CO2.**EXPLAIN** layout, construction and working of hydel Energy and Nuclear Energy plants.

CO3.**EXPLAIN** fundamental of Renewable Energy Systems.

CO4.**EXPLAIN** the energy need and role of Energy management.

CO5.**CARRY OUT** Audit of an organization/Industry.

CO6.**ANALYZE** the economics of power generation and **EXPLAIN** waste heat recovery systems.

Course Contents	
Unit 1	**Thermal Energy based plant and Environment Impact of Energy System**
Thermal Energy Based Plant: layout of modern thermal energy based plant with different circuits, site selection, classification of coal, coal benefication, selection of coal for thermal power plant, slurry type fuels, in-plant handling of coal, pulverized fuel handling systems, FBC systems, improved Rankine cycle: Rankine cycle with only reheating and only regeneration (Numerical Treatment), cogeneration. **Environmental impact of energy system**: Different pollutants from energy plants, methods to control pollutants: types of scrubbers; ash handling system; dust collections; ESP, carbon credits and footprints, water treatment in thermal energy based plant.	
Unit 2	**Hydel Energy and Nuclear Energy**
Hydel energy: Basics of hydrology, hydrograph, flow duration curve, mass curve (Numerical Treatment), hydel power plant (HPP)- site selection, classification of HPP (Based on head, nature of load, water quantity), criteria for turbine selection, components of HPP- dams; spillways; surge tank and forebay, advantages and disadvantages of HPP. **Nuclear energy:** Nuclear fission/fusion, elements of NPP, types of nuclear reactor (PWR, BWR, CANDU, LMCR, GCR, Fast Breeder) nuclear fuels, moderators, coolants, control rod and shielding, nuclear waste disposal, nuclear power development programme of India.	
Unit 3	**Renewable Energy Systems**
Solar thermal and photovoltaic energy: solar thermal plant based on flat plate collector; solar photovoltaic systems, applications, economics and technical feasibility. **Wind Energy:** wind availability, basic components of wind mills, performance operating characteristics, wind solar hybrid power plants, Cost economics and viability of wind farm. **Geothermal Energy:** typical geothermal field, superheated steam system, flash type, binary cycle plant, economics of geothermal energy. **Tidal Energy:** components, single basin, double basin systems **Ocean Thermal Energy:** working principle, Claude /Anderson /hybrid cycle Wave Energy: dolphin type wave machines **MHD Power Generation:** working principle, open/ close cycle MHD generator	

Fuel cell: main components, working Principle

Biomass Energy: biomass gasifier

Hydrogen Energy: principle of hydrogen production, hydrogen storage, applications.

Unit 4	**Energy Scenario and Management**

Energy needs of a growing economy, Current and long-term energy scenario - India and World, Concept of energy conservation and energy efficiency, Energy and environment, Need of Renewable energy,

Principles of Energy management, Energy policy, Energy action planning, Energy security and reliability, Energy sector reforms.

Unit 5	**Energy Audit**

Need of Energy Audit, Types of energy audit, Energy audit methodology, Energy audit instruments, Analysis and recommendations of energy audit, Benchmarking, Energy audit reporting, Introduction to software and simulation for energy auditing, Current Energy Conservation Act and Electricity Act and its features.

Unit 6	**Energy Economics of Power Generation and Waste Heat Recovery**

Economics of power generation: Cost of electrical energy, load curves, performance and operation characteristics of power plants, load division, all terminologies related to fluctuating load plant, tariff. analysis of energy bill.

Waste Heat Recovery: Classification, Application, Concept of Pinch analysis, Potential of WHR in Industries, Saving potential, CDM projects.

Books and other resources

Text Books:

1. Domkundwar & Arora, Power Plant Engineering, Dhanpat Rai & Sons, New Delhi
2. Domkundwar & Domkundwar- Solar Energy and Non-Conventional Sources of Energy, Dhanpat Rai& Sons, New Delhi.
3. R.K.Rajput, Power Plant Engineering, Laxmi Publications New Delhi.
4. Bureau of Energy Efficiency Study material for Energy Managers and Auditors Examination: Paper I to IV.

References Books:

1. E.I.Wakil, Power Plant Engineering, McGraw Hill Publications New Delhi
2. P.K.Nag, Power Plant Engineering, McGraw Hill Publications New Delhi.
3. R.Yadav , Steam and Gas Turbines ,Central Publishing House, Allahabad.
4. G.D.Rai, Non-Conventional Energy Sources, Khanna Publishers, Delhi
5. S.P.Sukhatme, Solar Energy,Tata McGraw-Hill Publications, New Delhi 6. G R Nagpal, Power Plant Engineering , Khanna Publication
6. Barney L. Capehart, Wayne C. Turner and William J. Kennedy, "Guide to Energy Management", Seventh Edition, The Fairmont Press Inc., 2012.
7. Craig B. Smith, "Energy Management Principles", Pergamon Press, 2015.
8. Hamies, "Energy Auditing and Conservation; Methods, Measurements, Management and Case Study", Hemisphere Publishers, Washington, 1980.
9. Albert Thumann P.E. CEM, William J. Younger CEM, "Handbook of Energy Audit", The Fairmont Press Inc., 7th Edition.
10. Wayne C. Turner, "Energy Management Handbook", The Fairmont Press Inc., , Georgia.

Web References:

For Energy Engineering

1. https://nptel.ac.in/courses/112107291
2. https://nptel.ac.in/courses/112103277
3. https://nptel.ac.in/courses/103103206
4. https://nptel.ac.in/courses/115103123
5. https://cea.nic.in/?lang=en

For Energy Audit

1. www.npcindia.gov.in
2. http://www.bee-india.nic.in
3. www.aipnpc.org (for entire course material along with case studies)
4. https://beeindia.gov.in/sites/default/files/EC%20Guidelines-Final.pdf

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering [Sandwich] (2019 pattern)

<table>
<tr><th colspan="6">402065: Industrial Engineering and Organizational Management
(Self-Study - IV)**</th></tr>
<tr><th colspan="2">Teaching Scheme</th><th colspan="2">Credits</th><th colspan="2">Examination Scheme</th></tr>
<tr><td>-</td><td>-</td><td>TH</td><td>3</td><td>In-Semester</td><td>30* Marks</td></tr>
<tr><td colspan="4">Self-Study, In-Semester Examination at Institute Level</td><td>End-Semester</td><td>70 Marks</td></tr>
</table>

Prerequisite: 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. Student shall learn various Industrial Engineering techniques implemented in relation to production management in actual industrial practice.
3. To introduce various aspects of facility design and undergo with various world class techniques in practice
4. To acquaint the students with various components and functions of Production Planning and Control and proper selection of process for production in actual practice in industry.
5. To acquaint the student about inventory management and approaches to control.
6. To acquire the students with concepts of ergonomics, value engineering and job evaluation.

Course Outcomes

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

CO1. Understand Concept of Industrial engineering and its role in production management.

CO2. Apply work study techniques and understands its importance for better productivity in organization..

CO3. Demonstrate the ability to select plant location, appropriate layout and material handling equipment.

CO4. Use PPC tools for effective planning, scheduling and managing the shop floor control and Plan inventory requirements to exercise effective control on manufacturing requirements.

CO5. Apply aspects of Process planning for process chart, ALB and group technology.

CO6. Apply Ergonomics and legislations for human comfort at work place and understands the role of value engineering in improving productivity.

Course Contents	
Unit 1	**Introduction, Management and Productivity**
Introduction to Industrial Engineering, Historical background and scope, applications of Industrial Engineering, Contribution of Taylor, Gilbert, Gantt, Maynard, Ford, Deming and Ohno to industrial engineering, Management: Basic concepts of Management, Principle, levels, types and functions of management, Maslow's hierarchy of needs. Productivity: Definition of productivity, Measures of Productivity, Scope and Measurement, Productivity Improvement methods for organizations	
Unit 2	**Organization and Work study**
Organization-types of business Organization, advantages and disadvantages, Organization structure, span of control, Types of Organization structures, organization chart. Method Study: Introduction, steps, tools and techniques used in method study, 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: Time study: 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. (Numerical) Introduction to PMTS, MTM, and MOST.	
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. Dynamic plant layout. **Material Handling:** Objectives and benefits of Material handling, Relationship between layout and Material handling, Equipment selection.	
Unit 4	**PPC and Inventory 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. Introduction to a line of balance, assembly line balancing, and progress control.

Forecasting techniques: Causal and time series models, Moving average, Exponential smoothing, Trend and Seasonality. (Numerical)

Inventory control: EOQ (Numerical), 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) and Supply Chain Management (SCM)

Moving average method, Exponential smoothing, capacity planning, Inventory control and classification-objectives of inventory control, EOQ(Numerical), inventory models, ABC,FMS,VED analysis.

Unit 5	**Process planning and Network Analysis**

Process planning: Introduction- Role of Product Engineering department, Phases of process planning, process planning concept and procedure, make or buy decision, process selection and procedure, process chart (root chart), Machine requirements, Line Balancing, advantages of assembly line, methods of Line balancing, numerical on ALB, Introduction to group technology

Network Analysis: Network technique, terminology, PERT, CPM, comparison and simple numerical.

Unit 6	**Ergonomics, Value Engineering and Job Evaluation**

Ergonomics: Introduction to ergonomics and human factors Engineering - physiological basis of human performance, basic anatomy of human body and its functional systems; principles of ergonomics, design of display and controls in relation to information processing by human being. Introduction to Rapid Upper Limb Assessment (RULA) and Rapid Entire Body Assessment (REBA)
Value engineering: VE concepts, Principles, Methodologies and standards, methods of functional analysis.
Job Evaluation and Wage Plan: Objective, Methods of job evaluation, job evaluation procedure, merit rating (Performance appraisal), method of merit rating, wage and wage incentive plans, Performance appraisal, concept of KRA (Key Result Areas), Introduction to industrial legislation.

Books & 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.
5. Prof L C Jhamb, "Production(Operations) Management, Everest Publishing house

6. Mukherjee & Kachwala, "Operations Management & Productivity Tech", Prentice Hall of India
7. P. Rama Murthy, "Production & Operation Management", New Age International (P) Ltd.
8. Adam EE & RJ Ebert, "Production and operation management:, Prentice Hall
9. Riggs. J. L., "Production system, planning, analysis and control", John Weily and sons
10. James Dilworth, "Production and operation management", McGraw Hill Book Company, New York.
11. Janat Shah, Supply Chain Management - Text and Cases, Pearson Education, 5th edition, 2012.

Reference 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; 3rd New edition (2010).
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. PremVrat, 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 McGinnes and John A. White, "Facility Layout and Location- An Analytical Approach", PHI, 1993
13. G.K.Agarawal, "Plant Layout and Material Handling", Jain Brothers, 2007

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

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering [Sandwich] (2019 pattern)

402054: 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
A. Yoga Practices **B.** Stress Management 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.

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering [Sandwich] (2019 pattern)

<table>
<tr><th colspan="6">402066: Design of Transmission Elements***</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>4 Hrs./week</td><td>TH</td><td>4</td><td>In-Semester</td><td>30 Marks</td></tr>
<tr><td>Practical</td><td>2 Hrs./week</td><td>PR</td><td>1</td><td>End-Semester</td><td>70 Marks</td></tr>
<tr><td colspan="4">In-Semester examination shall be of 1:30 Hrs.</td><td>TW</td><td>25 Marks</td></tr>
<tr><td colspan="4">End semester examination shall be of 3 Hrs.</td><td>OR</td><td>25 Marks</td></tr>
<tr><td colspan="6">Prerequisites: Classification of Gears, Gear Terminology, Terminology of Helical gear, Virtual number of teeth. Classification, selection and application of Belt, chain and rope drives.</td></tr>
<tr><td colspan="6">Course Objectives:
1. APPLY fundamentals for the design and/or selection of elements in transmission systems.
2. UNDERSTAND the philosophy that real engineering design problems are open-ended and challenging.
3. DEMONSTRATE design skills for the problems in real life industrial applications.
4. DEVELOP an attitude of team work, critical thinking, communication, planning and scheduling through design projects.
5. PERCEIVE about safety, ethical, legal, and other societal constraints in execution of their design projects.
6. BUILD a holistic design approach to find out pragmatic solutions to realistic domestic and industrial problems</td></tr>
<tr><td colspan="6">Course Outcomes:
On completion of the course, learner will be able to
CO1.APPLY the principle of Spur & Helical gear design for industrial application and PREPARE a manufacturing drawing with the concepts of GD&T.
CO2.EXPLAIN and DESIGN Bevel & Worm gear considering design parameters as per design standards.
CO3.SELECT&DESIGN Rolling and Sliding Contact Bearings from manufacturer's catalogue</td></tr>
</table>

for a typical application considering suitable design parameters.

CO4.**DEFINE** and **DESIGN** various types of Clutches, Brakes, used in automobile.

CO5.**APPLY** various concept to **DESIGN** Machine Tool Gear box, for different applications

CO6.**ELABORATE** various modes of operation, degree of hybridization and allied terms associated with hybrid electric vehicles.

Course Contents

Unit 1	**Spur and Helical Gears**

Introduction to gears: Material selection for gears, Modes of gear tooth failure, Gear Lubrication Methods.

Spur Gears: Number of teeth and face width, Force analysis, Beam strength (Lewis) equation, Velocity factor, Service factor, Load concentration factor, Effective load on gear, Wear strength (Buckingham's) equation, Estimation of module based on beam and wear strength, Estimation of dynamic tooth load by velocity factor and Buckingham's equation.

Helical Gears: Force analysis of Helical Gear, Beam Strength of Helical Gear, Wear strength and estimation of effective load based on Velocity factor (Barth factor) and Buckingham's equation. (No numerical on force analysis of helical)

Unit 2	**Bevel and Worm Gear**

Bevel Gears: Types of Bevel gears, Terminology, Virtual number of teeth, and force analysis of Straight Bevel Gear. Design of Straight Bevel Gear based on Beam Strength, Wear strength and estimation of effective load based on Velocity factor (Barth factor) and Buckingham's equation**.** (Simple numerical to be taken no design calculations)

Worm Gears: Worm and worm gear terminology and proportions of worm and worm gears, Force analysis of worm gear drives, Friction in Worm gears, efficiency of worm gears, Worm and worm gear material, Strength and wear ratings of worm gears (Bending stress factor, speed factor, surface stress factor, zone factor) IS 1443-1974, *(Simple numerical to be taken no design calculations)*

Unit 3	**Sliding and Rolling Contact Bearing**

Sliding contact bearing (Theoretical treatment only): Introduction to sliding contact bearing, classification, Reynolds's equation (2D), Petroff's equations, Sommerfeld number, Parameters of bearing design.

Rolling Contact Bearings: Types of rolling contact Bearings and its selection, Static and dynamic load carrying capacities, Stribeck's Equation, Equivalent bearing load, Load-life relationship,

Selection of bearing life, Selection of rolling contact bearings from manufacturer's catalogue, Design for cyclic loads, Types of failure in rolling contact bearings - causes and remedies. (Simple Numerical treatment)	
Unit 4	**Design of Clutches and Brakes**
Clutches: Introduction, Types of clutches, Material, Positive clutches, friction clutches, single plate, multiple plate, Cone clutch, and centrifugal clutches, Application of friction clutches automotive and industrial machinery sector. (Only Theoretical Treatment) **Brakes**: Introduction, Types of brakes, Material, Design of band brake, external and internal shoe breaks internal expanding shoe brakes, design of disc brakes. Application of brakes in automotive and industrial machinery sector. (Only Theoretical Treatment)	
Unit 5	**Design of Machine Tool Gear Box**
Introduction to Machine Tool Gearboxes, classification, basic considerations in design of drives and its Applications, Determination of variable speed range, Graphical representation of speed and structure diagram, Ray diagram, selection of optimum ray diagram, Kinematic /Gearing Diagram, Deviation diagram, Difference between numbers of teeth of successive gears in a change gear box. *(Note: Full design problem to be restricted up to 2 Stages only & No design problem on deviation diagram*)	
Unit 6	**Transmission system in Hybrid Electric Vehicle**
Introduction, Types of Hybrid Electric Vehicles: Basic Classification, Basic Modes of Operation, Other Derivatives, Degree of Hybridization. Power Split Devices (PSD): Simple and EM compound PSD, HEV Component Characteristics: The IC Engine, Electric Machines, Battery, HEV Performance Analysis: Series HEV, Parallel HEV, HEV Component Sizing: General Considerations, Sizing for Performance, Optimum Sizing, Power Management: Control Potential, Control.	
Books and other resources	
Text Books: 1. Shigley J.E. and Mischke C.R., Mechanical Engineering Design, McGraw Hill Publication. 2. Spotts M.F. and Shoup T.E., Design of Machine Elements, Prentice Hall International. 3. Bhandari V.B, Design of Machine Elements, Tata McGraw Hill Publication Co. Ltd. 4. Juvinal R.C, Fundamentals of Machine Components Design, John Wiley and Sons.	

References Books:

1. Design Data - P.S.G. College of Technology, Coimbatore.
2. Vehicle Powertrain Systems by Behrooz Mashadi, David Crolla. A John Wiley & Sons, Ltd
3. Automobiles–Power trains and Automobiles–Dynamics by Crolla, David, A John Wiley &Sons, Ltd
4. Automotive Engineering Powertrain, Chassis System and Vehicle Body by David A Crolla, Elsevier B H New York, London, Oxford.
5. lack P.H. and O. Eugene Adams, Machine Design, McGraw Hill Book Co. Inc.
6. Willium C. Orthwein, Machine Components Design, West Publishing Co. and Jaico Publications House.
7. P. Kannaiah, Design of Transmission systems‖, SCIETCH Publications Pvt Ltd.
8. C.S. Sharma and Kamlesh Purohit, Design of Machine Elements, PHI Learning Pvt. Ltd.
9. D.K. Aggarwal& P.C. Sharma, Machine Design, S.K Kataria and Sons.
10. P. C. Gope, Machine Design: Fundamentals and Applications, PHI Learning Pvt. Ltd.
11. Bhandari, V. B. Machine Design data book, Tata McGraw Hill Publication Co. Ltd.
12. K. Mahadevan, K. Balveera Reddy, Design Data Handbook for Mechanical Engineers, CBS Publishers.

Web Links:

1. https://www.youtube.com/watch?v=b42_IO87X4s
2. https://www.youtube.com/watch?v=vTZ4Gah3wfo
3. https://www.youtube.com/watch?v=ER6LC7ONCD8
4. https://www.youtube.com/watch?v=nMsB6Soz4Hc
5. https://www.youtube.com/watch?v=WOTDbCPukoM
6. https://www.youtube.com/watch?v=fMNQglkUfhs
7. https://freevideolectures.com/course/2363/design-of-machine-elements

Term Work

Student shall complete the following activity as a Term Work;

The Submission shall consist of completion of Two Design projects and study Assignments. Oral examination shall be based on the practical undertaken during the semester.

Design Project 1 (Any one)

1. Design of gearbox for wind mill application or sluice gate.
2. Design of gearbox for building Elevator.
3. Design of gearbox for Hoist.
4. Design of gearbox for Worm gear box for Sugar Industry.
5. Design of clutch system for automobile
6. Design of brake system for automobile

Design Project 2

Projects shall be in the form of design of mechanical systems on multi speed spindle gear box including design of belt and pulley, Prime mover selection etc.

The design project shall consist of two full imperial (A1) size sheets involving assembly drawing with a part list and overall dimensions and drawings of individual components.

Manufacturing tolerances, surface finish symbols and geometric tolerances should be specified for important surfaces. A design report giving all necessary calculations of the design of components and assembly should be submitted in a separate file. Design data book shall be used wherever necessary to achieve selection of standard components.

Assignment: Any Two (PPT Presentation and Report)

1. Application orientated Numerical on HEV
2. Lubricating oils: Properties, additives, selection of lubricating oils
3. Properties & selection of sliding bearing materials
4. Application of belt, rope and chain drives and its selection method for Industry
5. Transmission system of HEV

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering [Sandwich] (2019 pattern)

402067: Machine Dynamics and Vibration					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	3 Hrs./week	TH	3	In-Semester	30 Marks
Practical	2 Hrs./week	PR	1	End-Semester	70 Marks
				OR	25 Marks

Prerequisites: Engineering Mechanics, Strength of Materials, Kinematics of Machinery, Engineering Mathematics and Numerical Methods.

Course Objectives:

1. Conversant with balancing problems of machines.
2. Understand gyroscopic effect in mechanical systems.
3. Understand fundamentals of undamped and damped free vibrations.
4. Understand fundamentals of forced vibrations.
5. Develop analytical competency in solving vibration problems.
6. Understand the various techniques of measurement and control of vibration.

Course Outcomes:

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

CO1: APPLY balancing technique for static& dynamic balancing of rotating & reciprocating parts.
CO2: ANALYZE the gyroscopic effect in mechanical systems.
CO3: ESTIMATE natural frequency for single DOF un-damped & damped free vibratory systems.
CO4: DETERMINE response to forced vibrations due to harmonic excitation, base excitation and excitation due to unbalance forces.
CO5: ESTIMATE natural frequencies, mode shapes for 2 DOF un-damped free longitudinal and torsional vibratory systems.
CO6: DESCRIBE vibration measuring instruments for industrial / real life applications along with suitable method for vibration control.

Course Contents	
Unit 1	**Balancing**
Static and dynamic balancing, balancing of rotating masses in single and several planes. Primary and secondary balancing of reciprocating masses, balancing of single cylinder engines, balancing of multi-cylinder in-line engines. Introduction to Balancing machines- Types, Classification and Methods.	
Unit 2	**Gyroscope**
Introduction, Precessional angular motion, Gyroscopic couple, Effect of gyroscopic couple on airplane, naval ship and crushing mill, Stability of a Four Wheel drive moving in a curved path (Theoretical treatment only), Stability of a two wheel vehicle taking a turn (Theoretical treatment only), Effect of gyroscopic couple on a disc fixed rigidly at a certain angle to a rotating shaft.	
Unit 3	**Single Degree of Freedom Systems – Free Vibration**
Fundamentals of Vibration: Elements of a vibratory system, vector representation of S.H.M., degrees of freedom, Types of vibration, equivalent stiffness and damping, formulation of differential equation of motion (Newton, D'Alembert and energy method). **Undamped free vibrations:** Natural frequency for one DOF longitudinal, transverse and torsional vibratory systems. **Damped free vibrations:** Different types of damping, Viscous damping – over damped, critically damped and under damped systems, initial conditions, logarithmic decrement, Introduction to dry friction or coulomb damping - frequency and rate of decay of oscillations.	
Unit 4	**Single Degree of Freedom Systems –Forced Vibration**
Forced vibrations of longitudinal and torsional systems, Frequency Response to harmonic excitation, excitation due to rotating and reciprocating unbalance, base excitation, magnification factor, Force and Motion transmissibility, Quality Factor. Critical speed of shaft having single rotor of undamped systems.	
Unit 5	**Two Degree of Freedom Systems – Undamped Free Vibrations**
Equation of motion for free vibration of spring coupled two DOF systems – longitudinal and torsional, natural frequency and mode shapes. Matrix method- eigen value and eigen vector, Combined rectilinear and angular motion, Vibrations of Geared systems.	
Unit 6	**Measurement and Control of Vibrations**
Measurement: Vibration Measuring Instruments, Accelerometers, Impact hammer, Vibration shakers, Vibration Analyzer, Vibration based condition monitoring, Analysis of Vibration Spectrum, Standards related to measurement of vibration.	

Control: Vibration control methods, passive, semi active and active vibration control, control of excitation at the source, control of natural frequency, Vibration isolators, Tuned Dynamic Vibration Absorber.

Books and other resources

Text Books:

1. Rao S. S. Mechanical Vibrations‖, Pearson Education Inc. New Delhi.
2. Grover G. K. Mechanical Vibrations‖, New Chand and Bros., Roorkee
3. Wiiliam J Palm III, ¯Mechanical Vibration‖ Wiley India Pvt. Ltd, New Delhi
4. Uicker J.John, Jr, Pennock Gordon R, Shigley Joseph E.Theory of Machines and Mechanisms‖ International Version, OXFORD University Press, New Delhi.
5. S. S. Rattan, Theory of Machines, Third Edition, McGraw Hill Education (India) Pvt. Ltd.

References Books:

1. Weaver, Vibration Problems in engineering‖ 5th Edition Wiley India Pvt. Ltd.
2. Alok Sinha, Vibration of Mechanical System‖, Cambridge university Press.
3. Dr Debabrata Nag, Mechanical Vibrations‖, Wiley India Pvt. Ltd, New Delhi.
4. Kelly S. G. Mechanical Vibrations, Schaum_s outlines, Tata McGraw Hill Publishing
5. Meirovitch, Elements of Mechanical Vibrations‖, McGraw Hill
6. Shrikant Bhave, Mechanical Vibrations Theory and Practice, Pearson, New Delhi

Term Work

A] Any Eight Experiments (Sr. No. 1 to 11)

1. Balancing of wheel / rotor on computerized balancing machine OR Experimental verification of dynamic balancing of rotating masses.
2. To verify the gyroscopic effect on a spinning disc.
3. To determine the natural frequency of damped vibration of single degree freedom system and to find it ‘s damping coefficient.
4. To obtain frequency response curves of single degree freedom system of vibration for different amount of damping.
5. To verify natural frequency of torsional vibration of two rotor system and position of node.
6. To determine natural frequency of transverse vibration of beam using vibration analyzer
7. To determine critical speed of shaft with single rotor.

8. Experimental verification of principle of dynamic vibration absorber.
9. Experiment on shock absorbers and to plot its characteristic curve.
10. To determine the condition of a machine using vibration severity chart
11. A case study (Industrial visit / In-house) based on Conditioning Monitoring and Fault Diagnosis.

B] Compulsory Assignment: Any One

1. Simulation (using suitable software) of free response of SDOF damped system to demonstrate different damping conditions by solving differential equation numerically.

OR

2. Simulation (using suitable software) of total response of SDOF damped system to harmonic excitation by solving differential equation numerically.

OR

A case study based on conditioning monitoring and fault diagnosis using machine learning.

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering [Sandwich] (2019 pattern)

402068: Artificial Intelligence in Mechanical Engineering					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	3 Hrs./week	TH	3	In-Semester	30 Marks
Practical	2 Hrs./week	PR	1	End-Semester	70 Marks
				OR	25 Marks

Prerequisites: Linear Algebra, Probability, Statistics, Logical Reasoning.

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 mechanical 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 mechanical engineering problems.

Course Contents	
Unit 1	**Introduction to AI & ML**
Introduction to Artificial Intelligence, Machine Learning and Data Science, History of AI, Comparison of AI with Data Science, Need of AI in Mechanical Engineering, Applications of ML in Mechanical Engineering. **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, information gain, and Gini Index, Exhaustive, best first, Greedy forward & backward, Applications of feature extraction and selection algorithms in Mechanical Engineering **(Numerical on Ranking, Decision tree - Entropy reduction, information gain, and Gini Index)**	
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 Mechanical Engineering	
Unit 4	**Development of ML Model**
ML Model development: 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. **(Numerical on confusion matrix)**	
Unit 5	**Reinforced and Deep Learning**
Characteristics of reinforced learning; Algorithms: Value Based, Policy Based, Model Based; Positive vs 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 Mechanical Engineering. **(Numerical on ANN**)	

Unit 6	Applications

Human Machine Interaction, Predictive Maintenance, Fault Detection, Image-based part classification, Process Optimization, Material Inspection, Tuning of control algorithms.

(The applications should focus on the topics of Mechanical and Industrial Engineering. Published research papers along with reference books should be referred.)

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.

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
5. Kaushik Kumar, Divya Zindani, J. Paulo Davim - Artificial Intelligence in Mechanical and Industrial Engineering-CRC Press (2021)

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

Term Work

List of Experiments:

1. To study supervised/unsupervised/Reinforcement learning approach.
2. To acquire, visualize and analyze the data set (from time-domain/ frequency-domain/ etc.).
3. To extract features from given data set and establish training data.
4. To select relevant features using a suitable technique.

OR

5. To use PCA for dimensionality reduction.
6. To classify features/To develop a classification model and evaluate its performance (any one classifier).
7. To develop regression model and evaluate its performance (any one algorithm).
8. Markov process for modelling manufacturing processes.

OR

9. Reinforced Learning for optimizing engineering designs / Robot Guidance and Navigation.
10. GA for optimization of multi-dimensional function/path planning in robotics.

OR

11. NN for parameter and model identification/tuning of Control Algorithms.

Note:

- Students need to apply the computational algorithms using suitable software/programming language.
- Experiments 1, 2, 3, 6 & 7 are compulsory. Experiments 2 to 7 to be taken on same data set

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering [Sandwich] (2019 pattern)

402069A: Automobile Engineering					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	3 Hrs./week	TH	3	In-Semester	30 Marks
				End-Semester	70 Marks

Prerequisites: I. C. Engines, Theory of Machines, Thermal Engineering, Basics of Electrical and Electronics

Course Objectives:

1. To make the student conversant with basic automobile systems.
2. To develop competencies in analysis of vehicle types and categories.
3. To make the student conversant with automobile safety, electrical system and vehicle maintenance.
4. To understand the emerging trends of electric vehicles, hybrid electric vehicles.

Course Outcomes:

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

CO1. Identify the different part and types of the automobile
CO2. Describe the systems and sub-systems of a typical automobile
CO3. Apply analysis for selection of automobile sub systems
CO4. Understand and apply knowledge for selection of Automobile electrical systems.
CO5. Understand the environmental implications of automobile emissions and maintenance.
CO6. To apply the knowledge of EVs, HEVs and Engine Management system

Course Contents

Unit 1 **Introduction of Automobile**

Layout of automobile, Classification and Specification of Automobile, introduction to chassis and body components. Various types of frame.
Types of Car body - Saloon, convertibles, Limousine, Estate Van, Racing and Sports car. Car body construction, automotive vehicles terminologies.

Transmission System:

Clutches, principle, types, cone clutch, single plate clutch, multi plate clutch, magnetic and centrifugal clutches, fluid fly wheel – Gear boxes, types, sliding mesh, constant mesh, synchromesh gear boxes, epicycle gear box, over drive torque converter.

Propeller shaft – Hotch – Kiss drive, Torque tube drive, universal joint, final drive, differential and rear axles – types

Unit 2	Front Axle, Steering system, Suspension System

Front Axle: stub axle, rigid axle beam, different types of stub axles

Steering system: Functions, requirements, Steering geometry, center point steering. Types of steering mechanism – Ackerman steering mechanism, Davis steering mechanism, steering gears – types, steering linkages, power steering system, wheel alignment.

Suspension System: Functions and objectives, types of suspension springs- leaf, coil, rubber and composite material springs. shock absorbers, gas filled shock absorbers, torsion bar, types of suspension systems, front axle suspension, rear suspension systems, Air suspension system, active suspension,

Hydro gas, rubber suspension, interconnected suspension.

Unit 3	Braking System, Wheels and Tyres

Braking System: functions and types of brakes, operation and principle of brakes, classification of brakes Mechanical brake system, Hydraulic brake system, Master cylinder, wheel cylinder tandem master cylinder Requirement of brake fluid, Pneumatic and vacuum brakes. Introduction to ABS, EBD, ESP.

Wheels- Requirements of good wheel, Types of Wheels, Types of Rims, Construction of disc wheel, Wheel specifications.

Tyres- Requirements of good tyre, Construction of tyres and tyre specifications, Types of tyres. Tyre rotation, tyre retreading, factors affecting tyre performance and life, Inflation pressure and its effects, Tread Patterns.

Unit 4	Automobile Electrical System

Charging circuit, generator, current – voltage regulator – starting system, Bendix drive mechanism solenoid switch,

Lighting System: Principle of automobile illumination, head lamp mounting and construction, sealed beam auxiliary lightings,

Dashboard Instruments: horn, windscreen-wipers, signaling devices, Horn, fuel level indicating gauge, oil and temperature gauge, speedometer, odometer, engine temperature indicator.

Batteries and Starting System:

Different types of Batteries – principle, rating, testing and charging. Starter motors characteristics, capacity requirements. Drive mechanisms. Starter switches.

Unit 5	Automobile Maintenance

Types of vehicle maintenance schedules (daily, weekly and monthly), Break down, Preventive; Predictive maintenance practices, maintaining interior and exterior cleaning. Methods of repair/servicing and overhauling of
Clutch, gearbox, propeller shaft, differential, axles, steering system, suspension system, break system, electrical system.

Automotive Emission Control Systems: Sources of emission from engines, Automotive emission controls, controlling crankcase emissions, Controlling evaporative emissions, Exhaust gas recirculation, Catalytic converter, Emission standards- Euro I, II, III and IV norms, Bharat Stage norms.

Sensors and microprocessors in automobiles: Basic sensor arrangements. principle of working and application of various light

Sensors, proximity sensors and Hall effect sensors. Types of sensors – oxygen sensor, hot-wire anemometer sensor, vehicle speed sensor, detonation sensor, accelerometer sensor, crank position sensor. Microprocessor and microcomputer controlled devices in automobiles such voice warning system, travel information system, keyless entry system, automatic transmission system, electronic steering system.

Unit 6	Engine Management systems

Combined ignition and fuel management systems. Exhaust emission control, Digital control techniques – Dwell angle calculation, Ignition timing calculation and Injection duration calculation. Complete vehicle control systems, Artificial intelligence and engine management. Hybrid vehicles and fuel cells.

Electric vehicle: layout, Components of an EV, EV batteries, chargers, drives, transmission and power devices. Advantages and disadvantages of EVs, performance of electric vehicles, safety and challenges in electric vehicles.

Hybrid vehicles: Concepts of hybrid electric drive train, types, architecture of series and parallel hybrid electric drive train, merits and demerits, hybrid electric drive train design, mild and full hybrids, plug-in hybrid electric vehicles and range extended hybrid electric vehicles Hybrid electric vehicles, HEV drive train components, advantages of HV.

Books and other Resources

Text Books:

1. Dr. Kirpal Singh, “Automobile Engineering”, Standard Publishers distributors.
2. R. B. Gupta, Automobile Engineering, Satya Prakashan.
3. Narang G. B. S, “Automobile Engineering”, S. Chand and Company Ltd.

References Books:

1. Joseph Heitner, Automotive Mechanics, CBS publications
2. Srinivasan.S, Automotive Mechanics, 2nd Edition, Tata McGraw-Hill, 2003
3. Crouse and Anglin, Automotive Mechanism, 9th Edition. Tata McGraw-Hill, 2003.

4. Jack Erjavec, A Systems Approach to Automotive Technology, Cengage Learning Pub., 2009.
5. K. Newton and W. Seeds, T.K. Garrett, “Motor Vehicle”, 13thEdition, Elsevier publications.
6. N. K. Giri, Automobile Mechanics
7. SAE Manuals and Automotive Industry Standards (AIS)

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering [Sandwich] (2019 pattern)

402069B: Refrigeration and Air-Conditioning					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	3 Hrs./week	TH	3	In-Semester	30 Marks
				End-Semester	70 Marks

Prerequisites: Basic Thermodynamics- Laws of thermodynamics, Ideal gas processes, Thermodynamic cycles, Properties of pure substance, Basic Psychrometry; Fluid properties. Modes of heat transfer, Condensation and Boiling, Heat Exchangers.

Course Objectives:

1. Learning the fundamental principles and different methods of refrigeration and air conditioning
2. Study of various refrigeration cycles and evaluate performance of refrigeration systems.
3. Comparative study of different refrigerants with respect to properties, applications and environmental issues.
4. Understand the basic air conditioning processes on psychometric charts, calculate cooling load for its applications in comfort and industrial air conditioning
5. Study of the various equipment-operating principles, operating and safety controls employed in refrigeration air conditioning systems
6. Study air distribution systems for air conditioning unit.

Course Outcomes:

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

1. Illustrate the fundamental principles and applications of refrigeration and air conditioning system.
2. Evaluate the performance of vapor compression refrigeration systems.
3. Identify refrigerant for the particular application considering all the properties of refrigerant.
4. Calculate cooling load for air conditioning systems used for various applications.
5. Operate and analyze the refrigeration and air conditioning systems.
6. Develop air distribution duct system for air conditioning system.

Course Contents	
Unit 1	**Applications of Refrigeration and Air Conditioning and Refrigerants**

Domestic Refrigerator, Domestic Air Conditioners, Automotive Air Conditioners, Evaporative coolers, water coolers, Ice plant, window air conditioner, split air conditioner, central air conditioning systems - multiplex, hospitals, Thermoelectric refrigeration system, Vortex tube, Pulse tube refrigerator.

Refrigerants: Introduction, Classification of refrigerants, Designation of refrigerants, Desirable properties of refrigerants, important refrigerants, environmental issues, Ozone depletion and global warming, ODP, GWP & LCCP, selection of environment friendly refrigerants, primary and secondary refrigerants, anti-freeze solutions, oils used in refrigeration systems, refrigerant: recovery reclaims, recycle and recharge.

Unit 2	**Refrigeration Systems**

Vapour Refrigeration Systems: Working of simple vapour compression system, representation of vapour compression cycle (VCC on T-S and P-H diagram, COP, EER), effect of operating parameters on performance of VCC, actual VCC, methods of improving COP using flash chamber, sub-cooling liquid vapour heat exchanger, performance of VCC (Simple numerical).

Vapour Absorption Refrigeration Systems: Introduction, Working of simple vapour absorption system (VAS), desirable properties of binary mixture (aqua-ammonia), performance evaluation of simple VAS (simple numerical treatment), actual VAS, Li-Br absorption system, three fluid systems (Electrolux refrigeration), applications of VAS, comparison between VCC and VAC.

Unit 3	**Multiple pressure Refrigeration Systems**

Introduction, need of multistage system, cascade refrigeration system – applications and simple numerical, Intermediate pressure, two stage compression with flash gas removal and liquid intercooler, single compressor with multiple evaporator: individual and multiple expansion valves, individual compressors, Joule's Thomson effect and liquefaction of gases, Introduction to cryogenics (Linds-Hampson cycle) and applications, hazards in cryogenic engineering (no numerical treatment).

Unit 4	**Psychrometry and Air conditioning load estimation**

Basic Psychrometry and processes, BPF of coil, ADP, adiabatic mixing of two air streams, SHF, RSHF, GSHF, ESHF. Factors contributing to cooling load, Numerical based on load analysis.

Human Comfort: Thermodynamics of human body, comfort and comfort chart, factors affecting human comfort. concept of infiltration and ventilation, indoor air quality requirements.

Unit 5	Air Conditioning Systems and Components

Air Conditioning Systems, Working of summer, winter and all year round AC systems, all air system, all water system, air water system, variable refrigerant flow and variable air volume systems, unitary and central air conditioning.

Components of refrigeration and air conditioning systems: Working of reciprocating, screw and scroll compressors, working of air cooled, water cooled and evaporative condensers, working of DX, Flooded, Forced feed evaporators. Expansion devices - Capillary tube, TXV, EXV, operating and safety controls, charging of refrigeration unit, leakage testing.

Unit 6	Air Distribution Systems

Ducts: Classification of ducts, duct material, pressure in ducts, flow through duct, pressure losses in duct (friction losses, dynamic losses), air flow through simple duct system, equivalent diameter, Methods of duct system design: equal friction, velocity reduction, static regain method (numerical on duct system design)

Air handling unit: Air handling unit, Fan coil unit, types of fans used air conditioning applications, fan laws, filters, supply and return grills, sensors (humidity, temperature, smoke).

Books and other Resources

Text Books:

1. Arora C. P., Refrigeration and Air Conditioning, Tata McGraw-Hill
2. Manohar Prasad, Refrigeration and Air Conditioning, Willey Eastern Ltd, 1983
3. McQuiston, Heating Ventilating and air Conditioning: Analysis and Design, l Wiley India, 6th Edition
4. Arora and Domkundwar, Refrigeration & Air Conditioning, Dhanpatrai & Company, New Delhi
5. Khurmi R.S. and Gupta J.K., Refrigeration and Air conditioning, Eurasia Publishing House Pvt
6. Ballaney P.L., Refrigeration and Air conditioning, Khanna Publishers, New Delhi, 1992

References Books:

1. Dossat Ray J, Principles of refrigeration, S.I. version, Willey Eastern Ltd, 2000
2. Stockers WF and Jones J.W., Refrigeration and Air conditioning, McGraw Hill International.
3. Threlkeld J.L, Thermal Environmental Engineering, Prentice Hall Inc., New Delhi
4. Aanatnarayan, Basics of refrigeration and Air Conditioning, Tata McGraw Hill Publications
5. Roger Legg, Air Conditioning System Design, Commissioning and Maintenance
6. ASHRAE & ISHRAE handbook

Web References:

https://www.worldscientific.com/worldscinet/ijacr

https://onlinecourses.nptel.ac.in › noc19_me58

https://mail.google.com/mail/u/0/#inbox/QgrcJHsNjCXpqdQWsrZzxCBRtrPnKFxMJLv?projector=1

https://easyengineering.net/s-k-mondals-refrigeration-and-air-conditioning/

https://ishrae.in

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering [Sandwich] (2019 pattern)

402069C: Fluid Power Control					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	3 Hrs./week	TH	3	In-Semester	30 Marks
				End-Semester	70 Marks

Prerequisites: Fluid Mechanics, Machine tools, Industrial application, Mechatronics

Course Objectives:

1. To understand working principles of control devices and accessories.
2. To select different components from manufactures' catalogues.
3. To demonstrate the capabilities to simulate and design fluid power systems.
4. To undertake digitalization of fluid power system.

Course Outcomes:

On completion of the course, learner will be able to

CO1.**DEFINE** working principle of components used in hydraulic and pneumatic systems.
CO2.**IDENTIFY & EXPLAIN** various applications of hydraulic and pneumatic systems.
CO3.**SELECT** an appropriate component required for hydraulic and pneumatic systems using manufactures' catalogues.
CO4.**SIMULATE & ANALYSE** various hydraulic and pneumatic systems for industrial/mobile applications.
CO5.**DESIGN** a hydraulic and pneumatic system for the industrial applications.
CO6.**DESIGN & DEMONESTRATE** various IoT, PLC based controlling system using hydraulics and pneumatics.

Course Contents

Unit 1	**Basics of Fluid Power and Pumps**

Fluid power basics, applications of fluid power advantages and limitations, fluid power distribution, standard symbols, energy loss in hydraulic systems.

Pumps - types, classification, principle of working and constructional details of vane pumps, gear pumps, radial and axial plunger pumps, screw pumps, power and efficiency calculations, and characteristics curves.

Unit 2	Actuators and Power Unit

Linear and rotary actuators- types, construction and characteristics. Cylinder mountings, cushioning of cylinders.

Power units and accessories - types of power units, reservoir assembly, constructional details. Accumulators, Intensifiers.

Unit 3	Fluid Power Control

Direction control valves - center positions, methods of actuation, two stage valves, Flow control valves - pressure and temperature compensated. Pressure control valves - pressure reducing valve, sequence valve, unloading valve, brake valve, back pressure valve, counter balance valve, check valve, prefill valve, servo valves, cartridge valves, proportional valves.

Unit 4	Hydraulic Circuits and Contamination Control

Hydraulic circuits: Simple reciprocating, regenerative, speed control (meter in, meter out and bleed off), sequencing, synchronization, traverse and feed, automatic reciprocating, fail safe circuit, counter balance circuit, actuator locking, unloading circuit, motor breaking circuit etc.

Contamination control: Contamination, sources of contamination, suction strainer, filters, filtration, filter ratings.

Unit 5	Pneumatics-Components, Control Valves and Circuits

Compressors - Types, principle of working and constructional details. Comparison of pneumatic with hydraulic power transmissions. Types of filters, pressure regulators, lubricators, mufflers, dryers, direction control valves, pneumatic actuators, shuttle valve, two pressure valve, quick exhaust valve and time delay valves, electro-pneumatics. Speed regulating methods, pneumatic circuits, reciprocating, cascading time delay etc. Application of pneumatics in low cost automation and in industrial automation.

Unit 6	System simulation and IoT based system

Design, Simulation of industrial hydraulic and pneumatic circuits: selection of components using the manufacturer's catalogue and analysis using any open source/free/commercial software or application. Trouble shooting of fluid power system.

IoT based system to operate electro-pneumatic/hydraulic circuit from a remote location. Application of relay ladder logic or PLC.

Books and other Resources

Text Books:

1. Esposito A, Fluid Power with application, Prentice Hall
2. Majumdar S.R, Oil Hydraulic system- Principle and maintenance, Tata McGraw Hill

3. Majumdar S.R, Pneumatics Systems Principles and Maintenance, Tata McGraw Hill
4. Stewart H. L, Hydraulics and Pneumatics , Taraporewala Publication

References Books:

1. Pipenger J.J, Industrial Hydraulics, McGraw Hill
2. Andrew A. Parr, Hydraulics and Pneumatics, Elsevier Science and Technology Books
3. Fundamentals of Pneumatics, Vol I, II and III. FESTO
4. Fundamentals of fluid power control, John Watton Cambridge University press 2012
5. Introduction to Fluid power, Thomson Prentcie Hall 2004
6. Hydraulic Control Systems, Herbert E. Merritt John Wiley and Sons, Inc.
7. ISO - 1219, Fluid Systems and components, Graphic Symbols
8. Standard manufacturing catalogues

URL links:

1. https://nptel.ac.in/courses/112/106/112106175/
2. http://ndl.iitkgp.ac.in/document/QXBqK1czOUpyM3FlamVjTmREMWFEUFdEb25sZ01FZVRtZmhWNXlobUZ0MFJ0Zk1kU1dSYmEwK1RSZG1FMUNDNQ

Fluid Power Control: Web-Course Module-01 Module-02 Module-03 Module-04

Links of Video Lectures:

1. https://nptel.ac.in/courses/112/106/112106300/
2. https://www.digimat.in/nptel/courses/video/112105047/L01.html

Recommended on line courses: https://nptel.ac.in/course.html

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering [Sandwich] (2019 pattern)

402045C: Additive Manufacturing					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**TH**	**3**	**In-Semester**	**30 Marks**
				End-Semester	**70 Marks**

Prerequisite: Manufacturing processes, Engineering metallurgy, Solid mechanics

Course Objectives

1. To know the principle, methods, possibilities and limitations as well as environmental hazards of Additive Manufacturing technologies.
2. To get familiar with the characteristics of the different materials used in Additive Manufacturing technologies
3. To explore the potential of additive manufacturing technologies in real life applications.

Course Outcomes

On completion of the course, learner will be able to

CO1. **USE** and **CLASSIFY** the fundamentals of Additive Manufacturing Technologies for engineering applications.

CO2. **IDENTIFY** and **CATEGORIZE** the methodology to manufacture the products using light-based photo-curing, LASER based technologies and **STUDY** their applications, benefits.

CO3. **IDENTIFY** and **CATEGORIZE** the methodology to manufacture the products using extrusion-based deposition, inkjet-based technologies and **STUDY** their applications, benefits.

CO4. **SYNTHESIZE, RECOMMEND** and **DESIGN** the suitable material and process for fabrication and build behavior of verities of product.

CO5. **DESIGN** and **CONSTRUCT** the AM equipment's for appropriate applications and the input CAD model.

CO6. **DEVELOP** the knowledge of additive manufacturing for various real-life applications.

Course Contents

Unit 1	**Introduction to Additive Manufacturing**

Introduction to AM, Historical Development, Additive v/s Conventional Manufacturing, Role of AM in Product development cycle, Rapid prototyping, Relevance of AM in Industry 4.0, Current industry and manufacturing trends driving AM, AM Process-Chain, Reverse engineering, Advantages, Types of materials, Classification of AM Processes (Process-based, material form

based, application-based - direct and indirect processes and Micro- and Nano-additive processes), Process Planning for Additive Manufacturing.

Unit 2	**Light and LASER based Techniques**

Introduction, Process and mechanism, Materials, Process Physics, Parameters, Benefits, Drawbacks, Limitations and Applications of

Light-Based Photo-curing: Stereolithography (SLA), Digital Light Processing (DLP), Direct Laser Writing (DLW), Continuous Liquid Interface Production (CLIP)

Laser-Based Melting: Selective Laser Sintering (SLS), Direct Metal Laser Sintering (DMLS), Selective Laser Melting (SLM), Electron-Beam Melting (EBM), Laser Blown Powder, Laser Wire Deposition, Laser Engineered Net Shaping (LENS), 3D Laser Cladding

Unit 3	**Extrusion and energy based Techniques**

Introduction, Process and mechanism, Materials, Process Physics, Parameters, Benefits, Drawbacks, Limitations and Applications of

Extrusion-Based Deposition: Fused Deposition Modeling (FDM), Fused Filament Fabrication (FFF), Direct Ink Writing (DIW), Robocasting, Bio-printing

Inkjet(droplet)-Based Deposition and Fusion: Multi-jet Modeling (MJM), Polyjet Printing, Nanoparticle Jetting, Binder Jetting, Multi-Jet Fusion, Color-jet Printing (CJP), Energy Deposition Techniques: Plasma/TIG/MIG/Arc Deposition, Electron Beam-based DED, Direct Metal Deposition (DMD)

Unit 4	**Materials and Design for AM**

Introduction, Materials: Metals, Polymers, Ceramics & Bio-ceramics, Composites, Hierarchical Materials, Biomimetic Materials, Shape-Memory Alloys, 4D Printing & Bio-active materials, Material selection,

AM Material Specific Process Parameters: Processes, Heat or Chemical Treatments, Phase Transformations, Process Selection for various applications, DfAM: Process specific strategies, Rules and Recommendations,

Quality considerations and Post-Processing techniques: Requirements and Techniques, Support Removal, Sanding, Acetone treatment, Polishing, Heat treatments, Hot isostatic pressing, Materials science, Surface enhancement Techniques and its Material Science Analysis of AM's error sources.

Unit 5	**Hardware and Software for AM**

Construction of Basic AM Machines: Equipment Layout and sub-system Design, Construction,

Working, Equipment Topology/Layout Frame Designs, 3D Printer Design Considerations (Filament, Frame, Build Platform, Extruder Design, Nozzles, Print Bed, Heated build/Base Plate, Heater, Dispenser, Optical system, Cooling system, Gas Recirculation System, Laser controller, Gas Filtration, Inert Gas Cooling system, Powder Handling System, Loading/unloading System, Moving Parts and end stops, Sensors, Actuators, Motors and Control Electronics, Power supply, Machine Tool Peripheral), Raw Material Manipulation

Software and Controller: Types of In-fill, Types of slicing, Software Integration (with Process, Slicing, etc), Control system (PLC and safety PLC, micro control/ Microcontroller, Micro-processor control), CAD Software and Controller Interfacing, CURA Software, Relevant G/M Codes, Standard firmware (Merlin Software, etc), In-process Monitoring, Calibration.

Unit 6	**Case Studies, Application and Special Topics**

Case Studies and Application of AM: 3D printing in prominent industries (Aerospace, Electronics, Defense, Automotive, Construction, Architectural, Machine-Tools), Other industrial applications (Health-Care, Personalized Surgery, Bio-medical Applications, Assistive Devices, Food-Processing, Food & Consumer Applications, Art, Fashion, Jewelry, Toys & Other Applications, etc)

Special Topics: 4D/5D Printing, Bio-printing, Bio-materials, scaffolds and tissue and Organ Engineering, Mass Customization and Future trends.

Books & Other Resources

Text Books

1. Chua Chee Kai, Leong Kah Fai, "3D Printing and Additive Manufacturing: Principles & Applications", 4th Edition, World Scientific, 2015 2.
2. Amit Bandyopadhyay, Susmita Bose, "Additive manufacturing", CRC Press, Taylor & Francis Group, 2016 3.
3. Ian Gibson, David W. Rosen, Brent Stucker "Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing" Springer, 2010

Reference Books

1. L. Lu, J. Y. H. Fuh and Y.S. Wong, "Laser-Induced Materials and Processes for Rapid Prototyping", Springer, 2001
2. Andreas Gebhardt and Jan-Steffen Hötter, "Additive Manufacturing: 3D Printing for Prototyping and Manufacturing" Hanser Publishers, Munich, 2016.
3. Ben Redwood, FilemonSchöffer& Brian Garret, "The 3D Printing Handbook: Technologies, design and applications", 3D Hubs B.V. 2017
4. Ehsan Toyserkani, Amir Khajepour, Stephen F. Corbin, "Laser Cladding", CRC Press, 2004
5. Andreas Gebhardt, "Understanding Additive", Hanser Publishers, Munich, 2011
6. Ben Redwood, Filemon Schöffer & Brian Garret, "The 3D Printing Handbook – Technologies, Design and Applications" Part One:3D Printing Technologies and Materials.
7. Chee Kai, Kah Fai, Chu Sing, 'Rapid Prototyping: Principles and Applications", 2nd Ed.
8. D. T. Pham and S.S. Dimov, "Rapid Manufacturing" Springer, 2001
9. Rupinder Singh J. Paulo Davim, "Additive Manufacturing - Applications and Innovations" CRC Press Taylor& Francis Group, 2019
10. . I. Gibson, D. W. Rosen, B. Stucker, "Additive Manufacturing Technologies" Springer, 2010

11. L. Jyothish Kumar, Pulak M. Pandey, David Ian Wimpenny, “3D Printing and Additive Manufacturing Technologies” Springer, 2019.

Web References

1. NPTEL Course on Fundamentals of Additive Manufacturing Technologies by Prof. SajanKapil, IIT Guwahati, https://onlinecourses.nptel.ac.in/noc21_me115/preview
2. Introduction to Additive Manufacturing, https://www.youtube.com/watch?v=LCQoi10cG To NPTEL IIT Kanpur, “Rapid Manufacturing”, Dt. Janakarajan Ramkumar Prof. Amandeep Singh, https://onlinecourses.nptel.ac.in/noc20_me50/preview

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering [Sandwich] (2019 pattern)

402051C: Automation and Robotics					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**TH**	**3**	**In-Semester**	**30 Marks**
				End-Semester	**70 Marks**

Prerequisites: Mathematics, Systems in Mechanical Engineering, Programming and Problem Solving, Basic Electronics Engineering, Engineering Mechanics, Solid Modeling and Drafting, Electrical and Electronics Engineering, Kinematics of Machinery, Mechatronics, Design of Transmission Systems

Course Objectives:

1. Introduce the need of Industrial Automation
2. Learn various types of Robots and the functional elements of Robotics
3. Identify and Judge application specific selection of Robot Drive Systems
4. Recognize various types End-effectors and Sensors used in Robotic Automation
5. Study the basic Mathematical Modeling Techniques of Robot
6. Understand the basics of Robot Programming and Robotic Applications

Course Outcomes:

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

CO1. **UNDERSTAND** the basic concepts of Automation

CO2. **UNDERSTAND** the basic concepts of Robotics

CO3. **IDENTIFY** and **EVALUATE** appropriate Drive for Robotic Applications

CO4. **COMPARE** and **SELECT** End-effectors and Sensors as per Application

CO5. **DEVELOPE** the Mathematical Modeling Approaches of Robot

CO6. **EVALUATE** the fundamentals of robot programming and **CLASSIFY** the Applications

Course Contents	
Unit 1	**Introduction to Automation**
Introduction: Automation in Production systems, Automated Manufacturing Systems, Reasons for Automation, Automation Principles and Strategies, USA (Use, Simplify & Automate) Principle, Automation Migration Principle, Types of Automation, Classification by Function/ Transfer Method, Automation using Hydraulic/Pneumatic Systems, Electrical/Electronic Systems and Automated Assembly Systems - Selection criteria, components, applications **Automated Assembly Systems:** Types and Configurations, Part Feeding Devices, Part Orientation Devices, Part Conveying Devices, Feed tracks, Escapements and Part placing mechanism, Parts Delivery at workstations, Single-station and Multi-station Assembly Machines	
Unit 2	**Fundamentals of Robot Technology**
Introduction: History, Definitions specified by Agencies, Classification and Applications, Laws of robotics, Specifications of robots, Flexible automation Vs. Robotics technology, Safety measures in robotics, Role of Robots in Automation **Robot Anatomy and configurations:** Cartesian, Cylindrical, Polar, Articulated, SCARA, Pendulum Arm, Multiple Joint Arm, Parallel Manipulator, Work Envelope/Volume, Degree of Freedom associated with Robot Arm & Wrist, Joints & Joint Notification Scheme, Precision of Movement	
Unit 3	**Robot Drive Systems**
Pneumatic Drives, Hydraulic Drives, Mechanical Drives, Electrical Drives - D.C. Servo Motors, Stepper Motors, A.C. Servo Motors, BLDC - Salient Features, Applications and Comparison of all these Drives, Micro actuators, Selection of drive, Power and Motion Transmission Systems for Robot, Motion Conversion, Determination of Power of motor, Types of Gearbox - Planetary, Harmonic, Cycloidal Gearbox and Gear Ratio, Variable Speed Arrangements	
Unit 4	**End-effectors & Sensors in Automation**
End-effectors/Grippers/Tooling: Introduction, Types, Classification, Construction, Working, Selection and Design Considerations of End-Effectors/Grippers/Tooling Interface used in various Robotic Applications, Active and Passive Compliance **Sensors/Transducers:** Introduction, Types, Classification, Construction, Working, Selection and Design Considerations of Transducers, Sensors, Resolvers, Encoders, Switches, Position/Range/Touch/Force/Torque/Safety Sensors and Transduces, Machine Vision System used in various Robotic Applications	

Unit 5	Mathematical Modeling of Serial and Parallel Robots

Kinematics: General Mathematical Preliminaries on Vectors & Matrices, Link Equations and relationships, Direct Kinematics, Coordinate and Vector Transformation using matrices, Rotation matrix, Inverse Transformations, Composite Rotation matrix, Homogenous Transformations, Robotic Manipulator Joint Coordinate System, Inverse Kinematics of two joints/link manipulator, DH Parameters, Jacobian Transformation in Robotic Manipulation, Static Analysis

Dynamics: Direct Dynamics, Mass/Inertia and their Positions of links, Lagrangian/Eularian/Newtonian Approaches for formulation of equations of motion of planar two link/joint manipulator

Unit 6	Performance and Applications of Robots

Robot Performance and Economics: Introduction to Robotic Programming, Types of Robot Programming, Motion Programming, Simulation and Off-line Programming, Programming Examples such as Palletizing, Loading, Unloading, Material Handling, etc., Robot Economics, Functional Safety in Robotic Applications, Social Aspects of Robotics, Industry 4.0

Robots in Manufacturing Applications: Robot-based Manufacturing System, Robot Cell Design Considerations and Selection of Robot

Robots in Non-manufacturing Applications: Field And Service Robotics, Mobile Robots, Wheeled, Legged, Tracked, Hybrid Terrestrial Mobile Robots, Unmanned Aerial Vehicle (UAV), Autonomous Underwater Vehicles (AUV), Humanoids, Robotic Assistive Technologies for Rehabilitation of Humans

Books and other resources

Text Books:

1. Groover, M. P., (2016), "Automation, Production Systems, and Computer-integrated Manufacturing," Pearson Education, ISBN: 9789332572492
2. Derby, S. J., (2004), "Design of Automatic Machinery," CRC Press, ISBN: 9780824753696
3. Deb, S. R., Deb, S., (2017), "Robotics Technology and Flexible Automation," McGraw Hill Education, ISBN: 9780070077911
4. Sandler, B. Z., (1999), "Robotics: Designing the Mechanisms for Automated Machinery," Academic Press/Prentice Hall, ISBN: 9780137816002
5. Tsai, L. W., (1999), "Robot Analysis: The Mechanics of Serial and Parallel Manipulators," Wiley-Interscience, ISBN: 9780471325932
6. Nagarajan, R., (2016), "Introduction to Industrial Robotics," Pearson Education India, ISBN:

9789332544802

7. Gupta, A. K., Arora, S. K., Westcott, J. R., (2016), "Industrial Automation and Robotics: An Introduction," Mercury Learning & Information, ISBN: 9781938549304

References Books:

1. Niku, S. B., (2020), "Introduction to Robotics, Analysis, Control, Applications," Wiley, ISBN: 9781119527626
2. Groover, M. P., Weiss, M., Nagel, R. N., Odrey, N. G., R.,Dutta, A., (2017), "Industrial Robotics - Technology ,Programming and Applications," McGraw Hill Education, ISBN: 9781259006210
3. Ray Asfahl, C., (1992), "Robots and Manufacturing Automation," Wiley, ISBN: 9780471553915
4. Koren, Y., (1985), "Robotics for Engineers," McGraw-Hill, ISBN: 9780070353992
5. Saha, S. K., (2017), "Introduction to Robotics" McGraw-Hill Education, ISBN: 9789332902800
6. Mittle, R., Nagrath, I., (2017), "Robotics and Control," McGraw Hill Education, ISBN: 9780070482937
7. Craig, J., (2021), Introduction to Robotics: Mechanics and Control, Pearson, ISBN: 9781292164939
8. Mike Wilson, M., (2014), "Implementation of Robot Systems: An introduction to robotics, automation, and successful systems integration in manufacturing," Butterworth-Heinemann, ISBN: 9780124047334
9. Spong, M. W., Hutchinson, S., Vidyasagar, M., (2020), "Robot Modeling and Control," Wiley, ISBN: 9781119523994
10. Siegwart, R., Nourbakhsh, I. R., Scaramuzza, D., (2011), "Introduction to Autonomous Mobile Robots," The MIT Press, ISBN: 9780262015356

Web References:

- Pratihar, D. K., (2019), "Robotics,: IIT Kharagpur, https://onlinecourses.nptel.ac.in/noc19_me74/preview
- Asokan, T., Ravindran, B., Vasudevan, K., (2020), "Introduction to Robotics," IIT Madras, https://onlinecourses.nptel.ac.in/noc20_de11/preview
- www.roboanalyzer.com

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering [Sandwich] (2019 pattern)

<table>
<tr><th colspan="6">402045A: Product Design and Development</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>TH</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:
To explain student’s significance of
1. Product design and Product development
2. Market Survey & Product Specification Finalization
3. Concept Inception, Verification and selection
4. Concept Exploration & Development
5. Design Verification and Validation
6. Robust Design and Development</td></tr>
<tr><td colspan="6">Course Outcomes:
On completion of the course the learner will be able to;
CO1. UNDERSTAND Product design and Product development processes
CO2. UNDERSTAND Processes, tools and techniques for Market Survey & Product Specification Finalization
CO3. UNDERSTAND Processes, tools and techniques for Concept Inception, Verification and selection
CO4. UNDERSTAND Processes, tools and techniques for Concept Exploration & Development
CO5. UNDERSTAND Processes, tools and techniques for Design Verification and Validation
CO6. UNDERSTAND Processes, tools and techniques for Robust Design and Development</td></tr>
</table>

Course Contents	
Unit 1	**Introduction to Product Design and Development**
Topics- Product design and Development definition, Objectives of Product design and development, Engineering Design Process, Engineering Development Process (Gateway System), Product Design Vs Product Development, Features of successful product design and development, Essential Factors for product design, The challenges of product development, ASIMOW Model/Morphology of product design, Who design and develops product-Concurrent engineering approach/CFT Approach, Reasons for new product failure, Product Life Cycle	
Unit 2	**Market Survey & Product Specification Finalization**
Topics- Product definition, Types of products, Customer Population and Market segmentation- Types of customers and Needs, Customer need Models- Introduction to Kano Model, Triz Method/Altshuller Matrix, Design Thinking, etc. Types of Design information and the Various Sources of information, Product planning and its Phases, Mission statement and Technical Questioning, Technology forecasting and S-curve, Tools for gathering Customer needs, QFD and House of quality	
Unit 3	**Concept Inception, Verification and selection**
Topics- Idea generation and Idea generation approaches-Triz Method, Benchmarking, Brainstorming, Alternate thinking, Reverse Engineering etc, Product Policy of an organization, Selection of Profitable Concept- SWOT Analysis, Concept Selection Process, Pugh's Concept selection process, Concept Analysis- Marketing aspect, Product characteristics (Functional/ Operational/Durability/Aesthetic/Ergonomic Aspects), Economic analysis, Production aspect, functional Modelling and decomposition- Functional analysis system technique, Subtract and operate procedure	
Unit 4	**Concept Exploration & Development**
Topics-Solid Modelling of part and assembly, Product architecture, Digital product design of part and assembly with respect to Engineering drawing definition, Classification of engineering drawing, Elements of production drawing, Bill of material, Types of dimensions, Arrangement of dimensions, Principles of dimensioning, Limits, Fits and Tolerances, Geometric Tolerances, Datum System, Design for Assembly, Design for manufacturing, Design for processes, Product design Steps, Introduction of Ergonomics in product design, Design Review/Part Print Analysis	

Unit 5	Design Verification and Validation

Topics-FEA-CFD-MBD-FSI, Simulation driven design, Additive manufacturing, Policy and Homologation certification by National and International agencies, Introduction to Break Even analysis and Production capacity planning, Make VS buy Decision, Business case Preparation, Facility tooling and gauges design and Development- Vendor Development, Letter of Intent, Purchase order, Product costing, Product Testing and Validation, Introduction to Production part approval process tools (PPAP).

Unit 6	Robust Design and Development

Tools and Techniques for Robust design and Development- Advance Product Quality Planning, Design Failure Mode Effect Analysis, Value Analysis and Value Engineering, Product Life cycle management and Product Data Management etc.

Case studies on-

1. Team center application in Product design and Development
2. DFMEA (Minimum Three parts)
3. Process Flow Chart (Minimum Three Parts)
4. Part Print analysis (Minimum Three Parts)

Text Books:

1. K. Chitale; R.C. Gupta, Product Design and Manufacturing, Prentice Hall India.
2. Dieter George E., Engineering Design McGraw Hill Pub. Company, 2000.
3. How Products are made by Jocqueline L. Longe
4. Creating Innovative products Using Total Design by Don Clausing and Ron Andrade
5. Metrics and Case Studies For Evaluating engineering designs by Jay Alan Moody
6. Understanding Engineering Design by Richard Birmingham
7. Designing for quality by Robert H. Lochner
8. New Product development by Barclay Z. Dann P. Holroyd
9. Developing an Ergonomics Processes by Alison Heller

References Books:

1. Kevin Otto and Kristin Wood, Product Design: Techniques in Reverse Engineering and New Product Development, Pearson Education Inc.
2. Grieves, Michael, Product Lifecycle Management McGraw Hill
3. Bralla, James G., Handbook of Product Design for Manufacturing, McGraw Hill Pub.
2. 4. Karl Ulrich, product design and development, TMH.

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering [Sandwich] (2019 pattern)

402045D: Operations Research					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**TH**	**3**	**In-Semester**	**30 Marks**
				End-Semester	**70 Marks**

Prerequisites: Engineering Mathematics, Theory of Probability, Statistics, Basic Industrial Functions and Business Environment.

Course Objectives:

1. To familiarize the students with the use of practice oriented mathematical applications for optimization functions in an organization.
2. To familiarize the students with various tools of optimization, probability, statistics and simulation, as applicable in particular scenarios in industry for better management of various resources.

Course Outcomes

On completion of the course, learner will be able to

CO1. **EVALUATE** various situations of Games theory and Decision techniques and **APPLY** them to solve them in real life for decision making.

CO2. **SELECT** appropriate model for queuing situations and sequencing situations and **FIND** the optimal solutions using models for different situations.

CO3. **FORMULATE** various management problems and **SOLVE** them using Linear programming using graphical method and simplex method.

CO4. **FORMULATE** variety of problems such as transportation, assignment, travelling salesman and **SOLVE** these problems using linear programming approach.

CO5. **PLAN** optimum project schedule for network models arising from a wide range of applications and for replacement situations find the optimal solutions using appropriate models for the situation.

CO6. **APPLY** concepts of simulation and Dynamic programming

Course Contents	
Unit 1	**Introduction to OR, Theory of Games and Decision Analysis**
Introduction to OR: Origin of Operations Research, Definition, Evolution and Classification of Quantitative methods, Operations Research Techniques and Methodology, Advantages and Limitations, Scope and Applications of OR **Theory of Games:** Introduction, Classification of Games**,** Two-person Zero Sum Games, Solution of 2 x 2 Game with no Saddle Point, Dominance in Games, Subgame Method to Solve (2 x n or m x 2) Mixed Strategy Games, Graphical Method to Solve (2 x n or m x 2) Games **Decision Analysis:** Introduction, Decision Under Certainty, Decision Under Risk, Decision Under Uncertainty (Maximin, Minimax, Maximax, Minimin Criterions, Hurwicz Criterion, Laplace Criterion, Savage or MiniMax Regret Criterion), Decision Tree.	
Unit 2	**Queuing Theory and Sequencing Model**
Queuing Theory: Introduction, Elements of Queuing, Characteristics of Waiting Lines, Service discipline, Service Mechanism, Terminology and Kendall's Notation of Queuing system, Single Channel systems M/M/1: FCFS/∞/ ∞ and M/M/1: FCFS/N/ ∞ **Sequencing Models:** Solution of Sequencing Problem - Processing of n Jobs Through Two Machines, Processing of n Jobs Through Three Machines, Processing of Two Jobs Through m Machines, Processing of n Jobs Through m Machines	
Unit 3	**Linear Programming**
Introduction, Formulation of LPP, LPP by Graphical Method, Solution of LPP by Simplex Method, Big M Method and Two-phase method (Limited to 2 variables only), Conversion of Primal to Dual problems	
Unit 4	**Transportation and Assignment Model**
Transportation Model: Introduction**,** Formulation of Transportation problem, Methods to Find Basic Feasible Solution (Vogel's Approximation Method (VAM), Least Cost Method (LCM), North West Corner Rule (NWCR)), Unbalanced Transportation Problem, Degeneracy in Transportation Problem (Theoretical treatment only), Optimality Test- Modified Distributed Method **Assignment Model:** Introduction, Mathematical Formulation of Assignment Problem Difference between Transportation and Assignment Problem Assignment Problem, Hungarian Method, Balanced and Unbalanced Assignment problem, Maximization in Assignment Problems, Travelling Salesman Problem (Mathematical Formulation and Numerical)	

Unit 5	Project Management

Network Models: Fulkerson's Rule, Concept and Types of Floats, CPM and PERT, Crashing Analysis and Resource Scheduling

Replacement Analysis: Replacement of Items that Deteriorate, Replacement of Items that Fail Suddenly

Unit 6	Simulation and Dynamic Programming

Simulation: Introduction, Simulation Definition, Types of Simulation, Steps of Simulation, Advantages and Disadvantage of simulation, Stochastic Simulation and Random numbers, Monte Carlo simulation, Random number Generation

Dynamic Programming: Introduction, Dynamic Programming Model, Applications of Dynamic Programming Model to Shortest Route problems, Bellman Optimality Principle, Resource Allocation problem by Dynamic Programming.

Books and other resources

Text Books:

1. Prem Kumar Gupta, D. S. Hira, Problems in Operations Research: Principles and Solutions, S. Chand, 1991
2. J. K. Sharma, Operations Research: Theory and Application, Laxmi pub. India, 2010.
3. Operations Research, S. D. Sharma, Kedar Nath Ram Nath-Meerut, 2015.
4. L.C.Jhamb, Quantative Techniques Vol. I &II, Everest Publication, 2007.
5. Manohar Mahajan, Operation Research, Dhanpatrai Publication, 2006.
6. V. K. Kapoor, Operations Research: Quantitative Techniques for Management, Sultan Chand Publications, 2013.

References:

1. Hillier F.S., and Lieberman G.J., Operations Research, Eight Edition, Mc. Tata McGraw Hill, India, 2011.
2. Ravindran, ―Engineering optimization Methods and Applications‖, 2nd edition, Wiley, India
3. Ravindran, Phillips and Solberg, Operations Research Principles and Practice, Second Edition, Mc. WSE Willey,
4. Operations Research - An introduction, Hamdy A Taha, Pearson Education, 2010

Web References:

1. https://nptel.ac.in/courses/110106062
2. https://nptel.ac.in/courses/111107128
3. https://www.digimat.in/nptel/courses/video/110106062/L01.html
4. https://archive.nptel.ac.in/courses/112/106/112106134/

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering [Sandwich] (2019 pattern)

402051E: Electrical and Hybrid Vehicle					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**TH**	**3**	**In-Semester**	**30 Marks**
				End-Semester	**70 Marks**

Prerequisites: Mathematics, Physics, Chemistry, Systems in Mechanical Engineering, Basic Electrical Engineering, Electrical and Electronics Engineering, Kinematics of Machinery, Computer Aided Engineering, Design of Transmission Systems

Course Objectives:

1. Introduce the concepts of electric vehicle and allied technologies
2. Learn the concept and types of hybrid electric vehicle
3. Identify and Judge application specific selection of Prime Movers, Energy Storage and Controllers required for e-vehicles
4. Recognize the e-Vehicle Configurations and Understand the Mechanics of vehicle movement
5. Design and Select the body frame with relevant suspension system and Testing of e-Vehicle as per Regulation/Licensing/Approval Organizations
6. Understand the Battery Charging techniques and management

Course Outcomes:

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

CO1. **UNDERSTAND** the basics related to e-vehicle

CO2. **CLASSIFY** the different hybrid vehicles

CO3. **IDENTIFY** and **EVALUATE** the Prime Movers, Energy Storage and Controllers

CO4. **DISCOVER** and **CATAGORIZE** the Electric Vehicle Configuration with respect to Propulsion, Power distribution and Drive-Train Topologies

CO5. **DEVELOP** body frame with appropriate suspension system&**TESTING** of for e-Vehicles

CO6. **CLASSIFY** and **EVALUATE** Battery Charging techniques and management

Course Contents	
Unit 1	**Introduction to Electric and Hybrid 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	**Prime Movers, Energy Storage and Controllers**
Brief introduction to Motors: Classification, Construction, Working, Control, Design criteria, Application and Design Examples, Selection of Motor, Structural Configuration of Motor Layout, Motor Safety and Maintenance, Motor Torque and Power Rating **Brief introduction to Energy Storage Systems:** Classification - Types and Packs, Construction, Working, Comparison and Selection, Principle of Operation, Units of Battery/Fuel Cell Energy Storage, Battery Performance Parameters Estimation, Battery/Cell Modeling, Traction Batteries and their Capacity Calculation and Power Rating for standard drive cycles, Lifetime and Sizing Considerations, Power and Efficiency, Characteristic Curves, Battery Cooling/Thermal Control and Protection, Battery Safety and Maintenance, Auxiliary battery, Hybridization of energy storage devices, Ultra capacitor and Ultra flywheel **Controllers:** Configuration based on power electronics, Torque/Speed Coupling, Speed and Torque Controllers, BCU, MCU, Speed Control for Constant Torque/Power Operation of all electric motors, Control Methods	

Unit 4	Electric Vehicle Configuration and Mechanics of Vehicle Movement

Electric Vehicle Configuration with respect to Propulsion and Power distribution: Unicycle, Two-Wheeler (Bicycle, Dicycle, Motorcycle, Scooter, Scooteretts, Mopeds and Underbone), Three-Wheeler, and Four-Wheeler Electric Vehicles, Steering and Propulsion Configuration, Placement of Motors, Battery and Motion Transmission Systems

Electric Drive-Trains: Basic concept of Electric Traction, introduction to various Electric Drive-Train Topologies, Power flow Control in Electric Drive-Train Topologies, Fuel Efficiency Analysis, Mechanical Differential Vs. Electric Differential

Mechanics of Vehicle Movement: General description of vehicle movement, Power train Components and Sizing, Wheels and Tires, Load calculation, Torque/Traction Calculations, Power Calculation, Effect of Rolling, Pitch & Yaw on velocity and moments, Rolling resistance and its equation, Aerodynamic Drag/Lift and its equation, Grading resistance, Road resistance, Acceleration resistance, Total driving resistance, Dynamic equation, Brake System

Unit 5	Electric Vehicle Design, Manufacturing, Testing & Homologation

Frames and Suspension Design for varieties of Electric Vehicle Configuration: Introduction to Body loads, Driving dynamics and Comfort, Strength and Stiffness of chassis/frames, Types and constructional details of frames, Frame Materials, Frame building Problems, frame components, Front and Rear Suspension Systems, Panel meters and controls on Handle-bar/Dash-board, Body Manufacturing, Aesthetics and Ergonomics Consideration, Retrofitting and its associated Problems

Vehicle Testing & Homologation: Need of vehicle Testing and Homologation, National/International Testing/Regulation/Licensing/Approval Organizations and their Standards (AIS) for e-Vehicles, Hierarchy of Testing, Conformity of Production tests, Crash test, Side Impact Test, Rollover Test, Impact Test, Track Testing

Unit 6	EV Charging Infrastructure Management

Battery Charging: Basic Requirements for Charging System, Charging Methods and Standards, Converters, Charger Architectures, Grid Voltages, Frequencies and Wiring, Charger Functions, Real Power, Apparent Power, and Power Factor, Boost Converter for Power Factor Correction, Examples, Vehicle to Grid operation of EV's

Battery Management Systems: Necessity of Battery Management Systems, Typical Structure of BMSs, Representative Products, Keypoints of BMSs in Future Generation, Hazard/Safety Management.

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: 9780367137465
2. Tariq Muneer, Mohan Kolhe, Aisling Doyle, (2017), "Electric Vehicles: Prospects and Challenges," Electric Vehicles: Prospects and Challenges, ISBN: 9780128030219
3. Sandeep Dhameja, (2001), "Electric Vehicle Battery Systems", Newnes, ISBN: 9780750699167
4. Bruno Scrosati, Jürgen Garche, Werner Tillmetz, (2015), "Advances in Battery Technologies for Electric Vehicles," Woodhead Publishing, ISBN: 9781782423775
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
7. Dixon, John C., (2009), "Suspension Analysis and Computational Geometry," Wiley, ISBN: 9780470510216

8. Day, Andrew J., (2014), “Braking of Road Vehicles,” Butterworth Heinemann, ISBN: 9780123973146
9. Guiggiani, Massimo, (2018), "The Science of Vehicle Dynamics: Handling, Braking, and Ride of Road and Race Cars," Springer, ISBN: 978-3319732190
10. Chen, Yong, (2021), “Automotive Transmissions: Design, Theory and Applications,” Springer, ISBN: 9789811567025
11. Bentley Publishers, (2002), “Bosch Automotive Handbook,” Bentley Publishers, ISBN: 0837610974
12. Prasad, Priya and Belwafa, Jamel E., (2004), “Vehicle Crashworthiness and Occupant Protection,” American Iron and Steel Institute Southfield, Michigan, www.roadsafellc.com
13. Macey, Stuart and Wardle, Geoff, (2008), “H-Point: The Fundamentals of Car Design & Packaging,” designstudio Press, ISBN: 9781933492377
14. Sulabh Sachan, Sanjeevikumar Padmanaban, and Sanchari Deb, (2022), “Smart Charging Solutions for Hybrid and Electric Vehicles,” Scrivener Publishing, ISBN: 9781119768951

Web References:

- Majhi, S. and Kumar, P., (2019), “Introduction to Hybrid and Electric Vehicles,” IIT Guwahati, http://nptel.ac.in/courses/108103009/
- https://evreporter.com/

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering [Sandwich] (2019 pattern)

402050A: Quality and Reliability Engineering					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**TH**	**3**	**In-Semester**	**30 Marks**
				End-Semester	**70 Marks**

Prerequisites: Engineering Mathematics, Probability, Statistics

Course Objectives:

1. To analyze and apply Quality & Reliability Tools to solve real-life problems.
2. To plot control charts and calculate process capability.
3. To ascertain System reliability for sustainable product design.
4. To find out FMEA and understand reliability centered Maintenance.

Course Outcomes:

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

CO1. **UNDERSTAND** basic concepts of quality and **RELATE** various quality tools
CO2. **DEVELOP** analytical competencies to **SOLVE** problems on control charts and process capability.
CO3. **UNDERSTAND** fundamental concepts of reliability**.**
CO4. **EVALUATE** system reliability.
CO5. **IDENTIFY** various failure modes and **CREATE** fault tree diagram.
CO6. **UNDERSTAND** the concept of reliability centered maintenance and **APPLY** reliability tests methods.

Course Contents

Unit 1	**Introduction to Quality and Quality Tools**

Precision and accuracy, Quality dimensions, Statements, Cost of quality & value of quality, Deming"s cycles & 14 Points, Juran Trilogy approach, Seven Quality Tools, Introduction to N Seven Tools, Quality Circle, 5S, Kaizen, Poka yoke, Kanban, JIT, QMS (ISO 9000, TS16949, ISO14000). Criteria for Quality Award (National & International)

Unit 2	Statistical quality control

Statistical quality control: Statistical concept, Frequency diagram, Concept of variance analysis, Control, Chart for Variable (X & R Chart) & Attribute (P & C Chart), Process capability (Indices: cp, cpk, ppk), Statistical Process Control and six sigma. Acceptance Sampling: Sampling Inspection, OC Curve and its characteristics, sampling methods, Sampling Plans, calculation of sample size, AOQ, Probability of acceptance

Unit 3	Fundamental concepts of Reliability

Reliability definitions, failure, failure density, failure Rate, hazard rate, Mean Time to Failure (MTTF), Mean Time Between Failure (MTBF), pdf, cdf, safety and reliability, life characteristic phases, modes of failure, areas of reliability, quality and reliability assurance rules, importance of reliability, Uncertainty analysis, Probability theory and probability distributions

Unit 4	System Reliability & Allocation Techniques

Series, parallel, mixed configuration, k- out of n structure, analysis of complex systems, conditional probability method, cut set and tie set method, Redundancy & Types, Reliability allocation or apportionment, reliability apportionment techniques - equal apportionment, AGREE, ARINC, reliability predictions from predicted unreliability, minimum effort method

Unit 5	Reliability in Design & Development

Reliability techniques- Failure mode, effects analysis (FMEA), Failure mode, effects and criticality analysis (FMECA)-Case Studies, RPN, Basic symbols, Ishikawa diagram for failure representation, Fault Tree construction and analysis - case studies, minimal cut & tie set methods

Unit 6	Reliability Testing and Management

Objectives & types of maintenance, Maintainability, factors affecting maintainability, system down time, availability - inherent, achieved and operational availability, Reliability Centered Maintenance, Stress strength interaction, Introduction to reliability testing, Testing for Reliability and Durability- Accelerated Life Testing and Highly Accelerated Life Testing (HALT)

Books and other resources

Text Books:

1. L. S. Srinath, Reliability Engineering, EWP , 4th Edition 2011
2. E. Balgurusamy, Reliability Engineering, McGraw Hill Education 2002
3. S. S. Rao, Reliability Based Design, Mc Graw Hill Inc. 1992

References Books:

1. E. E. Lewis, Introduction to Reliability Engineering, John Wiley and Sons.
2. Alessandro Birolini, Reliability Engineering Theory and Practice, Springer.
3. B. S. Dhillon, Maintainability, Maintenance and Reliability for Engineers, CRC press.
4. K. C. Kapoor and L. R. Lubersome, Reliability in Engineering Design Willey Publication.
5. Basu S.K, Bhaduri , Terotechnology and Reliability Engineering, Asian Books Publication.

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering [Sandwich] (2019 pattern)

402044E: Internet of Things					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**TH**	**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:

1. Introduction to IoT, Overview of IoT Building Blocks
2. Build small applications in IoT for Mechanical Engineering Applications using Sensors, Actuators, Microcontrollers and Cloud
3. Learn commonly used IoT Simulation Hardware platforms
4. Understand different Communication Technologies used in IoT
5. Development of application level protocol and Security of IoT Ecosystem
6. 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 Mechanical Engineering [Sandwich] (2019 pattern)

402071: Systems Analysis Laboratory					
Teaching Scheme		**Credits**		**Examination Scheme**	
Practical	**2 Hrs./Week**	**PR**	**1**	**TW**	**50 Marks**
				OR	**50 Marks**

Prerequisites: Systems in Mechanical Engineering, All Mechanical Engineering subjects, Solid Modelling and Drafting, Computer Aided Engineering, Computational Fluid Dynamics, Computational Multi Body 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:

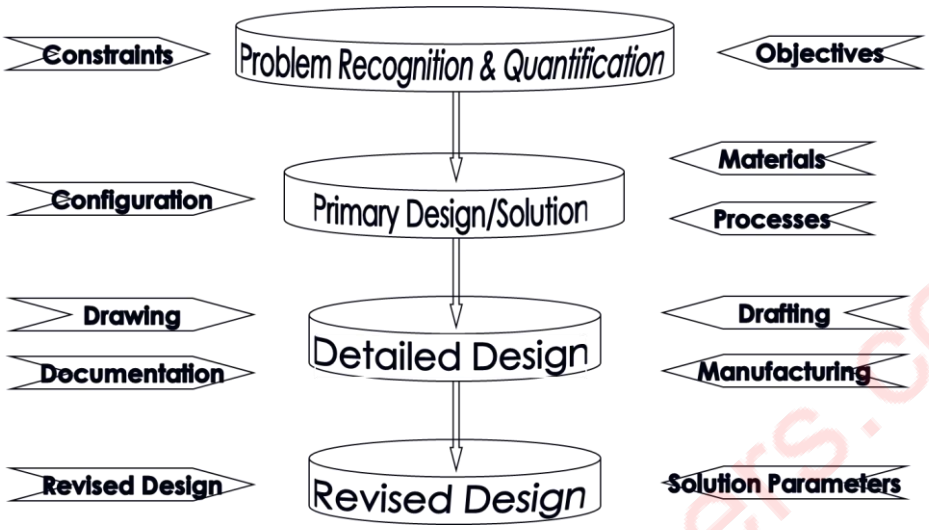
The term work shall consist of following **two parts**, each carry **equal weightage**:

A] Product based Case study

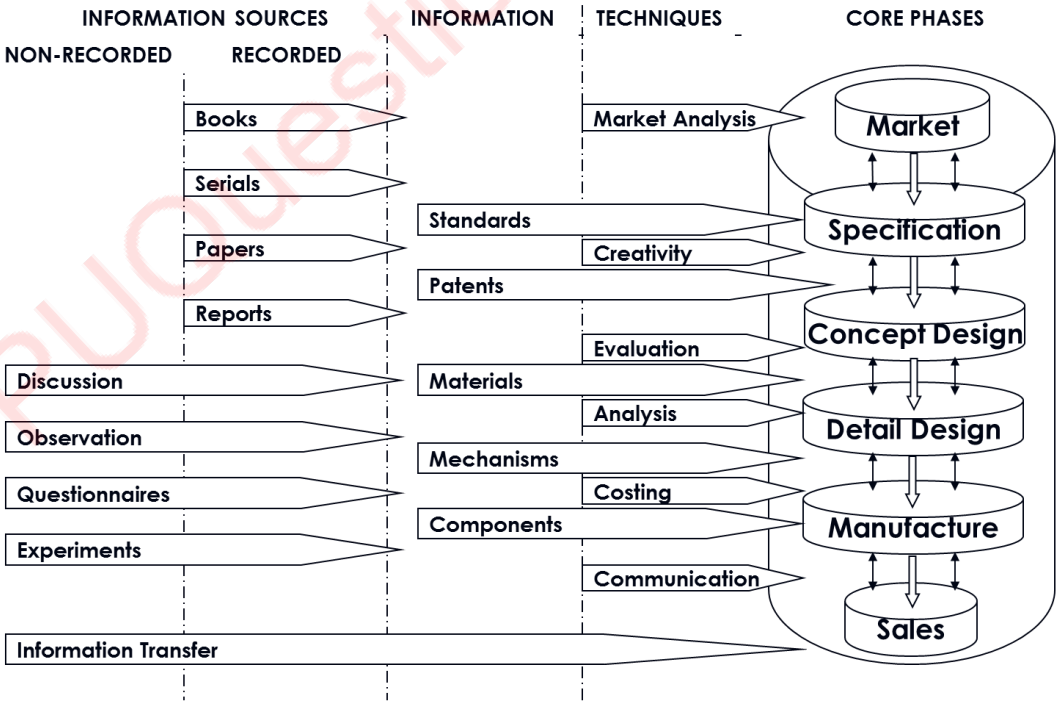
- **Individual student** will take up **one product based system analysis activity** by consultation with associated faculty and followed by development using available and learned computational tool. It will be in the form of Complete Report.
- The product can be but not limited to: any household product, Utility products, Hand/Process Tools/Equipments, Thermal Systems like, Heat exchangers, 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 mechanical 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 Five from each category)

- Following Assignment must be completely in a Computer Lab using Computational Fluid Dynamics and Multibody Dynamics Open source or Commercial Software:

B1) **CFD Assignments**

1. Numerical simulation and analysis of boundary layer over a flat plate (Blausius Equation)
2. Numerical simulation and analysis of boundary layer for a Developing flow through Pipe
3. Fully developed flow through a pipe
4. CFD Analysis of external flow: Circular Cylinder or Airfoil (NACA 0012)
5. CFD analysis of heat transfer in pin fin.
6. Numerical simulation and analysis of 2D square lid driven cavity.
7. Effect of Reynolds number on the vorticity patterns.
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. (Mandatory)

B2) **MBD Assignments**

Kinematic and Dynamic analysis of the following Multibody Systems:

1. Four bar mechanism/Slider crank mechanism
2. Cam and follower System
3. Serial Robot Manipulators
4. Parallel Robot Manipulators
5. Mobile Robot
6. Leg Mechanisms/Grippers Mechanisms
7. Automation/ Material Transporting Mechanism
8. Mini project on any practical application. Students should take a problem of their choice and verify the MBD solution with experimental data / research paper. (Mandatory)

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

Assessment of Term Work

The student shall complete the above mentioned activities and prepare a **Term Work Journal** and **Product based Case Study Report**

Important Note:

Term Work of the Student shall be evaluated based on the completion of individual **Product based Case Study Report** and **Assignments**. Continuous evaluation by the faculty shall be done for the award of the credit associated with the course. No practical examination shall be conducted for the award of the credit.

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering [Sandwich] (2019 pattern)

402055: Audit Course VIII[$]				
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
A. Managing Innovation **B.** Operations Management 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.