Savitribai Phule Pune University
Faculty of Science & Technology

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

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering (2019 pattern)

Course Code	Course Name	Teaching Scheme (Hrs./week)			Examination Scheme and Marks						Credit			
		TH	PR	TUT	ISE	ESE	TW	PR	OR	TOTAL	TH	PR	TUT	TOTAL
Semester-VII														
402041	Heating Ventilation Air-Conditioning and Refrigeration	3	2	-	30	70	-	-	25	125	3	1	-	4
402042	Dynamics of Machinery	3	2	-	30	70	-	-	25	125	3	1	-	4
402043	Turbomachinery*	2	2	-	-	50	25	-	25	100	2	1	-	3
402044	Elective – III	3	-	-	30	70	-	-	-	100	3	-	-	3
402045	Elective - IV	3	-	-	30	70	-	-	-	100	3	-	-	3
402046	Data Analytics Laboratory	-	2	-	-	-	50	-	-	50	-	1	-	1
402047	Project (Stage - I)	-	4	-	-	-	50	-	50	100	-	2	-	2
402054	Audit Course VII[$]	-	-	-	-	-	-	-	-	-	-	NC		
	Total	**14**	**12**	**-**	**120**	**330**	**125**	**-**	**125**	**700**	**14**	**6**	**-**	**20**
Semester-VIII														
402048	Computer Integrated Manufacturing	3	2	-	30	70	25	-	25	150	3	1	-	4
402049	Energy Engineering	3	2	-	30	70	25	-	25	150	3	1	-	4
402050	Elective - V	3	-	-	30	70	-	-	-	100	3	-	-	3
402051	Elective - VI	3	-	-	30	70	-	-	-	100	3	-	-	3
402052	Mechanical Systems Analysis Laboratory	-	2	-	-	-	25	-	25	50	-	1	-	1
402053	Project (Stage - II)	-	10	-	-	-	100	-	50	150	-	5	-	5
402055	Audit Course VIII[$]	-	-	-	-	-	-	-	-	-	NC			
		12	**16**	**-**	**120**	**280**	**175**	**-**	**125**	**700**	**12**	**8**	**-**	**20**

Elective-III		Elective-V	
402044A	Automobile Design	402050A	Quality and Reliability Engineering
402044B	Design of Heat Transfer Equipments	402050B	Energy Audit and Management
402044C	Modern Machining Processes	402050C	Manufacturing Systems and Simulation
402044D	Industrial Engineering	402050D	Engineering Economics and Financial Management
402044E	Internet of Things	402050E	Organizational Informatics
402044F	Computational Fluid Dynamics	402050F	Computational Multi Body Dynamics
Elective-IV		**Elective-VI**	
402045A	Product Design and Development	402051A	Process Equipment Design
402045B	Experimental Methods in Thermal Engineering	402051B	Renewable Energy Technologies
402045C	Additive Manufacturing	402051C	Automation and Robotics
402045D	Operations Research	402051D	Industrial Psychology and Organizational Behavior
402045E	Augmented Reality and Virtual Reality	402051E	Electrical and Hybrid Vehicle

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

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

Instructions:

- Practical/Tutorial must be conducted in **FOUR batches per division** only.
- Minimum number of Experiments/Assignments in PR/Tutorial shall be carried out **as mentioned in the syllabi** of respective courses.
- Assessment of tutorial work has to be carried out similar to term-work. The Grade cum marks for Tutorial and Term-work shall be awarded on the basis of **continuous evaluation.**
- End semester examination shall be of 2 hrs. for the ***** Marked Turbomachinery Course.
- $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 (2019 pattern)

402041: Heating, Ventilation, Air Conditioning and Refrigeration					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30 Marks**
Practical	**2 Hrs./Week**	**Practical**	**1**	**End-Semester**	**70 Marks**
				Oral	**25 Marks**

Prerequisites: Thermodynamics, Applied Thermodynamics, Fluid Mechanics, Heat and Mass Transfer.

Course Objectives:

1. To understand and compare different refrigerants with respect to properties, applications and Environmental issues and Air refrigeration systems.
2. To understand Multistage compression cycles and multistage evaporator systems.
3. To understand various components, operating and safety controls employed in Refrigeration and Air Conditioning systems and advanced refrigeration systems.
4. To understand the basic air conditioning processes on psychometric charts, human comfort and to provide the knowledge of indoor and outdoor air quality requirements.
5. To study the ventilation and infiltration in air conditioning and duct design for various comfort conditions and industrial air conditioning systems.
6. To understand advanced A/C systems and heat pump.

Course Outcomes:

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

CO1.**ANALYSE** different air-craft refrigeration systems and **EXPLAIN** the properties, applications and environmental issues of different refrigerants.

CO2.**ANALYSE** multi pressure refrigeration system used for refrigeration applications.

CO3.**DISCUSS** types of compressors, condensers, evaporators and expansion valves along with regulatory and safety controls and **DESCRIBE** Transcritical and ejector refrigeration systems.

CO4.**ESTIMATE** cooling load for air conditioning systems used with concern of design conditions and indoor quality of air.

CO5.**DESIGN** air distribution system along with consideration of ventilation and infiltration.

CO6.**EXPLAIN** the working of types of desiccants, evaporative, thermal storage, radiant cooling, clean room and heat pump systems.

Course Contents

Unit 1	**Gas Cycle Refrigeration and Refrigerants**

Gas Cycle Refrigeration: Application to air-craft refrigeration, Simple system, Bootstrap, Regenerative, reduced ambient system, Concept of Dry Air Rated Temperature (DART)

Refrigerants: Introduction, Definition and requirement, Classification of refrigerants, Designation of refrigerants, Desirable properties of Refrigerants-Thermodynamic, Chemical and Physical.

Properties of ideal refrigerant. Environmental issues like ODP, GWP & LCCP. Selection of environment friendly refrigerants, Alternative refrigerants, Secondary refrigerants, Anti-freeze solutions, Zeotropes and Azeotropes, Refrigerant recovery, reclaims, recycle and recharge.

Unit 2	**Multi Pressure Systems**

Multistage or Compound Systems: Need of multi staging, Two stage compression with flash gas removal, flash intercooler and complete multistage compression system.

Multi Evaporator Systems: Single compressor-individual expansion valve, Single compressor-multiple expansion valve, Individual compressor-multiple expansion valve, Individual compressor with compound compression and flash inter cooling. (Limited to two evaporators).

Ammonia-CO_2 cascade cycle. (Only theoretical approach).

Unit 3	**Practical aspects of Vapor Compression and Advanced Refrigeration Systems**

Major components of refrigeration cycle: Types of compressors, Characteristics of reciprocating and centrifugal compressors, Types of evaporators, Types of condensers and Types of expansion valves.

Safety Controls: LP/HP cut-off, Low temperature control, Frost control, Motor overload control, Oil pressure failure control. Capacity controls for different compressors.

Advanced Refrigeration System: Transcritical cycle and their types, Simple ejector refrigeration system (analysis and numerical)

Unit 4	**Applied Psychrometry**

Psychrometric Chart, Psychrometric processes using BPF, ADP, SHF, RSHF, GSHF, ESHF, ERSHF and adiabatic mixing of two air streams. Heat load estimation: - Air conditioning, heating & cooling load calculations.

Envelop Load estimation: Concept of sol-air temperature, Time lag & Decrement method and ETD or CLTD methods.

Thermal Comfort: Basic parameters, Thermodynamics of human body, Thermal comfort and Comfort charts, Factors affecting thermal comforts.

Indoor Air Quality (IAQ): Indoor air contaminants, Basic strategies to improve indoor air quality.

Outdoor Design Conditions: Outdoor air requirements for occupants, Use of outdoor weather data in design, Outdoor weather characteristics and their influence.

Unit 5	**Ventilation, Infiltration & Air Distribution systems (Ducts)**

Ventilation and infiltration: Natural ventilation, Mechanical ventilation.
Duct Design: Definition of duct and types of ducts, Economic factors influencing duct layout, Materials for ducts and its specification, Flow through duct, Pressure in ducts, Friction loss in ducts, Friction chart for circular ducts, Equivalent diameter of a circular duct for rectangular sections, Methods of duct designs. (Numerical treatment on duct design).

Air Distribution System: Factors considered in air distribution system, (simple numerical). Types of air distribution devices. Fan coil unit, Fan laws, Types of fans used in air conditioning applications, Types of supply air outlets, Selection and location of outlets, Filters, Diffusers, Grillers, and Dampers.

Unit 6	Advanced Air Conditioning Systems

Advanced AC Systems: Working of summer, winter and 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.

Desiccant-Based Air Conditioning Systems: Introduction, Sorbents & Desiccants, Dehumidification, Liquid spray tower, Solid packed tower, Rotary desiccant dehumidifiers, Hybrid cycles, Solid desiccant Air-Conditioning (Theoretical treatment).

Evaporative Cooling Air Conditioning Systems, Thermal storage Air Conditioning systems, clean room Air Conditioning systems, Radiant cooling. (No numerical), Heat pumps and its different circuits.

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. Arora and Domkundwar, Refrigeration & Air Conditioning, Dhanpatrai & Company, New Delhi
4. Khurmi R.S. and Gupta J.K., Refrigeration and Air conditioning, Eurasia Publishing House Pvt.Ltd, New Delhi,1994.
5. Ballaney P.L., Refrigeration and Air conditioning, Khanna Publishers, New Delhi, 1992.
6. S.N.Sapali , Refrigeration and Air conditioning ,Eastern Economy Edition.
7. Arora R.C., Refrigeration and Air Conditioning, PHI, India.

References Books:

1. Dossat Ray J, Principles of refrigeration, S.I. version, Willey Eastern Ltd, 2000.
2. Stockers W.F and Jones J.W., Refrigeration and Air conditioning, McGraw Hill International editions 1982.
3. Aanatnarayan, Basics of refrigeration and Air Conditioning, Tata McGraw Hill Publications.
4. Roger Legg, Air Conditioning System Design, Commissioning and Maintenance.
5. ASHRAE Handbook (HVAC Equipments) & ISHRAE handbook.
6. Shan Wang, Handbook of Refrigeration and Air Conditioning, McGrawHill Publications.
7. Wilbert Stocker, Industrial Refrigeration, McGrawHill Publications.
8. ASHRAE, Air Conditioning System Design Manual, IInd edition, ASHRAE.

Term Work

The student shall complete the following activity as a Term Work (Any eight experiments, No. 8 or 9 is compulsory):

1. Trial on Ice Plant.
2. Performance Simulation of Central Air-conditioning plant.
3. Trial on Air-conditioning system.
4. Performance analysis of Cooling tower.
5. Building heat load simulation using suitable software.
6. Design of cold storage with process layout.
7. Analysis of Vapor Compression Cycle using suitable software.
8. Visit to Refrigeration or cold storage Plant
9. Visit to Air Conditioning Plant.
10. Trial on heat pump/ejector/cascade/desiccant/evaporative systems.

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering (2019 pattern)

402042: Dynamics of Machinery					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30 Marks**
Practical	**2 Hrs./Week**	**Practical**	**1**	**End-Semester**	**70 Marks**
				Oral	**25 Marks**

Pre-requisites: Strength of Materials, Engineering Mechanics, Kinematics of Machinery, Engineering Mathematics and Numerical Methods

Course Objectives:

1. To conversant with balancing problems of machines.
2. To understand mechanisms for system control – Gyroscope.
3. To understand fundamentals of free and forced vibrations.
4. To develop competency in understanding of vibration in Industry.
5. To develop analytical competency in solving vibration problems.
6. To understand the various techniques of measurement and control of vibration and noise.

Course Outcomes:

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

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

CO2. **ANALYZE** the gyroscopic couple or effect for stabilization of Ship, Airplane and Four wheeler vehicles.

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** noise and vibration measuring instruments for industrial / real life applications along with suitable method for noise and vibration control.

Unit 1	**Balancing**

Static and dynamic balancing, balancing of rotating masses in single and several planes, primary and secondary balancing of reciprocating masses, balancing in single cylinder engines, balancing in multi-cylinder in-line engines, direct and reverse cranks method -radial and V engines. Introduction to Balancing machines – Types, Classification and Methods

Unit 2	Gyroscope

Introduction, Precessional angular motion, Gyroscopic couple, Effect of gyroscopic couple on an airplane, Effect of gyroscopic couple on a naval ship during steering, pitching and rolling, 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, Introduction to Physical and Mathematical modeling of vibratory systems: Bicycle, Motor bike and Quarter Car. types of vibration, equivalent stiffness and damping, formulation of differential equation of motion (Newton, D'Alembert and energy method)

Un-damped free vibrations: Natural frequency for longitudinal, transverse and torsional vibratory systems. (Numerical on only longitudinal and transverse systems.)

Damped free vibrations: Different types of damping, Viscous damping – over damped, critically damped and under damped systems, initial conditions, logarithmic decrement, Dry friction or coulomb damping - frequency and rate of decay of oscillations.(Numerical only on Logarithmic decrement)

Unit 4	Single Degree of Freedom Systems - Forced Vibrations

Forced vibrations of longitudinal and torsional systems, Frequency Response to harmonic excitation (Numerical on only longitudinal systems), excitation due to rotating and reciprocating unbalance, base excitation, magnification factor, Force and Motion transmissibility

Quality Factor. Half power bandwidth method, Critical speed of shaft having single rotor of undamped systems. (Theoretical treatment only)

Unit 5	Two Degree of Freedom Systems – Un-damped Vibrations

Free vibration of spring coupled systems – longitudinal and torsional, torsionally equivalent shafts, natural frequency and mode shapes, Eigen value and Eigen vector by Matrix method (Numerical only on longitudinal systems and Matrix Method)

Combined rectilinear and angular motion, Vibrations of Geared systems (Theoretical treatment only)

Unit 6	Measurement and Control of Vibrations, Introduction to Noise

A) 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.

B) 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 Absorbers.

C) Noise: Fundamentals of noise, Sound concepts, Decibel Level, Logarithmic addition, subtraction and averaging, sound intensity, noise measurement, Noise control at the Source, along the path and at the receiver, Reverberation chamber, Anechoic Chamber, Noise standards. (Unit VI – Only theoretical treatment)

Books

Textbook:

1. S. S. Rao, Mechanical Vibrations, Pearson Education Inc. New Delhi.
2. G. K. Grover, 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. M L Munjal, Noise and Vibration Control, Cambridge University Press India
6. S. S. Rattan, Theory of Machines, Third Edition, McGraw Hill Education (India) Pvt. Ltd. New Delhi.

References:

1. Weaver, Vibration Problems in Engineering, 5th Edition Wiley India Pvt. Ltd, New Delhi.
2. Bell, L. H. and Bell, D. H., Industrial Noise Control – Fundamentals and Applications‖, Marcel Dekker
3. Alok Sinha, Vibration of Mechanical System, Cambridge university Press, India
4. Debabrata Nag, Mechanical Vibrations, Wiley India Pvt. Ltd, New Delhi.
5. Kelly S. G., Mechanical Vibrations, Schaums outlines, Tata McGraw Hill Publishing Co. Ltd.
6. Meirovitch, L., Elements of Mechanical Vibrations‖, McGraw Hill.
7. Ver, Noise and Vibration Control Engineering, Wiley India Pvt. Ltd, New Delhi.
8. Bies, D. and Hansen, C., Engineering Noise Control - Theory and Practice, Taylor and Francis.
9. Shrikant Bhave, Mechanical Vibrations Theory and Practice, Pearson, New Delhi

Term Work

A] Compulsory Experiments (Sr. No. 1 to 6)

1. Balancing of wheel / rotor on computerized balancing machine OR Experimental verification of dynamic balancing of rotating masses.
2. To determine the natural frequency of damped vibration of single degree freedom system and to find it‘s damping coefficient.
3. To obtain frequency response curves of single degree freedom system of vibration for different amount of damping.
4. To verify natural frequency of torsional vibration of two rotor system and position of node.
5. To measure vibration of healthy and faulty beam using FFT analyzer in time and/ or frequency domain and further classify the condition.
6. To measure noise of any healthy and faulty machine element and represent it into time and/or frequency domain and further predict the condition in future.

B] Any Two Experiments from the following:

1. To determine critical speed of shaft with single rotor.
2. Experimental verification of principle of dynamic vibration absorber.
3. Experiment on shock absorbers and to plot its characteristic curve.
4. To determine the effect of active gyroscopic couple on a spinning disc and verify the gyroscopic effect.
5. Industrial visit based on Conditioning Monitoring and Fault Diagnosis.

C] List of Compulsory Assignment:

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

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

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402043: Turbomachinery					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**2 Hrs./week**	**Theory**	**2**	**In-Semester**	**-**
Practical	**2 Hrs./week**	**Term Work**	**1**	**End-Semester***	**50 marks**
				Term Work	**25 marks**
End semester examination shall be of 2 hrs.				**Oral**	**25 marks**

Prerequisites: Fluid Mechanics, Thermodynamics, Heat Transfer, Engineering Mathematics

Course Objectives:

1. To provide the knowledge of basic principles, governing equations and applications of Turbomachines.
2. To provide the students with opportunities to apply basic thermos-fluid dynamics flow equations to Turbomachines.
3. To explain construction and working principles of Turbomachines.
4. To evaluate the performance characteristics of Turbomachines.

Course Outcomes:

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

CO1: **VALIDATE** impulse moment principle using flat, inclined and curved surfaces and **INVESTIGATE** performance characteristics of hydraulic turbines.

CO2: **DETERMINE** performance parameters of impulse and reaction steam turbine along with discussion of nozzles, governing mechanism & losses.

CO3: **MEASURE** performance parameters of single & multistage centrifugal pumps along with discussion of cavitation and selection.

CO4: **EXPLAIN** performance parameters of centrifugal compressor along with discussion of theoretical aspects of axial compressor.

Course Contents

Unit 1	**Impact of Jet and Hydraulic Turbines**

Introduction and Impact of Jet: Introduction to Turbomachines (Hydraulic & Thermal), Classification of Turbo machines, Applications of Turbomachines. Impulse momentum principle and its application to fixed and moving flat, inclined, and curved plate/vanes. Velocity triangles and their analysis, work done equations, vane efficiency (No numerical)

Hydraulic Turbines:

Introduction to Hydro power plant, Classification of Hydraulic Turbines, Concept of Impulse and Reaction Turbines. Construction, Principle of Working, design aspects, velocity diagrams and its

analysis of Pelton wheel, Francis, and Kaplan turbines, Degree of reaction, Draft tube: types and efficiencies, governing of hydraulic turbines, Cavitation in turbines.

Unit 2	**Steam Turbines**

Steam Nozzle: Equations for velocity and mass flow rate (No derivation, no numerical)
Steam Turbines: Construction and working of Impulse and Reaction steam turbine, velocity diagram, work done efficiencies, Multi-staging, compounding, Degree of reaction, losses in steam turbine, governing of steam turbines

Unit 3	**Centrifugal Pumps**

Introduction & classification of rotodynamic Pumps, Main Components of Centrifugal Pump, Construction and Working of Centrifugal Pump, Types of heads, Velocitytriangles and their analysis, Effect of outlet blade angle, Work done and Efficiency, Series and parallel operation of pumps, Priming of pumps, specific speed

Unit 4	**Rotary Compressors**

Centrifugal Compressors: Classification of Centrifugal Compressor, construction and working, velocity diagram, flow process on T-S Diagram, Euler's work, actual work input, various losses in Centrifugal Compressor

Axial flow compressors: Construction and working, stage velocity triangle and it's analysis, enthalpy entropy diagram, stage losses and various efficiencies of axial flow compressors, [No numerical]

Books and other resources

Text Books:

1. Fluid mechanics and hydraulic machines, Dr. R.K. Bansal, Laxmi Publication
2. Hydraulics & Fluid Mechanics and Machinery, Modi P N & Seth S N, Standard Book House
3. Turbines, Compressors & Fans, S.M. Yahya, Tata-McGraw Hill
4. Turbomachines, B. U. Pai, Wiley India
5. Steam and Gas Turbines and Power Plant Engineering, R. Yadav, Central Publication house

Web References:

https://nptel.ac.in/courses/112105206
https://nptel.ac.in/courses/112105182
https://nptel.ac.in/courses/112104117

Guidelines for Laboratory Conduction

- Term work shall consist of eleven experiments.
- Experiment No1,3,8,10,11 and 12 are compulsory.
- From remaining experiments (2,4,5,6,7 and 9) any five experiments are to be performed.
- Data from any one trial performed should be analyzed by using suitable software.

Term Work

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

1. Study of Impulse momentum principle and its application to fixed flat, moving, inclined, and curved plates/vanes.
2. Verification of Impulse Momentum Principle.
3. Study of Unit quantities, Specific speed and performance characteristics of hydraulic turbines.
4. Study and Trial on Impulse water Turbine and plotting the main and operating characteristics
5. Study and Trial on any one hydraulic Reaction Turbine and plotting the main and operatingcharacteristics.
6. Study and Trial on Convergent-Divergent Air/Steam nozzle
7. Study and Trial on steam Turbine and plotting the operating characteristics.
8. Study of Cavitation, NPSH, Thoma's cavitation factor, maximum suction lift.
9. Study and Trial on Centrifugal Pump and plotting the operating characteristics.
10. Study of Surging, stalling and choking phenomenon in compressors, performancecharacteristics of Centrifugal and Axial flow Compressors.
11. Visit to hydro/steam power plant and report to be submitted.
12. Visit to Pumping Station and report to be submitted.

OR

12. Design of Pumping system installation using Manufacturers catalogue, specific to housing or industrial application.

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Board of Studies - Mechanical and Automobile Engineering

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402044A: Automobile Design					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30**
				End-Semester	**70**

Prerequisites: **E**ngineering Mathematics-I and II, Systems in Mechanical Engineering, Engineering Mechanics, Theory of Machines, Automobile Engineering, Design of Machine Elements

Course Objectives:

1. To help the students to acquire in-depth knowledge of design of Different engine components and engine subsystems.
2. To make students to understand the different chassis components selection and design.
3. To enable the students with the knowledge of Vehicle Packaging and System Integration and NVH.

Course Outcomes:

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

CO1: **COMPREHEND** the steps involved in the design process of Principal Engine Components.
CO2: **GAIN** the knowledge and design of Engine Sub-Systems.
CO3: **COMPUTE** the critical dimensions of chassis components involved in the Steering System and Differential and final drive of a vehicle.
CO4: **SELECT** the tyres and wheels required for automobile vehicle and design the various types automotive brakes.
CO5: **UNDERSTAND** the design concepts of Automotive Suspension system
CO6: **POSSES** the knowledge of Vehicle Packaging and System Integration, NVH.

Course Contents

Unit 1	**Principal Engine Components**

Design of cylinder and cylinder head, construction of cylinder liners, design of piston and piston-pins, piston rings, design of connecting rod. Design of crank-shaft and crank-pin, (Theoretical treatment only). Material for I. C. engine components.

Unit 2	**Engine Subsystems**

Design of cooling system - radiator, water pump and fan, Computation of air cooling system, Design of fuel system, Governor, Intake and exhaust system, Selection of lubricant, lubricating system, pump and filters.

Unit 3	**Steering System and Differential**

Mechanical Steering Gears, Power Steering Drives, Basic Principles of the Steering Process, Steering Kinematics, Steering Mechanism Design- Geometry for Correct Steering, Linkages, Basic Wheel

Alignment.
Design of propeller shaft. Design details of final drive gearing. Design of Bevel Gears in deferential, Design details of full floating, semi-floating and three quarter floating rear shafts.(Theoretical treatment only)

Unit 4	Wheels, Tyres and Automotive Brakes

Wheels and Tyres: Introduction, wheel tyre assemblies, wheels, rims, Wheel fixing, Tyres, Constructional details, Tread Design, Noise, Aspect Ratio, Tread Design consideration, Run Flat Tyres, Materials, Retreading and Manufacturing, Factors affecting tyre life.

Automotive Brakes: Mechanical Brakes, Hydraulic brakes, Servo brakes, Air brakes, ABS, Brake Lining, Brake efficiency, Stopping Distance, Theory of Internal Shoe Brake, banking of vehicles, Banking of vehicle on curved path. Numerical.

Unit 5	Automotive Suspension system

Springs - Types of Suspension Springs, Shock Absorbers, Independent Suspension system, Double wishbone suspensions, McPherson struts and strut dampers, Rear axle trailing-arm suspension, Semi-trailing-arm rear axles, Multi-link suspension, Air Suspension, Hydro-elastic suspensions, Rear Suspension (Dead Axle), Active Suspension, Suspension control systems,
Design of helical springs, Design of leaf springs, Numerical.

Unit 6	Vehicle Packaging and System Integration

Vehicle Packaging and System Integration: Introduction to Automotive Ergonomics, Vehicle Packaging background, Vehicle packaging organization, packaging engineering and ergonomics, Principles used in vehicle packaging, Vehicle packaging procedure, Mechanical packaging, Occupant packaging, driver package development steps and calculations, entry and exit considerations, driver field of view.

Engineering Anthropometry and Biomechanics: Engineering Anthropometry and Biomechanics, Use of Anthropometry in Designing Vehicles, Applications of Biomechanics in Vehicle Design

Books

Text Books:

1. Thomas D. Gillespie, "Fundamentals of Vehicle Dynamics", 2013, Society of Automobile Engineers Inc., ISBN: 978-1560911999
2. Engine Design – Giles J. G., Lliffe Book Ltd.
3. Engine Design – Crouse, Tata McGraw Publication, Delhi.
4. Design of Automotive Engine – A. Kolchin and V. Demidov
5. Automobile Engineering: Vol.1- Dr. Kirpal Singh, Standard Publishers Distributors.
6. A Textbook of Machine Design, R.S. Khurmi J.K. Gupta, Eurasia Publishing House.
7. Design of Machine Elements - V. B. Bhandari Tata McGraw-Hill, 2007
8. Automotive Product Development- A Systems Engineering Implementation- Vivek D. Bhise, CRC PressTaylor & Francis Group, ISBN-13: 978-1-4987-0681-0

References Books:

1. Chassis Handbook, Bernd Heißing | Metin Ersoy (Eds.) Vieweg+Teubner Verlag |Springer Fachmedien Wiesbaden GmbH 2011

2. The Motor Vehicle, T.K.Garrette, Steeds, Newton, Butterworth Heinemann.
3. The Automotive Chassis, Vol. 1: Components Design , Giancarlo Genta • Lorenzo Morello, ISBN: 978-1-4020-8673-1 e-ISBN: 978-1-4020-8675-5, 2009 Springer Science+Business Media B.V.
4. Ergonomics in the Automotive Design Process, Vivek D. Bhise, CRC Press, Taylor & Francis Group, ISBN-13: 978-1-4398-4211-9

Web References:

1. https://archive.nptel.ac.in/courses/107/106/107106088/
2. https://nptel.ac.in/courses/107103084

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering (2019 pattern)

402044B: Design of Heat Transfer Equipments					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30 Marks**
				End-Semester	**70 Marks**

Prerequisites: Thermodynamics, Heat Transfer

Course Objectives:

1. Understand the basic concept and design methodology of heat exchangers.
2. Identify the design requirements for different types of heat exchangers
3. Define the important heat-exchanger design parameters
4. Perform sizing of a given type of heat exchanger for a specific application.
5. Make use of basic knowledge of fluid mechanics, heat transfer, and material properties in both performance and design calculations.

Course Outcomes:

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

CO1: **EXPLAIN** the design aspect of heat exchanger considering fouling factor for Heat Transfer Applications

CO2: **SELECT** and **DESIGN** the double tube heat exchangers for process industry

CO3: **DESIGN** the Shell & Tube Heat Exchangers for specified conditions

CO4: **DESIGN** the condensers and evaporators for refrigeration applications

CO5: **DESIGN the** compact heat exchangers

CO6: **ANALYSE** the performance of counter and cross flow cooling tower.

Course Contents

Unit 1	**Fundamentals of Heat Exchanger Design**

Introduction: Introduction, classification of heat exchangers and their applications, different standards used for heat exchanger

Basics of heat exchanger design: Basic design equation, LMTD for parallel flow and counter flow arrangement, correction factor for LMTD for cross flow and multi –pass heat exchangers, Effectiveness - NTU method for heat exchanger design/analysis

Fouling of Heat Exchanger: Introduction, causes of fouling, types of fouling, effect of fouling, fouling factor, overall heat transfer coefficient with fouling, fouling factors for various process and services, methods to reduce fouling, cleaning process of fouled heat exchanger

Unit 2	Double Pipe Heat Exchanger

Constructional features, Applications, Thermal and Hydraulic design of inner tube and annulus, hairpin heat exchanger with bare and finned inner tube, total pressure drop, Rating and sizing problem. Correlations for tube side pressure drop and heat transfer coefficients. Pressure drop and heat transfer coefficient correlations for shell side flow, different methods to enhance the heat transfer coefficient (Theoretical Treatment only)

Unit 3	Shell & Tube Heat Exchangers

Tube layouts for exchangers, Baffled heat exchangers, Calculation of shell and tube heat exchangers, Shell side film coefficients, Shell side equivalent diameter (Kerns method, Bell-Delaware method), The temperature difference in a 1-2 heat exchanger. Shell side pressure drop, Tube side pressure drop, Analysis and performance of 1-2 heat exchanger and design of shell & tube heat exchangers.

Unit 4	Condensers and evaporators for Refrigeration systems

Design considerations of heat exchangers for refrigeration and air conditioning applications, thermal design of heat exchanger used for refrigeration applications, air cooled condenser, Design considerations of Evaporative condensers.

Evaporator: Evaporator for refrigeration and air-conditioning, thermal analysis of evaporator, standards for evaporators and condensers,

Unit 5	Design of compact heat exchangers

Classification of compact heat exchangers, Plate heat exchangers (Numerical treatment), plate fin heat exchanger, tube fin heat exchanger (Numerical treatment), coiled tube heat exchangers (Numerical treatment), mini and micro channel heat exchangers, factors affecting on design of heat exchanger, Thermal analysis in compact heat exchanger.

Unit 6	Direct Contact Heat Exchanger

Cooling towers, relation between wet bulb & dew point temperatures, Classification of cooling towers, Cooling tower internals and the roll of fills, Heat Balance, Analysis of cooling tower requirements, Deign of counter flow, cooling towers, Determination of the number of diffusion units.

Books and other resources

Text Books:

1. Fundamentals of Heat Exchanger Design by Ramesh K Shah, Wiley Publication
2. Compact Heat Exchangers by Kays, V.A. and London, A.L., McGraw Hill
3. Process Heat transfer by Donald Q Kern, McGraw Hill

References Books:

1. Heat Exchanger Design Handbook by Kuppan, T, Macel Dekker, CRC Press
2. Heat Exchanger Selection, Rating and Thermal Design by Sadik, Kakac, CRC Press

Web References:

1. https://www.pdfdrive.com/heat-exchanger-design-handbook-e56045839.html
2. https://www.pdfdrive.com/heat-exchangers-book-e25375475.html
3. https://www.pdfdrive.com/heat-exchangers-selection-rating-and-thermal-design-third-edition-e186214274.html
4. https://www.pdfdrive.com/compact-heat-exchangers-selection-application-design-and-evaluation-e186388889.html

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering (2019 pattern)

402044C - Modern Machining Processes					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30 Marks**
				End-Semester	**70 Marks**

Prerequisite

Engineering Materials and Metallurgy, Manufacturing Processes

Course Objectives

1. To understand the different modern machining process.
2. To evaluate the process parameters of modern machining processes.
3. To able to select the process for application.
4. To apply the knowledge of different modern machining for manufacturing.

Course Outcomes

On completion of the course, learner will be able to

CO1. **UNDERSTAND** and **ANALYZE** the mechanism, process parameters of mechanical assisted modern machining processes.

CO2. **UNDERSTAND** the mechanism, construction and working of laser, plasma and electron beam assisted machining.

CO3. **CLASSIFY** and **ANALYZE** the mechanism, process parameters of the chemical and electrochemical machining.

CO4. **RELATE** and **ANALYZE** the mechanism and select process parameters Electrical Discharge Machining for an application.

CO5. **ILLUSTRATE** the application of micromachining processes.

CO6. **SUGGEST** appropriate nanomachining process for the specific application.

Course Contents

Unit 1	**Mechanically Assisted Modern Machining Process**

Introduction to modern manufacturing processes, Need and classification of modern manufacturing methods.

Introduction to advanced Mechanical Energy Process machining processes and their classification, - Abrasive Jet Machining (AJM), Abrasive Water Jet Machining (AWJM), Ultra Sonic Machining (USM), Water Jet Machining (WJC) -Principle, Working, process parameters, Effect of process parameters on Material removal rate, tool wear, surface finish, Advantages, Limitations & applications, economics of machining.

Unit 2	Energy Assisted Modern Fabrication Process

Introduction to Energy Process machining processes, Principle, applications, classifications and selection, process parameters, concept of energy level, Heat Affected Zone and economics of the process in Laser beam machining (LBM) Laser Optics, Plasma arc machining (PAM), Electron Beam Machining (EBM), Focused Ion beam (FIB).

Unit 3	Electro-chemical Machining Process

Electro chemical machining (ECM): Introduction, Working Principle, equipment, process parameters, material removal rates, surface integrity, type of electrolyte, Advantages, limitations & applications of ECM, economics of machining.

Electrochemical Grinding (ECG), Electro stream Drilling (ESD), Photochemical machining (PCM) Chemical machining (ChM).

Unit 4	Electro-thermal Machining Process

Electric discharge machining (EDM): Introduction, Working Principle, EDM-Spark Circuits, selection of tool electrodes and dielectric fluids, process parameters, material removal rates, surface integrity, Heat Affected zone, Advantages, limitations & applications of EDM, Wire Electric Discharge Machining (W-EDM), Electric Discharge Grinding (EDG), Electric Discharge Diamond Grinding (EDDG), economics of machining. Electrochemical discharge machining (ECDM)

Unit 5	Micro And Precision Manufacturing Process

Micro machining processes that include working principle, material removal mechanism, effect of process parameters, materials processed, applications - Diamond turn machining, micro turning, Micro drilling, micro engraving, micro milling, Micro electro discharge machining, Case study on each process. economics of machining.

Unit 6	Nano-Machining And Nano Finishing Techniques

Fundamental of micro and nano technology, Effect of material aspects, concepts of micro and Nano systems and Microsystems Products, Microsystems and Microelectronics, Micro and Nano fabrication-wet and dry etching, photolithography-LIGA process, Application of Microsystems, Case study on MEMS.

Magnetic Abrasives Finishing (MAF), Abrasive Flow Finishing (AFF) Magnetorheological Finishing (MRF), Rotational - Magnetorheological Abrasive Flow Finishing (R-MRAFF).

Books & Other Resources

Text Books

1. V. K. Jain "Advanced Machining Processes" Allied Publishers Pvt. Ltd., New Delhi, 2007.
2. Pandey P.C. and Shan H.S. "Modern Machining Processes" Tata McGraw-Hill.
3. Production technology, HMT, McGraw Hill Education India Pvt. Ltd. 2001.
4. M. P Groover., "Fundamentals of Modern Manufacturing: Materials, Processes, and Systems", 6th edition, Wiley 2015.

Reference Books

1. V. K. Jain, "Micro manufacturing Processes", CRC Press.
2. R. Balasubramaniam, RamaGopal V. Sarepaka, Sathyan Subbiah, "Diamond Turn Machining:

Theory and Practice", CRC Press.
3. MEMS Material and Process Handbook, Reference proceedings, Reza Ghodssi, Pinyen Lin, Springer.
4. Hassan El-Hofy, "Advanced Machining Processes", McGraw Hill Publications.
5. Julian W. Gardner, "Microsensors MEMS and smart devices", Wiley.
6. Mc Geough, "Advanced Methods of Machining", Chapman and Hall, London, 1998.
7. A. Ghosh and A. K. Mallik, Manufacturing Science, East-West Press, New Delhi, 2006.

Web References

1. https://nptel.ac.in/courses/112/103/112103202
2. https://nptel.ac.in/courses/112/104/112104028
3. https://nptel.ac.in/courses/112/105/112105212

402044D: Industrial Engineering					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30 Marks**
Tutorial		**Tutorial**		**End-Semester**	**70 Marks**

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

Course Objectives:

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

Learner will be able to:

CO1. **EVALUATE** the productivity and **IMPLEMENT** various productivity improvement techniques.
CO2. **APPLY** work study techniques and **UNDERSTANDS** its importance for better productivity.
CO3. **DEMONSTRATE** the ability to **SELECT** plant location, appropriate layout and material handling equipment.
CO4. **USE** of Production planning and control tools for effective planning, scheduling and managing the shop floor control.
CO5. **PLAN** inventory requirements and **EXERCISE** effective control on manufacturing requirements.
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 to Industrial Engineering and Productivity**

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

Productivity: Definition of productivity, Measures of Productivity, Total Productivity Model, Need for Productivity Evaluation, Productivity measurement models, Productivity improvement

approaches, Principles, Productivity Improvement techniques – Technology based, Material based, Employee based, Product based techniques. (Numerical on productivity measurement)	
Unit 2	**Work Study**
Method Study: Introduction and objectives, Areas of application of work study in industry, Selection and Basic procedure. Recording techniques, Operations Process Chart, Flow Process Chart (Man, Machine & Material) Multiple Activity Chart, Two Handed process chart, Flow Diagram, String Diagram and Travel Chart, Cycle and chronocycle graphs, SIMO chart, Therbligs, Micro motion and macro-motion study: Principles of motion economy, Normal work areas and work place design. **Work Measurement**: Techniques, time study, steps, work sampling, Determination of time standards. Observed time, basic time, normal time, rating factors, allowances, standard time, and standard time determination. (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	**Production Planning and Control**
Types and methods of Production, and their Characteristics, functions and objectives of Production Planning and Control, Steps: Process planning, Loading, Scheduling, Dispatching and Expediting with illustrative examples, Capacity Planning, Aggregate production planning and Master production scheduling. 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)	
Unit 5	**Inventory and Inventory Control**
Materials: Profit Centre: Role of materials management techniques in material productivity improvement, cost reduction and value improvement. **Purchase Management**: Purchase management, incoming material control. Acceptance sampling and inspection. Vendor rating system.	

Inventory: Functions, Costs, Classifications, Deterministic inventory models and Quantity discount

Inventory Control: EOQ (Numericals), concepts, type of Inventory models-deterministic and probabilistic, Selective inventory control, Fundamental of Material Requirement Planning (MRP-I), Manufacturing Resource Planning (MRP-II), Enterprise Resource Planning (ERP), Just-in-Time system (JIT) and Supply Chain Management (SCM)

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 and other resources

Text Books:

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

References Books:

1. Askin, Design and Analysis of Lean Production System, Wiley, India
2. Introduction to Work Study by ILO, ISBN 978-81-204-1718-2, Oxford & IBH Publishing Company, New Delhi, Second Indian Adaptation, 2008.
3. H. B. Maynard, K Jell, Maynard's Industrial Engineering Hand Book, McGraw Hill Education.
4. Zandin K.B., Most Work Measurement Systems, ISBN 0824709535, CRCPress,2002
5. Martin Murry, SAP ERP: Functionality and Technical Configuration, SAP Press.
6. Barnes, Motion and time Study design and Measurement of Work, Wiley India
7. Sumanth, D.J, "Productivity Engineering and Management", TMH, New Delhi, 1990.
8. Edosomwan, J.A, "Organizational Transformation and Process re- Engineering", British Cataloging in publications, 1996.
9. Prem Vrat, Sardana, G.D. and Sahay, B.S, "Productivity Management - A systems approach", Narosa Publications, New Delhi, 1998.
10. Francis, R.L., and White, J.A, "Facilities layout and Location", Prentice Hall of India, 2002.
11. James A. Tompkins, John A. White, "Facilities Planning", Wiley, 2013
12. Richard L. Francis, Leon F Mc Ginnes and John A. White, "Facility Layout and Location-

An Analytical Approach", PHI, 1993
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 (2019 pattern)

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

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

Course Objectives:

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 (2019 pattern)

402044F: Computational Fluid Dynamics					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30 Marks**
				End-Semester	**70 Marks**

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

Course Objectives:

1. Model fluid / heat transfer problems, apply fundamental conservation principles and Identify Discretization methods
2. Formulate a model the for conduction and advection problems
3. Formulate a model the for Convection-Diffusion problems
4. Understand the External/Internal flow simulation
5. Recognize the Scales of turbulence and Understand the formulation methods
6. Understand the Fluid-Structure Interaction Problems and their applications

Course Outcomes:

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

CO1. **DISTINGUISH** and **ANALYSE** the governing equations of fluid mechanics and heat transfer in various formulations

CO2. **ANALYZE** and **MODEL** the conduction and advection problems

CO3. **ANALYZE** and **MODEL** the Convection-Diffusion problems

CO4. **IDENTIFY** and **EVALUATE** the External/Internal flow and its simulation

CO5. **DISTINGUISH** and **COMPARE** concepts of stability and turbulence.

CO6. **USE** and **APPLY** a CFD tool for effectively solving practical Fluid-Structure Interaction problems

Course Contents

Unit 1	**Introduction to Computational Fluid Dynamics**

Introduction to Computational Fluid Dynamics, CFD as a research and design tool, Applications in various branches of Engineering, Derivation and physical interpretation of governing equations (conservation of mass, momentum and energy) in differential form, Concept of substantial derivative, divergence and curl of velocity, Mathematical behavior of Governing Equations and boundary conditions, Discretization methods for the CFD (FDM, FVM, FEM, Hybrid Methods), Intro to Meshless Methods, Meshed Vs Meshless Methods

Unit 2	Conduction and Advection

Conduction: Solution of two dimensional steady and unsteady heat conduction equation using finite volume method (Implicit and Explicit) with Dirichlet, Neumann, Robbin boundary conditions, Stability Criteria

Advection: Solution of two dimensional steady and unsteady heat advection equation using finite volume method (Implicit and Explicit) with Dirichlet BC, Stability Criteria, Introduction to first order upwind, CD, second order upwind and QUICK convection schemes

Unit 3	Convection-Diffusion

Solution of two dimensional steady and unsteady heat convection-diffusion equation for slug flow using finite volume method (Implicit and Explicit), Stability Criteria, 1-D transient convection-diffusion system, Peclet Number

Unit 4	Introduction to External/Internal flow simulation

Solution of Navier-Stoke' equation for incompressible flow using SIMPLE algorithms for lid driven cavity flow problem, Introduction to external flow simulation – Flow over circular Cylinder and Aerfoils.

Unit 5	Turbulent Flow Modeling

Introduction to turbulence, Scales of turbulence, Reynolds Averaged Navier-Stokes (RANS) equation, One equation model (Derivation) and two equation model, Introduction to Direct Numerical Simulation (DNS), Large Eddy Simulation (LES)

Unit 6	Introduction to Fluid-Structure Interaction

Types of Fluid-Solid Couplings, Applications, Mechanical Forces and Equilibrium, Rigid Body Motions, Balance Laws in Lagrangian and Eulerian Form, Lagrangian Solid System, Eulerian Fluid System, Kinematics of Eulerian and Lagrangian Modeling, Continuum Mechanics of Moving Domains, Coupled Fluid-Structure Equations, Application of Arbitrary Lagrangian Eulerian (ALE) Formulation

Books and other resources

Text Books:

1. Ghoshdastidar, P. S. (2017), "Computational Fluid Dynamics and Heat Transfer," Cengage learning, ISBN: 9788131533079
2. Atul Sharma, A., (2016), "Introduction to Computational Fluid Dynamics: Development, Application and Analysis," Wiley, ISBN: 9781119002994
3. Versteeg, H. K., Malalasekhara, W., (2007), "An Introduction to Computational Fluid Dynamics: The Finite Volume Method," PHI, ISBN: 9780131274983
4. Muralidharan, K., Sundarajan , T., (2009), "Computational Fluid Flow and Heat Transfer," Narosa Pub, ISBN: 9788173195228
5. Rao, J.S., (2017), "Simulation Based Engineering in Fluid Flow Design," Springer, ISBN: 9783319463810
6. Anderson, Jr., D. A. A (2017), "Computational Fluid Dynamics - the Basics with

Applications," , McGraw Hill Education, ISBN: 9781259025969
7. Jaiman, R. K. and Joshi, V., (2022), "Computational Mechanics of Fluid-Structure Interaction: Computational Methods for Coupled Fluid-Structure Analysis," Springer, ISBN: 9789811653544

References Books:

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

Web References:

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

402045A: Product Design and Development					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30 Marks**
				End-Semester	**70 Marks**

Pre requisites: Basic Engineering Science - Physics, Chemistry, Material Science, Engineering Metallurgy, Manufacturing processes Etc.

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

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

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. Teamcenter 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 (2019 pattern)

402045B: Experimental Methods in Thermal Engineering					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30 Marks**
				End-Semester	**70 Marks**

Prerequisites: Basics of Physics. Fundamentals of Thermodynamics, Fluid Mechanics & Heat transfer.

Course Objectives:

1. To introduce the theory and experimentation in thermal engineering - Problem solving approaches, types of engineering experiments, computer simulation and physical experimentation.
2. To enhance the knowledge of various measuring instruments, techniques and importance of error and uncertainty analysis.
3. To give the exposure to measurement of pressure, flow velocity, measurement of temperature, optical methods of measurement.

Course Outcomes:

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

CO1. **IDENTIFY** the suitable instrument for measuring parameters as per performance characteristics

CO2. **ANALYZE** experimental data by using different statistical techniques and estimate error

CO3. **DISTINGUISH** different methods of temperature measurements and thermal radiation

CO4. **CLASSIFY** various pressure measurement instruments and their comparison

CO5. **EXPLAIN** different flow measurement methods and flow visualization techniques

CO6. **APPLY** knowledge of modern engineering experimentation, including calibration, data acquisition, analysis and interpretation using different AI and ML techniques

Course Contents

Unit 1	**Measuring instruments**

Basics of measuring instruments: Fundamental elements of a measuring instrument, Calibration, System response, Importance of measurement and experimentation, Selection of measuring system

Characteristics of instruments: Elements of Measuring Instruments Performance characteristics - Static & Dynamic characteristics, Response of general form of instrument, Random and transient input, Instrument loading under static and dynamic condition, Transducer and sensor used for thermal systems

Unit 2	Design of Experiments

Analysis of Experimental Data: Analysis of experimental data, Causes and type of experimental errors, data reduction techniques, statistical analysis of experimental data, Statistical distributions, probability distributions and curve fitting, Regression analysis, Co-relations

Uncertainty Analysis: Nomenclature, Precision Vs Accuracy, Errors in measurement, Sampling. (**Numerical on Uncertainty analysis)**

Design of Experiments: Factorial Design, Taguchi Method, Response Surface Design **(Case studies of experimental work)**

Unit 3	Temperature, Heat flux and Radiation measurements

Temperature and Heat flux measurement: Overview of thermometry, Thermoelectric temperature measurement, Hg-in-glass thermometer, RTD (Resistance Temperature Detector), thermistor, thermocouple, thermopile, liquid-crystal thermography, optical pyrometer. Themo well, Issues in Heat flux measurements. Thermos profile of heat exchanger. Non-contact type temperature Measurements

Thermal radiation measurements: Detection of thermal radiation, Radiation Thermometry, Measurement of emissivity, Reflectivity and transmissivity measurements, Solar radiation measurements.

Unit 4	Pressure measurements

Different pressure measurement instruments and their comparison, Types of Sensors used in Pressure Measurement, Manometers, bourdon tube pressure gauge, diaphragm gauge, bellow gauge, McLeod gauge, Pirani gauge and ionization gauge. Transient response of pressure transducers. Pressure measurements in combustions. Applications of Pressure measurements. (**Numerical on Pressure measurements)**

Unit 5	Flow measurements and Visualization techniques

Flow measurements: Introduction to Flow Measurement, Positive displacement flow meters, Flow obstruction methods, Magnetic flow meters, LDA (Laser Doppler Anemometry), Other methods. Applications of flow measurements.

Flow visualization techniques: Shadowgraph, Schlieren and interferometer. Other methods. Ultrasonic flow measurement. Flow measurements techniques used to validate CFD results. Micro channel flow measurement. Velocity measurement based on thermal effect.

Unit 6	DAS and AIML

Data Acquisition System (DAS) and Signal analysis: General Data Acquisition System, Signal conditioning, storage, Data transmission, - A/D & D/A conversion - Data storage and Display

AI & ML (Artificial Intelligence & Machine Learning) Applications: Introduction to AI / ML.

Approaches of AI/ ML. Predication of Measurement Parameter using ML Approaches such as Regression/ Classification. Finding Statistical Parameter such as ANOVA (Analysis of Variance), Correlation.

Books and other resources

Text Books:

1. Holman, J.P., "Experimental methods for engineers", Tata McGraw hill 7th Edition, 2007
2. E.O. Doebelin, Measurement systems, Application and Design, 5 th edition, Tata McGraw-Hill, 2008
3. Beckwith & Buck : Mechanical Measurements
4. Willard, Mertt, Dean,Settle : Instrumental Methods of analysis

References Books:

1. Morris A.S, "Principles of Measurements and Instrumentation", 3 Edition, Butterworth-Heinemann, .
2. Prebrashensky V., "Measurement and Instrumentation in Heat Engineering", Vol.1, MIR Publishers, .
3. T.G. Beckwith, J.H. Lienhard V, R. D. Marngoni, Mechanical Measurements, 5 th edition, Pearson Education, 2010
4. D.C. Montgomery, Design and Analysis of Experiments, John Wiley, New York.
5. Introduction to Machine learning, Nils J.Nilsson
6. Introduction to Machine Learning with Python A guide for data scientists, Andreas, C. Muller & Sarah Guido, O'Reilly

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Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering (2019 pattern)

402045C: Additive Manufacturing					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**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, 3D Hubs, 2017
7. Chee Kai, Kah Fai, Chu Sing, 'Rapid Prototyping: Principles and Applications", 2nd Ed., 2003
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 (2019 pattern)

402045D: Operations Research					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**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 (2019 pattern)

402045E: Augmented Reality and Virtual Reality					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30 Marks**
				End-Semester	**70 Marks**

Prerequisites: Mathematics, Physics, Programming and Problem Solving, Engineering Graphics, Solid Modeling and Drafting, Numerical & Statistical Methods, Mechatronics, Artificial Intelligence &Machine Learning, Computer Aided Engineering

Course Objectives:

1. Learn the fundamental Computer Vision, Computer Graphics and Human-Computer interaction Techniques related to VR/AR
2. Review the Geometric Modeling Techniques
3. Review the Virtual Environment
4. Discuss and Examine VR/AR Technologies
5. Use of various types of Hardware and Software in Virtual Reality systems
6. Simulate and Apply Virtual/Augmented Reality to varieties of Applications

Course Outcomes:

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

CO1. **UNDERSTAND** fundamental Computer Vision, Computer Graphics and Human-Computer Interaction Techniques related to VR/AR
CO2. **UNDERSTAND** Geometric Modeling Techniques
CO3. **UNDERSTAND** the Virtual Environment
CO4. **ANALYZE** and **EVALUATE** VR/AR Technologies
CO5. **APPLY** various types of Hardware and Software in Virtual Reality systems
CO6. **DESIGN** and **FORMULATE** Virtual/Augmented Reality Applications

Course Contents

Unit 1	**Introduction to Virtual Reality (VR)**

Virtual Reality and Virtual Environment, Computer graphics, Real time computer graphics, Flight Simulation, Virtual environment requirement, benefits of virtual reality, Historical development of VR, Scientific Landmark

Unit 2	**Computer Graphics and Geometric Modelling**

The Virtual world space, positioning the virtual observer, the perspective projection, human vision, stereo perspective projection, Color theory, Conversion From 2D to 3D, 3D space curves, 3D boundary representation, Simple 3D modelling, 3D clipping, Illumination models, Reflection models, Shading algorithms, Geometrical Transformations: Introduction, Frames of reference,

Modelling transformations, Instances, Picking, Flying, Scaling the VE, Collision detection

Unit 3	Virtual Environment

Input/Output Devices: Input (Tracker, Sensor, Digital Gloves, Movement Capture, Video-based Input, 3D Menus & 3D Scanner, etc.), Output (Visual/Auditory/Haptic Devices)
Generic VR system: Introduction, Virtual environment, Computer environment, VR technology, Model of interaction, VR Systems, Animating the Virtual Environment: Introduction, The dynamics of numbers, Linear and Nonlinear interpolation, the animation of objects, linear and non-linear translation, shape & object in between, free from deformation, particle system
Physical Simulation: Introduction, Objects falling in a gravitational field, Rotating wheels, Elastic collisions, projectiles, simple pendulum, springs, Flight dynamics of an aircraft

Unit 4	Augmented Reality (AR)

Taxonomy, Technology and Features of Augmented Reality, AR Vs VR, Challenges with AR, AR systems and functionality, Augmented Reality Methods, Visualization Techniques for Augmented Reality, Enhancing interactivity in AR Environments, Evaluating ARsystems

Unit 5	Development Tools and Frameworks

Human factors: Introduction, the eye, the ear, the somatic senses
Hardware: Introduction, sensor hardware, Head-coupled displays, Acoustic hardware, Integrated VR systems
Software: Introduction, Modelling virtual world, Physical simulation, VR toolkits, Introduction to VRML

Unit 6	AR / VR Applications

Introduction, Engineering, Entertainment, Science, Training, Game Development

Books and other resources

Text Books:

1. Coiffet, P., Burdea, G. C., (2003), "Virtual Reality Technology," Wiley-IEEE Press, ISBN: 9780471360896
2. Schmalstieg, D., Höllerer, T., (2016), "Augmented Reality: Principles & Practice," Pearson, ISBN: 9789332578494
3. Norman, K., Kirakowski, J., (2018), "Wiley Handbook of Human Computer Interaction," Wiley-Blackwell, ISBN: 9781118976135
4. LaViola Jr., J. J., Kruijff, E., McMahan, R. P., Bowman, D. A., Poupyrev, I., (2017), "3D User Interfaces: Theory and Practice," Pearson, ISBN: 9780134034324
5. Fowler, A., (2019), "Beginning iOS AR Game Development: Developing Augmented Reality Apps with Unity and C#," Apress, ISBN: 9781484246672
6. Hassanien, A. E., Gupta, D., Khanna, A., Slowik, A., (2022), "Virtual and Augmented Reality for Automobile Industry: Innovation Vision and Applications," Springer, ISBN: 9783030941017

References Books:

1. Craig, A. B., (2013), "Understanding Augmented Reality, Concepts and Applications," Morgan Kaufmann, ISBN: 9780240824086
2. Craig, A. B., Sherman, W. R., Will, J. D., (2009), "Developing Virtual Reality Applications, Foundations of Effective Design," Morgan Kaufmann, ISBN: 9780123749437
3. John Vince, J., (2002), "Virtual Reality Systems, "Pearson, ISBN: 9788131708446
4. Anand, R., "Augmented and Virtual Reality," Khanna Publishing House
5. Kim, G. J., (2005), "Designing Virtual Systems: The Structured Approach", ISBN: 9781852339586
6. Bimber, O., Raskar, R., (2005), "Spatial Augmented Reality: Merging Real and Virtual Worlds," CRC Press, ISBN: 9781568812304
7. O'Connell, K., (2019), "Designing for Mixed Reality: Blending Data, AR, and the Physical World," O'Reilly, ISBN: 9789352138371
8. Sanni Siltanen, S., (2012), "Theory and applications of marker-based augmented reality," Julkaisija –Utgivare Publisher, ISBN: 9789513874490

Web References:

1. Manivannan, M., (2018), "Virtual Reality Engineering," IIT Madras, https://nptel.ac.in/courses/121106013
2. Misra, S., (2019), "Industry 4.0: Augmented Reality and Virtual Reality," IIT Kharagpur, https://www.youtube.com/watch?v=zLMgdYI82IE
3. Dube, A., (2020), "Augmented Reality - Fundamentals and Development," NPTEL Special Lecture Series, https://www.youtube.com/watch?v=MGuSTAqlZ9Q
4. http://cambum.net/course-2.htm

402046: Data Analytics Laboratory					
Teaching Scheme		**Credits**		**Examination Scheme**	
Practical	**2 Hrs.**	**Practical**	**1**	**Term Work**	**50**

Prerequisites: Engineering Mathematics**,** Artificial Intelligence & Machine Learning, Numerical and Statistical Methods, Fundamental of Mechanical Engineering

Course Objectives:

1. To explore the fundamental concepts of data analytics.
2. To understand the various search methods and visualization techniques.
3. To apply various machine learning techniques for data analysis.

Course Outcomes:

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

CO1: **UNDERSTAND** the basics of data analytics using concepts of statistics and probability.
CO2: **APPLY** various inferential statistical analysis techniques to describe data sets and withdraw useful conclusions from acquired data set.
CO3: **EXPLORE** the data analytics techniques using various tools
CO4: **APPLY** data science concept and methods to solve problems in real world context
CO5: **SELECT** advanced techniques to conduct thorough and insightful analysis and interpret the results

Course Contents

Preamble:

The motivation behind the data analytics lab for mechanical engineers is to make them competent to learn data-driven decision-making involving predictive, prescriptive, descriptive, and diagnostic analytics. Data analytics offers a new paradigm of bottom-up versus top-down modelling and solving supported by the traditional physics-based approach. An engineer involved in traditional modelling (e.g., developing a finite analysis or a reliability model) looks at the problem of interest and in essence, fits in the model he/she was trained to use. An engineer equipped with data science knowledge gathers historical data and uses data-mining tools to build the model of interest. If needed, he/she can further optimize this data-driven model with tools such as evolutionary computation algorithms.

Possible approaches:

Predictive Analytics:

Predictive analytics involves the use of mathematical methods and tools such as machine learning, data mining, statistical analysis, and predictive models. It is used to:

- Identify anomalies in the process, which help in preventive maintenance.
- Estimate the demand for product, raw material etc.: based on historical data and current

scenario.

- Forecast possible outcomes based on data obtained from the process.

Prescriptive Analytics:

Prescriptive analytics is used to identify ways in which an industrial process can be improved. While predictive analytics tells when could a component/asset fails, prescriptive analytics tells what action you need to take to avoid the failure. So, you can use the results obtained from prescriptive analysis to plan the maintenance schedule, review your supplier, etc. Prescriptive analytics also helps you manage complex problems in the production process using relevant information.

Descriptive Analytics:

The core purpose of descriptive analytics is to describe the problem by diagnosing the symptoms. This analytics method also helps discover the trends and patterns based on historical data. The results of a descriptive analytics are usually shown in the form of charts and graphs. These data visualization tools make it easy for all the stakeholders, even those who are non-technical to understand the problems in the manufacturing process.

Diagnostic Analytics:

Diagnostic analytics is also referred to as root cause analysis. While descriptive analytics can tell what happened based on historical data, diagnostic analytics tells you why it happened. Data mining, data discover, correlation, and down and drill through methods are used in diagnostic analytics. Diagnostic analytics can be used to identify cause for equipment malfunction or reason for the drop in the product quality.

TERM WORK:

A] Experiments (Any 6)

Sr. No.	Data Domain	Objective	Methodology	Data type
1	Thermal / Heat Transfer / HVAC / Fluid Mechanics / Fluid Power	Predictive / Prescriptive / Descriptive / Diagnostic (but not limited to)	Statistical / mathematical /numerical/computational/intelligent (but not limited to)	Numeric or image based or data in any suitable form
2	Solid Mechanics / Design			
3	Machining / Manufacturing			
4	Automation & Robotics			
5	Maintenance / Reliability / Condition Monitoring			
6	Quality Control			
7	Materials and Metallurgy			
8	Energy Conservation and Management			
9	Industrial Engineering, Estimation, and Costing			
10	Automotive technology			

B] List of Assignments (Any Three)

The survey of methods used for data analysis in the data domain mentioned above **(Any Three)** and discussion on any case studies.

Guidelines for selection of data domain, source, size, etc.:

- The data domain must be selected from various fields of mechanical engineering such as (but

not limited to) thermal, heat power, design, manufacturing, automotive, HVAC, condition monitoring, process industry, solid and fluid mechanics, quality, materials and metallurgy, automation & robotics, energy conservation and management, ERP, Industrial engineering, estimation, and costing, etc.

- The volume of data should be considerably larger size in view of extracting meaningful insights, such as hidden patterns, unknown correlations, trends, and customer preferences through tools such as machine learning, deep learning, reinforcement learning, etc. Though the data size cannot be bluntly defined or there is no threshold, however, the data gathered from small trials/experimentation to analyse the input-output relationship should not be considered such as a trial on an external gear pump for studying its characteristics considering limited range of parameters for few trials. The appropriate data size must be selected as per the relevant data domain to yield a reliable model. For example, in the case of vibration-based condition monitoring based on numeric data, the size of data gathered depends on the sampling frequency of data acquisition and ranges from 5 kHz to 20 kHz or even more than that as per the data domain. Same for image data, the minimum number of images with appropriate resolution should be selected w.r.t data domain to yield a robust model.
- The data collected through real-time experiments is preferred however in case of no resources/facility available, data collected through simulation, survey, etc. can also be considered. The benchmark datasets made available by standard technical/academic/research/commercial/professional societies and organizations are also allowed.
- The standard instrumentation is preferred for performing experiments and data collection; however, the use of open-source hardware for building in-house low-cost data acquisition systems is also recommended.
- The choice of programming language and software depends on the data domain and the provision of the methodology used for its processing. Any standard programming language and data analytics software can be used.
- The approach mentioned above (but not limited to) should be considered while defining the problem and objectives, selecting the data domain, and deciding the methodology. The methodology can be statistical, mathematical, numerical, computational, or intelligent.

Books and Other Resources

Text Books:

1. Brunton, S. L., & Kutz, J. N. (2022). Data-driven science and engineering: Machine learning, dynamical systems, and control. Cambridge University Press.
2. Dunn, P. F., & Davis, M. P. (2017). Measurement and data analysis for engineering and science. CRC press.
3. Roy, S. S., Samui, P., Deo, R., & Ntalampiras, S. (Eds.). (2018). Big data in engineering applications (Vol. 44). Berlin/Heidelberg, Germany: Springer.
4. Middleton, J. A. (2021). Experimental Statistics and Data Analysis for Mechanical and

Aerospace Engineers. Chapman and Hall/CRC.
5. Brandt, S. (1970). Statistical and computational methods in data analysis.
6. Robinson, E. L. (2017). Data analysis for scientists and engineers. In Data Analysis for Scientists and Engineers. Princeton University Press.
7. Araghinejad, S. (2013). Data-driven modeling: using MATLAB® in water resources and environmental engineering (Vol. 67). Springer Science & Business Media.
8. Niu, G. (2017). Data-driven technology for engineering systems health management. Beijing, China: Springer.

References Books:

1. Zsolt Nagy, "Artificial Intelligence and Machine Learning Fundamentals", Packt Publishing, 2018, ISBN: 978-1-78980-165-1
2. Hastie, Trevor, Robert Tibshirani, Jerome H. Friedman, and Jerome H. Friedman. The elements of statistical learning: data mining, inference, and prediction. Vol. 2. New York: springer, 2009.
3. Zaki, Mohammed J., Wagner Meira Jr, and Wagner Meira. Data mining and analysis: fundamental concepts and algorithms. Cambridge University Press, 2014.
4. Kumar, Zindani, Davim, Artificial Intelligence in Mechanical and Industrial Engineering, CRC Press, 2021.

Assessment of Term Work

The student shall complete the above mentioned activities and prepare a Term Work in the form of Journal.

Important Note:

Term Work of the Student shall be evaluated based on the completion of experiments, group assignments and case studies. Continuous evaluation by the faculty shall be done for the award of the credit associated with the course.

402047: Project (Stage I)					
Teaching Scheme		**Credits**		**Examination Scheme**	
Practical	**4 Hrs./Week**	**Practical**	**2**	**Term Work**	**50 Marks**
				Oral	**50 Marks**

Prerequisites: Project Based Learning, Internship/Mini Project, Laboratory works, Skill Development, Audit Courses, Industrial Visits

Course Objectives:

1. To provide an opportunity of designing and building complete system or subsystems based on areas where the student likes to acquire specialized skills.
2. To obtain hands-on experience in converting a small novel idea / technique into a working model / prototype involving multi-disciplinary skills.
3. To embed the skill in a group of students to work independently on a topic/ problem/ experimentation selected by them and encourage them to think independently on their own to bring out the conclusion under the given circumstances of the curriculum period in the budget provided with the guidance of the faculty.
4. To encourage creative thinking processes to help them to get confidence by planning and carrying out the work plan of the project and to successfully complete the same, through observations, discussions and decision making process.

Course Outcomes:

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

CO1. **IMPLEMENT** systems approach.
CO2. **CONCEPTUALIZE** a novel idea / technique into a product.
CO3. **THINK** in terms of a multi-disciplinary environment.
CO4. **TAKE ON** the challenges of teamwork, and **DOCUMENT** all aspects of design work.
CO5. **UNDERSTAND** the management techniques of implementing a project.
CO6. **DEMONSTRATE** the final product for Functionality, Designability, and Manufacturability.

Course Contents

Project work in the seventh semester is an integral part of the Term Work. The project work shall be based on the knowledge acquired by the student during the graduation and preferably it should meet and contribute towards the needs of the society.

1. Fabrication of product/testing setup of an experimentation unit/small equipment, in a group.
2. Experimental verification of principles used in Mechanical Engineering Applications

3. Projects having valid database, algorithm, and output reports, preferably software based.
4. Study projects are strictly **not** allowed.

Project Lab

1. There has to be a **Project Lab** in the department.

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

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

Books and other resources

Web References:

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

Guidelines for Project Execution

At the end of the VIth Semester

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

During the VIIth Semester

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

Term Work

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

Rational Requirement Analysis.

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

Work Diary to be maintained by a group and countersigned by the guide (weekly). The contents of work diary shall reflect the efforts taken by project group for;

a. Searching suitable project work

b. Brief report preferably on journals/research or conference papers/books or literature surveyed to select and bring up the project.

c. Brief report of feasibility studies carried to implement the conclusion.

d. Rough Sketches/ Design Calculations

e. Synopsis

- The group should submit the synopsis in the following form.
  - i. Title of Project
  - ii. Names of Students
  - iii. Name of Guide
  - iv. Relevance
  - v. Present Theory and Practices
  - vi. Proposed work
  - vii. Expenditure
  - viii. References
- The synopsis shall be signed by each student in the group, approved by the guide (along with external guide in case of sponsored projects) and endorsed by the Head of the Department.
- Presentation: The group has to make a presentation in front of the faculty of department at the end of semester.

Examination Scheme

- During university examination Internal examiner (preferably the guide) and External examiners jointly, evaluate the project work.
- During the process of monitoring and continuous assessment & evaluation the individual and team performance is to be measured.
- The project term work shall be evaluated on the basis of reviews. In first semester two reviews are to be taken and evaluated for total 50 marks (25 marks each)
- Review 1 and 2 will be based on synopsis submission (team members, Title of the Project Work, Abstract, Problem Definition, work done earlier, Objectives of the Project, Methodology of the Project, Application / Significance of the Project, Duration of the Project, Individual Role of the Student, References, sponsored etc.)
- The final presentation shall be taken in front of external examiner and to be evaluated for 50 marks

  20 marks for presentation (Oral, Written)

  30 marks for quality of the project work

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

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.

402048: Computer Integrated Manufacturing					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30 Marks**
Practical	**2 Hrs./Week**	**Practical**	**1**	**End-Semester**	**70 Marks**
				Term Work	**25 Marks**
				Oral	**25 Marks**

Prerequisites: knowledge of earlier studied subjects like Solid Modeling and Drafting, Computer Aided Engineering, Industrial Engineering

Course Objectives:

1. **Understand and realize** need of CIM and factory automation.
2. **Learn** to integrate hardware and software elements for CIM.
3. **Generate and Integrate** CNC program for appropriate manufacturing techniques.
4. **Learn** to integrate processes planning, quality and MRP with computers.
5. **Know** about flexible, cellular manufacturing and group technology.
6. **Understand** IOT, Industry-4.0 and cloud base manufacturing.

Course Outcomes:

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

CO1. **EXPLAIN** CIM and factory automation.
CO2. **UNDERSTAND** the integration of hardware and software elements for CIM
CO3. **APPLY** CNC program for appropriate manufacturing techniques.
CO4. **ANALYZE** processes planning, quality and MRP integrated with computers.
CO5. **INTERPRET** flexible, cellular manufacturing and group technology.
CO6. **ANALYZE** the effect of IOT, Industry-4.0 and cloud base manufacturing.

Course Contents

Unit 1	**Introduction to CIM**

Need of CIM, Introduction, Evolution of CIM,CIM Hardware and software, Role of CIM System, Definition of CIM, automation and types of automation, Reasons for automation, Types of Production, Functions in Manufacturing, CIM wheel, Computerized element of CIM, Advantages of CIM

Unit 2	**Data Integration**

CAD-CAM Integration, Product development through CIM, Design Activities in a networked

environment, Networking in a manufacturing company, hardware elements of networking, CIM Database, Database requirements of CIM, Database management, Database Models, EDM, Product Data Management (PDM), Product life cycle Management(PLM)

Unit 3	**Computer Aided Manufacturing (CAM)**

Introduction to Computer Aided Manufacturing (CAM), Coordinate system, working principal of CNC Lathe, Turning Centers, Milling Machine, Machining Centers. Steps in developing CNC part program, Tool and geometric compensations, CNC Lathe and Mill part programming, Canned cycles, subroutine and Do loop, CIM Integrable Machines

Unit 4	**Computer Aided Process Planning and Quality Control**

Process Planning: Computer Aided Process Planning (CAPP), Benefits of CAPP, Logical steps in Computer Aided Process Planning, Approaches to CAPP, Material Requirement Planning, Capacity Planning, Manufacturing Resource Planning (MRP) - Input, working, outputs and benefits, Concept of dependent demand, structure of MRP system, planning & implementation issues, MRP-II & Enterprise Resource Planning (ERP), Computer Aided Production Scheduling, Control Systems: Shop Floor Control, Inventory Control, Computer Aided Inspection and Quality Control, Manufacturing Execution System(MES)

Unit 5	**FMS & Cellular Manufacturing**

Introduction Flexible Manufacturing Systems, FMS components, Material handling and storage system, applications, benefits, computer control systems, types of FMS Layout, FMS planning and design issues, Automated Storage and Retrieval Systems, AS/RS and Automatic parts identification systems and data capture.

Group Technology(GT), Part Families – Parts Classification and coding, Simple Problems in Opitz Part Coding system – Production flow Analysis, Cellular Manufacturing – Composite part concept – Machine cell design and layout, Quantitative analysis in Cellular Manufacturing – Rank Order Clustering Method, Arranging Machines in a GT cell – Hollier Method – Simple Problems

Unit 6	**Future Smart Factories**

Industry 4.0: Functions, Applications and Benefits. Components of Industry 4.0, Introduction to Industry 5.0, Internet of Things (IoT): IoT applications in manufacturing, Big-Data and Cloud Computing for IoT, IoT for smart manufacturing, influence of IoT on predictive maintenance, Supply-Chain Optimization, Supply-Chain & logistics, Internet of Things and M_2M Communication Technologies

Digital Manufacturing w.r.t. Industry 4.0: Industrial Automation, Cyber-Physical Manufacturing Systems, Digital Twin Driven Smart Manufacturing, Digital Manufacturing, Assembly and Automation Systems, Scheduling and Cloud Manufacturing, Knowledge Management, Digital Supply Chains, Reconfigurable Manufacturing Systems, Web based Application in Manufacturing

Books and other resources

Text Books:

1. Automation, Production system & Computer Integrated manufacturing, M. P. Groover Person

India, 2007 2nd edition.
2. Principles of Computer Integrated Manufacturing, S. Kant Vajpayee, Prentice Hall India

References Books:

1. Chang, T.C. and Wysk, R.A., 1997. Computer-aided manufacturing. Prentice Hall PTR.
2. Xu, X., 2009. Integrating Advanced Computer-Aided Design, Manufacturing, and Numerical Control. Information Science Reference.
3. Weatherall, A., 2013. Computer integrated manufacturing: from fundamentals to implementation. Butterworth-Heinemann.
4. Nanua Singh, Systems Approach to Computer Integrated Design and Manufacturing, John Wiley Publications.
5. Harrington J, Computer Integrated Manufacturing Krieger Publications 1979.
6. Zeid, CAD/CAM, Tata McGraw Hill.
7. Jha, N.K. "Handbook of Flexible Manufacturing Systems ", Academic Press Inc., 1991.

NPTEL Link:

1. https://youtube.com/playlist?list=PLFW6lRTa1g808_CfYhZKdv2eXplAQiAwS
2. https://nptel.ac.in/courses/112104289
3. https://onlinecourses.nptel.ac.in/noc22_me10/preview
4. https://archive.nptel.ac.in/courses/112/104/112104289/
5. https://archive.nptel.ac.in/noc/courses/noc20/SEM1/noc20-me44/

Link for Virtual Lab: - http://vlabs.iitkgp.ac.in/cim/#

Guidelines for Laboratory Conduction

1. Practical/Tutorial must be conducted in FOUR batches per division only.
2. Minimum 08 numbers of Experiments/Assignments shall be completed.
3. Experiments shall be conducted following 'Case Based Methodology'
4. Open source software, simulation tools may be used wherever required.

Term Work

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

1. Modelling of Mechanical Component using any 3D CAD software, Preparing CNC part program using any CAM software, and execute it on CNC Turning.
2. Modelling of Mechanical Component using any 3D CAD software, Preparing CNC part program using any CAM software, and execute it on CNC Milling.
3. Generate Bill of Material (BOM) from Assembly and other data using CAD Software.
4. Prepare Computer Aided Process Plan for selected part using variant type of CAPP Software.
5. Use MRP (Material Resource Planning) Software for CIM and Assembly.
6. Generate Part Family Code for a machine components using OPITZ Method
7. Study FMS system from Video clip and identify various elements of FMS and its controlling by computer.
8. Modeling and Simulation of Computer Integrated Manufacturing System. (VLab IIT, Kharagpur OR comparable sources)
9. Machine vision based quality control. (VLab IIT, Kharagpur OR comparable sources)
10. Remote Monitoring and Operation of a Computer Integrated Manufacturing System. (VLab IIT, Kharagpur OR comparable sources)

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering (2019 pattern)

402049: Energy Engineering					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30 Marks**
Practical	**2 Hrs./Week**	**Practical**	**1**	**End-Semester**	**70 Marks**
				Term Work	**25 Marks**
				Oral	**25 Marks**

Prerequisites: Thermodynamics, Applied Thermodynamics, Heat Transfer, Turbo machines

Course Objectives:

1. To study the energy scenario, the components of thermal energy based plant, improved Rankine cycle
2. To understand details of steam condensing plant, cooling tower system, analysis of condenser, the environmental impacts and methods to reduce various pollution from energy systems
3. To study layout, component details of diesel engine power plant, hydel and nuclear energy systems
4. To understand components; layout of gas and improved power cycles
5. To learn basic principles of energy management, storage and economics of power generation
6. To study the working principle , construction of renewable energy systems

Course Outcomes:

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

CO1: **EXPLAIN** the power generation scenario, the layout components of thermal power plant and **ANALYZE** the improved Rankine cycle.

CO2: **ANALYZE** the performance of steam condensers, cooling tower system; RECOGNIZE an environmental impact of energy systems and methods to control the same.

CO3: **EXPLAIN** the layout, component details of diesel engine plant, hydel and nuclear energy systems.

CO4: **ANALYZE** gas and improved power cycles.

CO5: **EXPLAIN** the fundamentals of renewable energy systems.

CO6: **EXPLAIN** basic principles of energy management, storage and economics of power generation.

Course Contents

Unit 1	**Energy Scenario and Thermal Energy based Power Plants**

Energy Scenario: global and Indian energy scenario, role of Government and Private organizations,

energy crisis, energy security, energy policy, India's low carbon transition.

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, high pressure boilers, improved Rankine cycle: Rankine cycle with only reheating and only regeneration (Numerical Treatment) **,** energy conservation in boilers

Unit 2	**Steam Condensers, Cooling Towers and Environmental Impact of Energy System**

Steam condensers: need, elements of steam condensing plant, classification, Dalton's law of partial pressure, condenser efficiency, vacuum efficiency, cooling water requirements (Numerical Treatment), air leakage and its effects on condenser performance, air pumps (Numerical Treatment for Air Pump capacity), steam condenser market.

Cooling Towers: need, classification of condenser water cooling systems, classification of cooling pond and cooling towers. environmental effects of cooling towers, next generation cooling towers

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 3	**Diesel, Hydel, Nuclear Energy systems**

Diesel engine power plant: general layout; different systems of DEPP, plant layout of high/medium /low capacity DEPP, performance operating characteristics based on heat rate, advantages; disadvantages; applications; methods of energy conservation

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 4	**Gas and Improved Power cycle**

Gas turbine power plant: components, general layout of GTPP, open & closed cycle gas turbine plant, Brayton cycle analysis for thermal efficiency, work ratio, maximum & optimum pressure ratio, methods to improve thermal efficiency of GTPP: only inter-cooling; only reheating & only regeneration cycle (numerical treatment),

Improved cycle based Power Plant: gas and steam combined cycle plant, Cogeneration, introduction to tri-generation, steam power plants with process heating (Numerical Treatment), Integrated Gasification Combined Cycle (IGCC) plant, Kalina (Cheng) Cycle.

Unit 5	Energy Management, Storage and Economics of Power Generation

Energy management and storage: energy management with storage systems, energy demand estimation, energy pricing, thermal energy storage methods.

Power plant instrumentation: layout of electrical equipment, switch gear, circuit breaker, protective devices, measurement of high voltage, current and power.

Economics of power generation: cost of electrical energy, fixed and operating cost [methods to determine depreciation cost] (numerical treatment), load curves, performance and operation characteristics of power plants, load division, all terminologies related to fluctuating load plant, tariff (numerical treatment), analysis of energy bill

Unit 6	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.

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

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

Web References:

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

Term Work

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

1. Trial on Steam Power Plant to determine
   a) Plant Efficiency, Rankine Efficiency Vs Load
   b) Specific Steam consumption Vs Load
   c) Rate of Energy Input Vs Load
   d) Heat Rate and Incremental heat Rate Vs Load
2. Trial on Diesel Power Plant to determine
   a) Plant Efficiency Vs Load
   b) Total fuel consumption Vs Load
   c) Rate of Energy Input Vs Load
   d) Heat Rate and Incremental heat Rate Vs Load
3. Analysis of HT/LT electricity bill and recommendations for energy saving opportunities.
4. Case study on different control systems in thermal power plant .
   (Review of control principles, Combustion control, pulveriser control, control of air flow, Furnace pressure and feed water, steam temperature control, turbine control, Safety provisions / Interlocks)
5. Design and component selection for solar photovoltaic power plant with net metering.
6. Estimation of annual energy from wind data and component selection for wind mill.
7. Case study on cogeneration in Sugar mill/Paper mill/Cement kiln.
8. Design and performance analysis of steam surface condenser for steam thermal power plant.
9. Design and performance analysis of cooling tower system for steam thermal power plant.
10. Case study on biomass gasification and analysis of properties of syngas.
11. Case study on production of bio-diesel and evaluation of its properties and its use in diesel engine based power plant.
12. Design and performance analysis of Thermal energy storage system.
13. Case study on energy management in conventional/ renewable energy power plant
14. Visit to Thermal Energy Based plant /Co-generation Power plant.
15. Visit to GTPP/Combined Cycle/renewable energy plants.

IMP Notes for Term Work:

1. Eight experiments from No.1 to 15 from above list should be conducted.
2. Experiment No, 1and 2 are compulsory.
3. Any six experiments can be performed 3 to 15.

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering (2019 pattern)

402050A: Quality & Reliability Engineering					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**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.

402050B: Energy Audit and Management					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30**
				End-Semester	**70**

Prerequisites: Engineering Thermodynamics, Applied Thermodynamics, Heat and Mass Transfer, HVAC, Turbomachines

Course Objectives:

1. To impart basic knowledge to the students about current energy scenarios, energy conservation, energy audit and energy management.
2. To inculcate the systematic knowledge and skill in assessing the energy efficiency, energy auditing and energy management.
3. To carry out an energy audit of Institute/Industry/Organisation

Course Outcomes:

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

CO1. **EXPLAIN** the energy need and role of energy management
CO2. **CARRY OUT** an energy audit of the Institute/Industry/Organization
CO3. **ASSESS** the ENCON opportunities using energy economics
CO4. **ANALYSE** the energy conservation performance of Thermal Utilities
CO5. **ANALYSE** the energy conservation performance of Electrical Utilities
CO6. **EXPLAIN** the energy performance improvement by Cogeneration and WHR method

Course Contents

Unit 1	**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 2	**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 3	**Energy Economics**

Costing of Utilities (Numerical): Determination of the cost of steam, fuels, compressed air and

electricity

Financial Analysis Techniques (Numerical): Simple payback, Time value of money, Net Present Value (NPV), Return on Investment (ROI), Internal Rate of Return (IRR), Risk and Sensitivity analysis, Energy performance contracts and role of ESCOs.

Unit 4	**Evaluation of Thermal Utilities**

Energy performance opportunities and assessment of Boilers and Furnaces (Numerical on direct method), Heat exchangers, Cooling towers, DG sets, Fans & blowers, Pumps, Compressors, Compressed air systems and HVAC systems. Assessment of steam distribution losses, Steam leakages, Steam trapping, Condensate and flash steam recovery system.

Unit 5	**Evaluation of Electrical Utilities**

Electricity billing, Electrical load management and maximum demand control, penalties, Power factor improvement and benefits, Selection and location of capacitors. Distribution and transformer losses, Harmonics.

Electrical motors: Types, Efficiency, Selection, Speed control, Energy efficient motors

Lamp types and their features, recommended illumination levels, Lighting system performance assessment and efficiency improvement (Numerical), Electricity saving techniques.

Unit 6	**Cogeneration and Waste Heat Recovery**

Cogeneration: Need, applications, advantages, classification, Introduction to Trigeneration

Waste Heat Recovery: Classification, Application, Concept of Pinch analysis, Potential of WHR in Industries, Commercial WHR devices, saving potential, CDM projects and carbon credit calculations.

Case Studies: Energy Audit of Institute/MSMEs/Organization, Guidelines for Energy Manager and Energy Auditor examination conducted by BEE.

Books and other resources

Text Books:

1. Bureau of Energy Efficiency Study material for Energy Managers and Auditors Examination: Paper I to IV.

References Books:

1. Barney L. Capehart, Wayne C. Turner and William J. Kennedy, "Guide to Energy Management", Seventh Edition, The Fairmont Press Inc., 2012.
2. Craig B. Smith, "Energy Management Principles", Pergamon Press, 2015.
3. Hamies, "Energy Auditing and Conservation; Methods, Measurements, Management and Case Study", Hemisphere Publishers, Washington, 1980.
4. Albert Thumann P.E. CEM, William J. Younger CEM, "Handbook of Energy Audit", The Fairmont Press Inc., 7th Edition.
5. Wayne C. Turner, "Energy Management Handbook", The Fairmont Press Inc., , Georgia.
6. Abbi Y. A., Jain Shashank, "Handbook on Energy Audit and Environment management",

TERI, Press, New Delhi, 2006.
7. Anthony L Kohan, “Boiler Operator’s Guide”, Fourth Edition, McGraw Hill
8. Robert L. Loftness, “Energy Hand Book”, Second edition, Von Nostrand Reinhold Company
9. G. G. Rajan, “Optimizing Energy Efficiencies in Industry”, Tata McGraw Hill, 2001
10. Amlan Chakrabarti, “Energy Engineering and Management”, Prentice Hall, India 2011

Web References:

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 (2019 pattern)

402050C: Manufacturing System and Simulation					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3Hrs./Week**	**Theory**	**3**	**In-Semester**	**30 Marks**
				End-Semester	**70 Marks**

Prerequisites: Understanding of manufacturing and business processes, industrial engineering principles and concepts.

Course Objective:

1. To help mechanical engineers understand broadly the functioning of manufacturing systems.
2. To describe the role of facilities and support systems.
3. To enable students understand various types of simulations used in manufacturing environment.
4. To acquaint with the methodology of manufacturing simulation using computer software and the repercussions of changes & variability therein, over time.
5. To showcase the areas of simulation applications in manufacturing and allied field.

Course Outcomes

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

CO1. **UNDERSTAND** the concepts of manufacturing system, characteristics, type, etc.

CO2. **UNDERSTAND** the concepts of Facilities, manufacturing planning & control and Support System.

CO3. **UNDERSTAND** the concepts of manufacturing towards solving productivity related problems.

CO4. **DEVELOP** a virtual model to solve industrial engineering related issues such as capacity. utilization, line balancing.

CO5. **BUILDING** tools to view and control simulations and their results.

CO6. **PLAN** the data representation & Evaluate the results of the simulation.

Course Contents

Unit 1	**Manufacturing System**

Preamble: Industrial Revolutions, Smart manufacturing, Challenges, Digitalization, Manufacturing System, Simulation, Data Analysis & Predictive decision-making, Types and classification of production systems and their characteristics, Introduction to manufacturing systems (manual, worker-machine and automated), Components & classifications, principles of manufacturing systems

Characteristics, requirements and operation of Manufacturing Systems: Custom manufacturing system, Intermittent manufacturing system, Continuous manufacturing system, Flexible manufacturing system, Mass customization, Assembly systems: Manual assembly systems,

Automated assembly systems, Hybrid assembly systems, and Reconfigurable manufacturing systems, Laws of Manufacturing, Manufacturing Systems as a Foundations of World-Class Practices, Performance measures of manufacturing systems and approaches to enhance the performance

Unit 2	Facilities and Manufacturing Support System

Overview, characteristics, principles and requirements of following facilities and manufacturing support systems:

Facilities: Material Handling Equipment, Quality control approaches, Computer systems to control manufacturing operations, Factory and Plant Layout, Group Technology (GT) & Cellular Layout, Robotics

Manufacturing Planning: Process Planning, Production Planning, Master Scheduling, Material requirement planning and capacity planning

Manufacturing Control: Shop floor control, Inventory control, Quality Control and Maintenance strategies

Business Functions: Business functions and Sequence of information processing activities.

Unit 3	Manufacturing Simulation: Introduction

History of simulation, basic simulation concept, purpose, appropriateness and considerations, advantages and disadvantages of simulation, areas of application, Overview of types of simulations [Discrete event simulation (DES), System dynamics (SD), Agent-based modeling (ABM), Intelligent simulation using artificial intelligence (AI) techniques, Petri net, Monte Carlo simulation (MCS), Virtual simulation], Steps in simulation study, simulation as a decision making tool

Unit 4	Discrete Event Simulation: Introduction

Problem Formulation: Formulating problem statement, Tools for Developing the Problem Statement, Orientation Process, simulation project objectives, evaluation of simulation project

System Definition: Discrete versus Continuous, Components and Events to Model, Manufacturing System Processes and Events

Input Data Collection and Analysis: Sources for input data, collecting input data, deterministic vs. probabilistic input data, discrete vs. continuous input data, random numbers, variables, common input data distributions, analyzing input data

Unit 5	Discrete Event Simulation: Model Translation, Validation and Analysis

Simulation Program Selection: Overview of various simulation software like AutoMod, ProModel, Arena, WITNESS Horizon, Quest, SIMFACTORY, FlexSim etc. Case study on translation to showcase model box, elements, building the model, attributing the data, queuing, material handling and conveyors, etc., output data)

Verification, and Validation: Verification of Simulation Models, Calibration and Validation of Models, Face Validity, Validation of Model Assumptions, Validating Input-Output Transformations (Using Historical Input Data, Using a Turing Test), Design of Simulation Experiments, What if analysis, Sensitivity Analysis, Predictive decision-making

Interpretation of Outputs: Measures of Performance and their estimation, Analysis of terminating and non-terminating systems

Unit 6	**Discrete Event Simulation: Applications and Case Studies**

Applications: Assembly line balancing (Design and balancing of assembly lines), Capacity planning (Uncertainty due to changing capacity levels, increasing the current resources, improving current operations to increase capacity), Cellular manufacturing (Comparing planning and scheduling in CM, comparing alternative cell formation), Just-in-time (Design of Kanban systems), Scheduling (rules, capacity, layout, analysis of bottlenecks, performance measurement), Production planning and inventory control (Safety stock, batch size, bottlenecks, forecasting, and scheduling rules), Resource allocation (Allocating equipment to improve process flows, raw materials to plants, resource selection), Scheduling (Throughput, reliability of delivery, job sequencing, production scheduling, minimize idle time, demand, order release), Robotics, PLCs, Material Handling Equipments (Electronic Monorail System, Power & Free Conveyors, AGVs,)

Case Studies: 1-2 detailed case studies on above applications

Books and other resources

Text Books:

1. Obi S. C., Introduction to manufacturing systems, Author House, 2013.
2. Banks J. and Carson J.S., Nelson B.L., "Discrete event system simulation", 4th Edition, Pearson., United Kingdom, 2005.
3. Christopher A. Chung, Simulation Modeling Handbook: A Practical Approach, CRC Press, 2004
4. Al-Aomar, R., Williams, E. J., & Ulgen, O. M. (2015). Process simulation using witness. John Wiley & Sons.

References Books:

1. Peiter Mosterman, Discrete-Event Modeling and Simulation: A Practitioner's Approach, Taylor & Francis Group, 2009
2. David Elizandro and Hamdy Taha , Performance Evaluation of Industrial Systems: Discrete Event Simulation in Using Excel/VBA, Second Edition, CRC Press, 2012
3. Evon M. O. Abu-Taieh, Asim Abdel Rahman El Sheikh, Handbook of Research on Discrete Event Simulation Environments: Technologies and Applications, Information science reference, 2010
4. Steffen Bangsow (Ed.), Use Cases of Discrete Event Simulation: Appliance and Research, Springer 2012
5. Byoung Kyu Choi, Donghun Kang, Modeling And Simulation Of Discrete-Event, Systems, John Wiley & Sons, Inc, 2013

6. Ernst G. Ulrich, Vishwani D. Agrawal, Jack H. Arabian, Concurrent And Comparative Discrete Event Simulation, Springer Science+Business Media, 1992
7. Lawrence Leemis, Steve Park, Discrete-Event Simulation: A First Course, Prantice Hall, 2004
8. Theodore T. Allen, Introduction to Discrete Event Simulation and Agent-based Modeling, Springer.

Web References:

1. https://archive.nptel.ac.in/courses/110/106/110106044/
2. https://archive.nptel.ac.in/courses/112/107/112107220/
3. https://www.youtube.com/user/WitnessSimulation/videos
4. https://vimeo.com/lanner
5. https://www.lanner.com/en-gb/insights/customer-stories/
6. https://onlinecourses.nptel.ac.in/noc19_me45/preview

402050D: Engineering Economics and Financial Management					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30 Marks**
Tutorial		**Tutorial**		**End-Semester**	**70 Marks**

Prerequisites: Understanding of economics & Finance in organizational functions and zeal to learn the subject

Course Objectives:

1. To introduce the concepts of economics & finance in industry.
2. To understand cost analysis and pricing
3. To acquire knowledge on basic financial management aspects and develop the skills to analyze financial statements
4. To understand the budgetary process and control.
5. To understand the international business process and associated financial facets
6. To introduce the entrepreneurial financial aspects.

Course Outcomes

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

CO1. **UNDERSTAND** the business environment, concepts of economics and demand-supply scenario.

CO2. **APPLY** the concepts of costing and pricing to evaluate the pricing of mechanical components.

CO3. **UNDERSTAND** accounting systems and analyze financial statements using ratio analysis

CO4. **SELECT** and **PREPARE** the appropriate type of budget and understand the controlling aspects of budget.

CO5. **UNDERSTAND** the international business and trade system functioning

CO6. **DEMONSTRATE** understanding of financing decisions of new ventures and performance

Course Contents

Unit 1	**Introduction to Business and Economics**

Business: Structure of Business Firm, Theory of Firm, Types of Business Entities, Limited Liability Companies, Sources of Capital for a Company, Non-Conventional Sources of Finance

Economics: Significance of Economics, Micro and Macro Economic Concepts, Various terms and

Concepts, Importance of National Income, Inflation, Money Supply in Inflation, Factors of Production, Business Cycle, Features and Phases of Business Cycle. Nature and Scope of Business Economics, Role of Business Economist, Multidisciplinary nature of Business Economics

Market Structures: Nature of Competition, Features of Perfect competition, Monopoly, Oligopoly, Monopolistic Competition

Demand and Supply: Elasticity, Types of Elasticity, Law of Demand, Measurement and Significance of Elasticity of Demand, Factors affecting Elasticity of Demand, Elasticity of Demand in decision making, Demand Forecasting: Characteristics of Good Demand Forecasting, Steps in Demand Forecasting, Methods of Demand Forecasting. Determinants of Supply, Supply Function & Law of Supply. Utility and Laws of returns

Unit 2	**Costs and Cost Accounting**

Costs: Standard cost, estimated cost, First cost, Fixed cost, Variable cost, Incremental cost, Differential cost, Sunk and marginal cost, Cost curves, Breakeven point and breakeven chart, Limitations of breakeven chart, Interpretation of breakeven chart, margin of safety, Angle of incidence and multi product break even analysis, Cost Output Decision and Estimation of Cost, Zero Based Costing and numerical

Cost Accounting: Objectives of cost accounting, elements of cost: material cost, labor cost, and expenses, allocation of overheads by different methods, Costing based on direct and indirect costs, Overheads apportionment and absorption, Different Models of Depreciation. Numerical on costing

Pricing: Contribution, P/V-ratio, profit-volume ratio or relationship, Types of Pricing, Pricing policies, Pricing methods, Product Life Cycle based Pricing, Price fixation, depreciation and methods of calculating depreciation

Unit 3	**Financial Accounting**

Accounting, Cost accounting & Management accounting, Various types of business entities, Accounting principles, postulates & meaning of accounting standards, Accounting cycle, Capital and revenue, Revenue, Expenses, Gains & Losses, Types of accounts & their rules, Journal Entries Create ledger, Preparation of Trial Balance, Finalizations, Preparation of Trading & Profit & Loss account, Understanding of Assets & Liabilities

Balance sheet and related concepts - Profit & Loss Statement and related concepts, Financial Ratio Analysis, Cash flow analysis, Funds flow analysis, Comparative financial statements, Analysis & Interpretation of financial statements, Concept of Ratio Analysis, Preparation of Balance sheet (numerical)

Investments: Risks and return evaluation of investment decision, Average rate of return, Payback Period, Net Present Value, Internal rate of return

Unit 4	**Budget and Budgetary Control**

Budgeting and Budgetary Control: Concept of budget, Types and classification of budgets,

Advantages and limitations, Methods of budgeting

Budgetary Control: objectives, merits and limitations, Budget administration. Functional budgets. Fixed and flexible budgets, Installation of Budgetary Control System, Zero base budgeting, Taxes and Financial Planning, Impact of Taxation and Inflation on Financial Management

Unit 5	**International Business and Finance**

Concept of globalization, factors influencing globalization, concept of international business and motives, international trade, institutional framework in international business, the significance of foreign trade policy, export-import procedures

Definition and function of money, Qualities of a good money, classification of money, value of money, index numbers, appreciation and depreciation of money, Gresham's Law and its limitations, Theory of exchange, barter, stock exchange, Speculation Taxation and Insurance

Balance of Trade and Balance of Payments, Barriers to Trade, Benefits of Trade/Comparative Advantage, Foreign Currency Markets/Exchange Rates, Monetary, Fiscal and Exchange rate policies, Economic Development

Unit 6	**Entrepreneurial Finance**

Sources of Funds for Entrepreneurs and Start Ups: Entrepreneurial Finance Vs. Corporate Finance; Traditional Sources of Funds, Early-Stage Sources of Funds- Incubators, Accelerators, Crowd Funding, Business Angels, Mezzanine Funds, Venture Capitals, Private Equity, LBO, Funding Process - Deal Sourcing, Deal Negotiation, Deal Agreement, Term Sheet

Investment Decisions for Start Ups: Time Value of Money, Types of Investment Decisions, Capital Budgeting Process - Investment Evaluation, Risk Analysis in Capital Budgeting - Risk Adjusted Discount Rate, Certainty Equivalent, Decision Tree, Sensitivity Analysis, Scenario Analysis

Valuation and Measurement of Financial Performance: Pre Money and Post Money Valuation, Factors Influencing Valuation, Valuation Methods, Dilution and Valuation of Equity, Metrics used for Performance Evaluation, Harvesting-Exit Strategies

Books and other resources

Text Books:

1. Hay, Donald A. and Derek J. Morris. Industrial Economics and Organization: Theory and Evidence, 2nd Edition (Oxford: Oxford University Press), 1991.
2. Lall, Sanjaya. Competitiveness, Technology and Skills (Cheltenham: Edward Elgar), 2001. 4. Scherer, F. M. and D. Ross. Industrial Market Structure and Economic Performance, 3rd Edition (Houghton: Mifflin), 1990.
3. Financial Accounting", Dr. Kaustubh Sontakke [Himalaya Publishing House]
4. Chandra, Prasanna (2004). Financial Management: Theory and Practice. New Delhi: TATA McGraw Hill

References Books:

1. Accounting Theory & Practice Prof Jawahar Lal [Himalaya Publishing House]

2. Brearley, Richard A. and Myers, Stewart C. (1988). “Principles of Corporate Finance”, New Delhi: McGraw-Hil
3. Engineering Economics, Tara Chand, Nem Chand and Brothers, Roorkee
4. Engineering Economy, Thuesen, G. J. and Fabrycky, W. J., Prentice Hall of India Pvt. Ltd.
5. Mechanical Estimating and Costing, T. R. Banga and S. C. Sharma, Khanna Publishers, Delhi
6. Industrial Organization and Engineering Economics, T. R. Banga and S. C. Sharma, Khanna Publishers, New Delhi
7. Mechanical Estimating and Costing, D. Kannappan et al., Tata McGraw Hill Publishing Company Ltd., New Delhi
8. A Text Book of Mechanical Estimating and Costing, O. P. Khanna, Dhanpat Rai Publications Pvt. Ltd., New Delhi
9. Industrial Engineering and Management, O. P. Khanna, Dhanpat Rai and Sons, New Delhi
10. Financial Management, I. M. Pandey, Vikas Publishing House Pvt. Ltd., New Delhi
11. Engineering Economics, James L. Riggs, David D. Bedworth and Sabah U. Randhawa, Tata McGrawHill Publishing Co. Ltd., New Delhi
12. Engineering Economy, Paul DeGarmo, Macmillan International Inc., New York
13. Entrepreneurial Finance-The Art and Science of Growing Ventures, Edited by Alemany L. and Andreoli, J.J, 2018, Cambridge University Press.
14. Rogers, S and Makonnen, R, Entrepreneurial Finance: Finance and Business Strategies for the Serious Entrepreneur, 4th Ed., Mc Graw Hill Education, 2020

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2. https://onlinecourses.nptel.ac.in/noc22_hs72/
3. https://onlinecourses.nptel.ac.in/noc22_mg63/
4. https://onlinecourses.nptel.ac.in/noc22_mg108/
5. https://onlinecourses.nptel.ac.in/noc22_hs113/
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Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering (2019 pattern)

402050E: Organizational Informatics					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30 Marks**
				End-Semester	**70 Marks**

Prerequisites: Understanding of design, manufacturing and business processes, industrial engineering principles and concepts and information technology. Manual processes of data / information generation, handling and interpretation / usage.

Course Objectives:

1. To provide a comprehensive grounding in many facets of Organizational Information systems.
2. To describe the role of information technology at various levels of organization.
3. To introduce integrated and co-ordinate network of components required for information system.
4. To enable students understand the Product Data Management (PDM) and Product Lifecycle Management (PLM) spanning product development and beyond.
5. To acquaint with information needs and ERP for manufacturing activities.
6. To introduce manufacturing execution system.
7. To describe the information requirements for successful integration of business activities.

Course Outcomes

Learner will be able to:

CO1. Demonstrate an understanding of the scope, purpose and value of information systems in an organization.

CO2. Understand the constituents of the information system.

CO3. Demonstrate the Understanding of the management of product data and features of various PLM aspects.

CO4. Relate the basic concepts of manufacturing system and the ERP functionalities in context of information usage.

CO5. Understand the manufacturing execution system and it's applications in functional areas.

CO6. Outline the role of the information system in various types of business and allied emerging technologies.

Course Contents

Unit 1	**Information Systems in the Enterprise**

Types of information: operational, tactical, strategic and statutory, Pyramid Diagram, management structure, requirements of information at different levels of management and various functions, Information Quality

The Need for Information Systems: Digital Convergence and the changing Business Environment,

Information and Knowledge Economy, Contemporary Approach to IS and Management Challenges, Information requirements for Industry 5.0

Information Systems in the Enterprise: Types of Information Systems in the Organization- Transaction Processing System (TPS), Decision Support System (DSS), Management Information System (MIS) and Executive Support System (ESS). Functional Perspective of IS; Enterprise Systems; Strategic uses of Information Systems; Economic, Organizational and Behavioral Impacts; IT Impact on Decision Making; Leveraging Technology in the Value Chain; MIS and Core Competencies; Strategic Information Systems (SIS)

Unit 2	**Components of Information System**

Introduction to technical and non-technical components of Information System Hardware, Software and IT Infrastructure: Evolution of IT Infrastructure; Digital Storage; IT Infrastructure Components; Current Trends in Hardware Platforms; Enterprise Software; Groupware

Databases and Data Warehouses: Traditional vs Database approach; Database Models, Introduction to Relational Model, and Object Oriented Model; Relational Operations SQL, Data Modelling; Databases on the Web, Data Warehousing, Advances in Database Technology, Network fundamentals, LAN hardware, Ethernet LANs, Token Ring LAN

Unit 3	**Product Data and Product Lifecycle Management System**

Product Data Management: Product Data, Product Data Management, Basic Functions of a PDM System, Product Data issues - Access, applications, Archiving, Availability, Change, and Confidentiality. Product Workflow, The Link between Product Data and Product Workflow, Key Management Issues around Product Data and Product Workflow

Product Life-cycle Management system: system architecture, Information models and product structure, Information model, the product information data model, the product model, functioning of the system. Reasons for the deployment of PLM systems. Introduction, modules and features of various PLM software like Arena, TeamCenter, Windchill, Oracle, SAP, Aras etc.

Unit 4	**Manufacturing Information System**

The Evolution from MRP to MRP II to ERP, ERP: Principle, ERP framework, Business Blue Print, Business Engineering V/S Business Process Reengineering (BPR), Introduction to various ERP software like SAP, People soft, Baan and Oracle, Comparison, ERP Modules, their Features and applications, Customization and ERP Implementation, Manufacturing Information Systems in lean manufacturing and industry 5.0 environments, Manufacturing Database Integration.

Unit 5	**Manufacturing Execution System**

Concept, functional hierarchy model, generic activity model of manufacturing operations management, various modules like detailed production scheduling, product definition management and production execution management, Historians, diverse reporting and tracking & tracing, plant dashboard, workflow management, interfaces, integration with ERP, and Plant modules, Advantages

per Functional Area, MES implementation

Unit 6	Business Information System

Electronic Commerce and the Digital Organization: Cross functional Enterprise Information System, Internet based Business Models. B2B, EDI and B2C Models; Role of Intranets/Extranet, Web Enabled Business Management, Strategic Enterprise Systems - Information requirement and systems for SCM, CRM, SRM

Emerging Technologies in IS: Cloud Computing, Artificial intelligence systems; Knowledge based expert system (KBES), Knowledge Management System

Management of Information System: Implementation Processes, Maintenance, Evaluation and Security of Information System, Protection of Information System

Books and other resources

Text Books:

1. Kenneth C. Laudon & Jane P. Laudon. "Management Information Systems". Pearson Publishing
2. W. S. Jawadekar, Management Information Systems, Tata McGraw Hill, 2002
3. Robert Schultheis and Mary Summer, Management Information Systems –The Managers View, TataMcGraw Hill, 2008.
4. Goyal D.P., Management Information Systems –A Managers Perspective, Macmillan Publishers.
5. David L Olson: Managerial Issues of Enterprise Resource Planning Systems, McGraw Hill, International Edition-2009.
6. Rainer, Turban, Potter: Introduction to Information Systems, WILEY-India, 2009.
7. Vaman, ERP in Practice, TMH, 2009
8. Sartori, L.G., "Manufacturing Information Systems", Addison-Wesley Publishing Company
9. Date, C.J.,"An Introduction to Database Systems" Addison Wesley", 8th Edn,. 2003
10. Orlicky, G., "Material Requirements Planning", McGraw-Hill, 1994.
11. Kerr, R., "Knowledge based Manufacturing Management", Addison-Wesley
12. Franjo, C., "Manufacturing Information & Data Systems Analysis, Design & Practice", Butterworth-Heinemann, 2002.
13. Weiming S, "Information Technology for Balanced Manufacturing Systems", Springer, 2006.

References Books:

1. Gupta Uma G., Management Information Systems –A Managers Perspective, Galgotia Publications.
2. Gordon Davis, Management Information System: Conceptual Foundations, Structure and Development, Tata McGraw Hill, 2000.
3. Haag, Cummings and Mc Cubbrey, Management Information Systems for the Information Age, McGraw Hill, 2005.
4. Turban, McLean and Wetherbe, Information Technology for Management –Transforming Organizations in the Digital Economy, John Wiley, 2007.

5. Raymond McLeod and Jr. George P. Schell, Management Information Systems, Pearson Education, 2007.
6. James O Brien, Management Information Systems – Managing Information Technology in the Ebusiness enterprise, Tata McGraw Hill, 2002.
7. Avgerou, C., Ciborro, C., & Land, F. (2004). The social study of information and communication technology: Innovation, actors, and contexts. London: Oxford University Press.
8. Kallinikos, J. (2011). Governing through technology: Information artefacts and social practice. New York: Palgrave Macmillan.
9. Luff, P., Hindamarsh, J., & Heath, C. (2000). Workplace studies: Recovering work practice and informing system design. London: Cambridge University Press.
10. Alex Leon and Mathew Leon: "Data Base Management Systems", Vikas Publishing House, New Delhi.
11. Mahadeo Jaiswal, Monika Mital: "Management Information System", Oxford University Press, New Delhi, 2008.
12. Murthy C.S.V.: "Management Information System", Himalaya Publications, New Delhi, 2008.
13. Panneerselvam R.: "Database Management System", PHI Private Limited, New Delhi, 2008.
14. Philip J, Pratt, Joseph J. Adamski: "Database Management Systems", Cengage Learning, New Delhi, 2009.
15. Grieves Michael, Product Lifecycle Management- Driving the Next Generation of Lean Thinking, McGraw-Hill, 2006.
16. Antti Saaksvuori, Anselmi Immonen, Product Life Cycle Management - Springer, 1st Edition
17. Stark, John. Product Lifecycle Management: 21st Century Paradigm for Product Realization, Springer-Verlag, 2004
18. Alexis Leon: ERP (Demystified), 5/E, Tata McGraw-Hill, 2009.
19. C. S. V. Murthy: Management Information System, Himalaya, 2009
20. James A. Obrein: Management Information Systems, TMH, 2009

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1. https://onlinecourses.nptel.ac.in/noc20_mg60/preview
2. https://nptel.ac.in/courses/106105195
3. https://nptel.ac.in/courses/110105148
4. https://onlinecourses.nptel.ac.in/noc19_mg54/preview
5. https://nptel.ac.in/courses/110106146
6. https://www.youtube.com/watch?v=NzyhYxUCjlg

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering (2019 pattern)

402050F: Computational Multi Body Dynamics					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30 Marks**
				End-Semester	**70 Marks**

Prerequisites: Mathematics, Physics, Systems in Mechanical Engineering, Solid Modeling and Drafting, Kinematics of Machinery, Numerical & Statistical Methods, Computer Aided Engineering, Design of Transmission Systems, Dynamics of Machinery

Course Objectives:

1. Study basic terminology and concepts used in Multibody Dynamics
2. Understand the types of joints, its kinematics and relevant transformations
3. Understand the formulation methods and Formulate problems using Principals of Dynamics
4. Analyze the kinematics and dynamics of rigid Planar inter-connected bodies
5. Analyze the kinematics of rigid spatial inter-connected bodies
6. Analyze the kinematics and dynamics of rigid spatial inter-connected bodies and Recognize the applications of Multibody Dynamics with applications to machine and structural dynamics

Course Outcomes:

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

CO1. **APPLY** the basic terminology and concepts used in Multibody Dynamics to solve varieties of motion related applications

CO2. **IDENTIFY and EVALUATE** the types of joints, its kinematics and relevant transformations

CO3. **DISTINGUISH and COMPARE** the formulation methods

CO4. **DERIVE** equations of motion and **EVALUATE** the kinematics and dynamics of rigid Planar inter-connected bodies

CO5. **DERIVE** equations of motion and **EVALUATE** the kinematics of rigid Spatial inter-connected bodies

CO6. **APPLY** MBD tool effectively and **SIMULATE** it to solve and validate practical Multibody Dynamics problems and its solutions

Course Contents

Unit 1	**Introduction to Computational Multi Body Dynamics**

Introduction: Single Body Dynamics Vs Multi Body Dynamics, Machine-Design Approach Vs Control-System Approach, Basic Building Blocks (Bodies, Constraints or Joints, Forces, Motions, Sensors, Controllers, Reference Frames, Contacts, etc.)

Kinematics: Angular velocity, matrix representation of angular velocity, simple angular velocity, Differentiation in two reference frames, angular acceleration, velocity and acceleration equations, two points fixed on a rigid body, point moving on a rigid body

Unit 2	**Joints and Kinematics**

Types of joints (planar and spatial joints), Vector formulation of Constraint equations, Jacobian, Computation of Kinematics, Transformations (body-fixed and space-fixed rotations), Velocity Transformations

Unit 3	**Basic Principles of Dynamics**

D'Alembert's Principle, Equilibrium and Virtual work, Virtual displacements, generalized forces, workless constraints, Lagrange's equation, Non-holonomic constraints, Lagrange's form of D'Alembert's principle - Jourdain - Kane Method, Generalized Inertia, Mass matrix

Newton-Euler Equations: Constraint equations, augmented formulation, Lagrange multipliers, embedding technique and amalgamated formulation

Principle of virtual work and Lagrange's Equation: Kinetic energy, potential energy function, generalized forces on a rigid body, derivation of equations of motion using Lagrange's method

Unit 4	**Planar Multi Body Dynamics Motion Simulation**

Planar Kinematic Analysis: Joint constraints (Revolute, prismatic, gear and cam pairs, etc), Motion/Force Constraints, The automatic assembly of the systems of equations for position, velocity and acceleration analysis, Iterative solution of systems of non-linear equations,

Dynamics of Planar Systems: Dynamics of Planar systems, Geometry of masses, computation and assembly of mass matrix. Computation of planar generalized forces for external forces and for actuator-spring-damper element, Simple applications of Forward and Inverse Dynamic Analysis

Unit 5	**Kinematic Analysis of Spatial Systems**

Kinematics of Rigid bodies in Space: Reference frames for the location of a body in space, Euler angles and Euler parameters. Screw motion in space, Velocity, Acceleration and Angular Velocity, Relationship between the Angular Velocity Vector and the time derivatives of Euler parameters, Articulated Rigid Body Dynamics

Dynamic Analysis of Spatial Systems: Basic kinematic constraints. Joint definition frames. The constraints required for the description in space of common kinematic pairs (revolute, prismatic, cylindrical, spherical, screw, etc). Equations of motion of constrained spatial systems

Unit 6	**Spatial Multi Body Dynamics Motion Simulation and its Applications**

Computation of spatial generalized forces for external forces. Computation of reaction forces from Lagrange's multipliers, Recursive Inverse Dynamics

Survey of Existing Kinematic and Multibody dynamics Simulation software, Varieties of Applications

Books and other resources

Text Books:

1. Nikravesh, P.E., (2019), "Planar multibody dynamics: formulation, programming with MATLAB®, and applications," CRC Press, ISBN: 9781138096127
2. Shabana, A.A., (2020), "Dynamics of Multobody Systems," Cambridge University Press, ISBN: 9781108485647
3. Rao, J.S., (2011), "Kinematics of Machinery Through HyperWorks," Springer, ISBN: 9789400711556
4. Haug, E.J., (1988), "Computer-Aided Kinematics and Dynamics of Mechanical Systems, Volume-I, Basic Methods," Prentice Hall, ISBN: 9780205116690
5. Haug, E.J., (2021), "Computer-Aided Kinematics and Dynamics of Mechanical Systems, Volume-II, Modern Methods," www.researchgate.net

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1. Wittenburg, J., (2012), "Dynamics of Systems of Rigid Bodies," Vieweg+Teubner Verlag, ISBN: 9783322909435
2. Roberson, R.E., Schwertassek, R., (2012), "Dynamics of Multibody Systems," Springer, ISBN: 9783642864667
3. Huston, R.L., (1990), "Multibody Dynamics," Butterworth-Heinemann, ISBN: 9780409900415
4. Schielen, W., (1990), "Multibody Systems Handbook," Springer, ISBN: 9783540519461
5. Rampalli, R., Ferrarotti, G. and Hoffmann, M., (2012), "Why Do Multi-Body System Simulation?," NAFEMS, ISBN: 9781874376545
6. Greenwood, D.T., (1987), "Principles of Dynamics," Pearson, ISBN: 9780137099818
7. Moon, F. C., (2008), "Applied Dynamics with Applications to Multibody and Mechatronic Systems," Wiley-VCH, ISBN: 9783527407514
8. Kane, T.R, Levinson, D.A., (1985), "Dynamics: Theory and Applications," McGraw-Hill, ISBN: 9780070378469
9. de Jalon, J.C., Bayo, E., (2011), "Kinematic and Dynamic Simulation of Multibody Systems," Springer, ISBN: 9781461276012
10. Jazar, R. N., (2011), "Advanced Dynamics: Rigid Body, Multibody, and Aerospace Applications," John Wiley & Sons, ISBN: 9780470398357
11. Nandihal, P., Mohan, A., and Saha, S.K., (2021), "Dynamics of Rigid-Flexible Robots and Multibody Systems," Springer, ISBN: 9789811627972
12. Shah, S., Saha, S.K., and Dutt, J.K., (2012), Dynamics of Tree-type Robotic Systems, Springer, ISBN: 9789400750050

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- https://www.youtube.com/channel/UCN3-GeDjFM4A3muyhsS9mpQ

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering (2019 pattern)

402051A: Process Equipment Design					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30 Marks**
				End-Semester	**70 Marks**

Prerequisites: Design of Machine Elements

Course Objectives:

1. Understand the process flow diagrams (PFD) and design codes
2. Understand the content of piping and instrument diagrams (P&ID)
3. Understand the design of Cylindrical and Spherical Vessels and Thick Walled High Pressure Vessels
4. To enable students to apply the requirements of the relevant industry standards to the mechanical design of equipment's used in the process industry and above ground atmospheric storage

Course Outcomes:

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

CO1. **INTERPRET** the different parameters involved in design of process Equipments.
CO2. **ANALYZE** thin and thick walled cylinder
CO3. **DESIGN** cylindrical vessel, spherical vessel, tall vessels and thick walled high pressure vessels
CO4. **DESIGN** different process Equipments and select pump, compressor etc. and auxiliary services
CO5. **EVALUATE** Process parameters and their correlation
CO6. **APPLY** the concepts of process equipment design for specific applications

Course Contents

Unit 1	**Process Design**

Basic concepts in process design, block diagrams for flow of processes, material flow balance. Design pressures -–temperatures, design stresses, factory of safety, minimum shell thickness and corrosion allowance, weld joints efficiency, design loading, stress concentration and thermal stresses, failure criteria, optimization technique such as Lagrange's multiplier and golden section method, cost and profitability estimation. Introduction to design codes like IS-2825, ASME-SECT, EIGHT-DIV-II TEMA.API-650, BS-1500 & 1515

Unit 2	Piping design

Process Piping Design: Thin and thick walled cylinder analysis, pre stressing, Piping codes for design, construction and inspection, Piping flow diagrams and pipe work symbols, design of layout of water, steam and compressed air pipes work, Types of couplings

Unit 3	Thin and Thick Vessels

Design of Cylindrical and Spherical Vessels: Types and classes of vessels, types design of end closers, local stresses due to discontinuity or change of shape of vessel, vessel opening compensation, design of standard and non-standard flanges, design of vessels and pipes under external pressure, design of supports for process vessels

Design of Tall Vessels: Determination of equivalent stress under combined loadings including seismic and wind loads application of it to vertical equipment like distillation column

Design of Thick Walled High Pressure Vessels: Thick walled cylinder analysis, pre stressing of thick cylinders, Design by various theories of failure, construction of these vessels with high strength steel and other special methods.

Unit 4	Process Equipment Design

Process Equipment Design: Storage vessels, reaction vessels, agitation and mixers, heat exchangers, filters and driers, centrifuges. Code practices, selection and specification procedures used in design. Selection of pumps, compressors, electrical equipment's and auxiliary services, safety, etc., pipe fitting, linings and flanged connections. Types of valves used on pipe line. Fabrication of pipe lines, expansion joints and pipe supports

Unit 5	Process Control

Process Control: Processes, Process parameters and their correlations, Fundamentals of process measurements and control modern control devices and other controls of major unit operation and processes.

Unit 6	Execution and Application of specific process Equipment Design

Execution: Planning, manufacture, inspection and erection of process equipment like pressure vessels, chimneys, ducting, heat exchangers, pulverizing equipment, etc. protective coatings, lining of Vessels

Application of specific process Equipment Design: Fuel pumping stations, fire extinguishers, HVAC, fume extraction systems with IOT and AI

Books and other resources

Text Books:

1. Process Equipment Design : By Dr. M.V. Joshi, Mc-Millan.
2. Process Equipment Design : By Browell and Young, John Wiley.
3. Plant Design and Economics : Max and TimasulausKalus – McGraw Hill.
4. Industrial Instrumentation servicing Hand Book : Cannel Grady, McGraw Hill.

References Books:

1. Handbook of Instrumentation and Control : Kellen Heward, McGraw Hill
2. Chemical Engineering Handbook: Perry John, McGraw Hill.
3. Chemical Equipment Design: B.C. Bhattacharya.
4. Industrial Pipe Work: D.N.W. Kentish, McGraw Hill.
5. Chemical Engineering: J.M. Coulson, Richardson, Sinnott Vol. VII, Maxwell, McMillan.
6. Pressure Vessel Design Hand Book: H. Bedna.
7. Dryden's outlines of Chemical Technology for the 2: By Roa M. Gopala, Sitting M., East West Press Pvt. Ltd., New Delhi.
8. Applied Process Design for Chemical and Petrochemical, Vol. I, II and III: By E.E. Ludwig, Gulf Publication Co., Houston.
9. Chemical Process Control: An Introduction to Theory and Practice: By Stephanopoulos G., Prentice Hall of India, New Delhi.
10. Chemical Process Equipment Selection and Design: By Stanley M.Walas, Butterworth-Heinemann Series in Chemical Engineering.
11. Process System Analysis and Control: By D.R. Coughanowr, McGraw Hill, New York.
12. Engineering Optimization: Theory and Practice: By Rao S.S., New Age Publishing Co., New Delhi.
13. Optimization of Chemical Processes: By Edgar T.F., Himmelblau D.M., McGraw Hill Book Co., New York.
14. Control Devices, Vol. I and II : Liptak
15. Analysis, synthesis and design of Chemical Processes : Richard Turton, Richard C. Bailie, Wallace B. Whiting, Josheph A. Shaewitz, Prentice Hall Int. Series in Physical and Chemical Science.

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering (2019 pattern)

402051B: Renewable Energy Technologies					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30**
				End-Semester	**70**

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

Course Objectives:

1. To understand fundamentals, needs and scopes of renewable energy technologies.
2. To design and applications of solar thermal conversion systems.
3. To explain constructions, working and design of solar photovoltaic system used for domestic applications.
4. To design a wind energy system.
5. To study Wind farm and Solar Photovoltaic grid-connected Systems**.**
6. To describe biomass energy conversion systems.

Course Outcomes:

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

1. **DESCRIBE** fundaments, needs and scopes of renewable energy systems.
2. **EXPLAIN** performance aspects of flat and concentric solar collectors along with applications.
3. **DESIGN** solar photovoltaic system for residential applications.
4. **DESIGN AND ANALYSIS** of wind energy conversion system.
5. **APPLY** Installation practices of Wind and Solar Photovoltaic Systems for grid connection.
6. **DETERMINE** performance parameters of bio-energy conversion systems.

Course Content

Unit 1 Introduction to Renewable Energy Technologies

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

Solar Energy Fundamentals: Solar Radiation and Measurement, Solar constant, Solar angles, day length, angle of incidence on tilted surface, Extra-terrestrial characteristic, Effect of earth atmosphere, Measurement and estimation on horizontal and tilted surfaces (numerical treatment on Solar angles and Measurements), Analysis of Indian solar radiation data and applications, Basics of solar cell, Forming the PN junction solar cells, Photo conversion efficiency, Theoretical limits

Wind Energy Fundamentals: Wind speed, Wind direction, Data measurement and analysis, Variation of wind speed with height and time, Wind potential assessment (numerical treatment), and

wind resources worldwide and in India, wind energy forecast

Unit 2	Solar Thermal Systems and Applications

Solar thermal collectors: Flat plate collectors, Thermal analysis, Heat capacity effect, Testing methods, Evacuated tube collectors (ETC) analysis, its design and application, Numerical on flat plate collectors.

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

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

Unit 3	Solar Photovoltaic Systems

Solar Cells and Modules: Classification of Solar cells, First generation: Single crystalline, Poly crystalline, Second Generation: Thin film, Cd-Te, CIGS, Third Generation: Polymer based, DSSC, Perovskites, Hybrid, Quantum Dots, Multi Junction Tandem cells, Inorganic and Hybrid cells, Different losses and mitigation, Factors Affecting Electricity Generated by a Solar cell, types of modules, PV panel and array, solar cell equation, Fill factor and maximum power, Shading and hot-spot formation.

Power Conditioning Equipment: Inverters, Regulators, Other Devices, System Analysis-Design Procedure, Design Constraints, selection of components, calculation of life cycle costing, payback time and Levelized Energy Cost (LEC) (Numerical treatment on- Designing solar PV system to find power consumption, Size the PV panel, Inverter and battery size, Solar charge controller size and costing for domestic applications only)

Recent PV market trends, Benchmark cost of different PV components

Unit 4	Wind Energy Systems

Components of wind turbines, Types of wind turbines- Horizontal axis and Vertical axis

Aerodynamics of wind turbines: Aerofoil sections and lift and drag coefficients, relative wind velocity, Power extraction from the wind energy, Wind power generation curve, Maximum power and Betz coefficient, Power Coefficient of a wind turbine (C_p), Axial thrust and torque developed by the turbine, Design tip speed ratio and solidity

Design parameters: Rotor axis rotation: Horizontal or Vertical, Rotor position - upwind and downwind of tower, Rotor Speed - constant or variable, Type of hub: rigid, teetering, hinged blades or gimballed, Number of blades, Tower Structure, Materials used for wind turbine components, calculation of life cycle costing, payback time and Levelized Energy Cost (LEC). Performance

evaluation of Wind energy system.

Note: Numerical on aerodynamics, design parameters and payback estimation.

Unit 5	**Design of grid connected Wind and Solar Photovoltaic Systems**

Wind Farm: Off-shore and on-shore wind farms, Small wind turbines special considerations and designs, testing, noise issues, Site selection and turbine spacing, rotor selection, ICT based monitoring and control of wind farms, Annual Energy Output (AEO) with numerical treatment, optimal placement of wind turbine in a wind farm, Wind power farm: installation operation and maintenance

Design of Wind Energy Conversion Systems: Power control**:** stall, variable pitch, controllable aerodynamic surfaces and yaw control. Yaw Control: driven yaw, free yaw or fixed yaw

Design of Solar PV systems: Site selection for solar photovoltaic plants, choice of module and their techno-economical characteristics, Series and parallel combination of PV array installation and output calculation with numerical treatment**,** off grid, on-grid, standalone system, grid interface. Enhancing array performance: cooling, concentrator, Solar PV tracking, effect of dust on PV and remedies, Installation of electrical and electronic components: array combiner box, inverter, Distribution boxes, safety devices, Maintenance procedure of solar photovoltaic plants, DPR preparation for roof-top and MW scale solar plants

Unit 6	**Bio Energy Systems**

Bio-mass: Biomass types, Characteristics (Ultimate analysis, Proximate analysis, Calorific value, Physical Properties, Thermodynamic properties, Feedstock Handling Characteristic, Thermo-gravimetric analysis), Biomass estimation, Biomass formulation (Numerical Treatment).

Bio-fuel: Introduction to bio-fuels, feedstocks for bio-fuel production, bio-diesel, bio-hydrogen, concept of bio-refinery

Thermo-chemical conversion: Pyrolysis, Liquefaction and Gasification, Gasifier and types. Gas production, environmental effects, Producer gas utilization, Biomass integrated gasification/combined cycles systems (Numerical Treatment).

Bio-chemical Conversion: Biodegradation, Aerobic Digestion, Anaerobic digestion; Biogas digester types and biogas utilization

Books and other resources

Text Books:

1. S P Sukhatme and J P Nayak, Solar Energy: Principles of Thermal Collection and Storage, McGraw-Hill Education, 2017
2. G. N. Tiwari, Solar Energy: Fundamentals, Design, Modelling and Applications, Alpha Science, 2002

3. Rabindra Satpathy, Venkateswarlu Pamuru, Solar PV power: Design, manufacturing and applications from sand to sand to systems.
4. B. H. Khan, Non-Conventional Energy Sources, Second Edition. Tata Mc-Graw Hill.
5. J. F. Manwell, J. G. McGowan and A. L. Rogers., Wind Energy Explained- Theory, Design and Application. John Wiley and Sons Ltd.
6. G. D. Rai, Energy Sources, Khanna Publications.
7. John R. Balfour, Introduction To Photovoltaic System Design (The Art and Science of Photovoltaics), Jones and Bartlett Publishers,
8. Michel C. Allard, Bioenergy Systems, Biological Sources and Environmental Impact, Nova Science Publishers, Inc.; UK ed. edition 2013.
9. Prabir Basu, Biomass Gasification, Pyrolysis and Torrefaction, Academic Press, Elsevier, 2013.
10. Meisam Tabatabaei, Biogas: Fundamentals, Process, and Operation (Biofuel and Biorefinery Technologies, Springer; 2018.

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1. G. N. Tiwari, Arvind Tiwari, Handbook of Solar Energy: Theory, Analysis and Applications, Springer, 27-Jun-2016 - Technology & Engineering.
2. S. Yang, H.A. El-Enshasy, N. Thongchul (Eds.), Bioprocessing Technologies in Biorefinery for Sustainable Production of Fuels, Chemicals and Polymers, Wiley, 2013.
3. Handbook of Renewable Energy Springer; 1st ed. 2017.
4. Richard Jemmett, Methane Production Guide - How to Make Biogas. Three simple anaerobic digesters for home construction: Generate your own renewable energy from waste, RW Jemmett; 3rd edition (13 February 2011).
5. Wim Soetaert, Biofuels, Wiley, 2011.

Web Courses:

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

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Cost Analysis Of Energy Savings
Link: https://egyankosh.ac.in/bitstream/123456789/47587/1/Unit-3.pdf

National Electricity Plan
https://powermin.gov.in/en/content/national-electricity-plan-0
Report : https://powermin.gov.in/sites/default/files/uploads/NEP-Trans1.pdf

Economic & Financial Evaluation of Renewable Energy Projects
https://pdf.usaid.gov/pdf_docs/PNADB613.pdf
https://energypedia.info/wiki/The_Economics_of_Renewable_Energy

Analyzing The Falling Solar And Wind Tariffs: Evidence From India
https://www.adb.org/sites/default/files/publication/566266/adbi-wp1078.pdf

Mapping India's Energy Subsidies 2020
https://www.iisd.org/system/files/publications/india-energy-transition-2020.pdf

Jawaharlal Nehru National Solar Mission policies and initiatives:
Presentation: https://iitj.ac.in/CSP/material/JNNSM-Final.pdf
Report: https://mnre.gov.in/img/documents/uploads/file_f-1608040317211.pdf

Benchmark costs for Grid-connected Rooftop Solar PV systems:

https://www.yellowhaze.in/mnre-solar-benchmark-cost-2021-22/

Benchmark costs for Grid-connected Rooftop Solar Photo-voltaic systems for the financial year 2021-22

https://mnre.gov.in/img/documents/uploads/file_f-1629353920466.pdf

Installation & Maintenance of Solar Panel

https://rdso.indianrailways.gov.in/works/uploads/File/Handbook%20on%20Installation%20&%20maintenance%20of%20Solar%20Panel(1).pdf

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering (2019 pattern)

402051C: Automation and Robotics					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**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

402051D: Industrial Psychology and Organizational Behavior					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**3**	**In-Semester**	**30 Marks**
				End-Semester	**70 Marks**

Prerequisites: Understanding psychology as natural science, Infancy and Preschool Years, Diversity and Social Interaction, zeal to contribute for individual, group, social and national development.

Course Objectives:

1. To develop an understanding of the nature, functioning and design of organization as social collectivities.
2. To orient the students to the application of principles of psychology in an industrial and organizational workplace
3. To demonstrate the understanding of job requirement and related fatigue, boredom and ways to handle it.
4. To develop the insights into performance management and understanding related improvement strategies.
5. To have an understanding of human behavior in groups and develop knowledge and skills in leadership, power, communication, negotiation and conflict management.
6. To develop the acumen to understand the organizational culture, change management and organizational development.

Course Outcomes

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

CO1. **DEMONSTRATE** fundamental knowledge about need and scope of industrial - organizational psychology and behavior.
CO2. **ANALYZE** the job requirement, have understanding of fatigue, boredom and improve the job satisfaction.
CO3. **UNDERSTAND** the approaches to enhance the performance.
CO4. **KNOWLEDGE** of theories of organizational behavior, learning and social-system.
CO5. **UNDERSTAND** the mechanism of group behavior, various aspects of team, leadership and conflict management.
CO6. **EVALUATE** the organizational culture, manage the change and understands organizational development approaches.

Course Content

Unit 1	**Industrial Psychology: Introduction**

Introduction to Industrial Psychology, Brief History of Industrial Psychology, Nature, Scope and Problems, psychology as a science and areas of applications, Individual differences and their

evaluation, Role of heredity and environment, study of behavior and stimulus to response behavior, Types of individual differences, Scientific management and it's limitations

Hawthorne Studies: Introduction, Hawthorne Studies, Implication of Hawthorne Studies, Criticisms of Hawthorne Studies, Relevance of Industrial psychology in era of Industry 5.0

Unit 2	**Job Analysis and Industrial Fatigue**

Job Analysis and Evaluation, Employee Selection, Performance Evaluation, training and development

Industrial Fatigue: Introduction, Concept and Meaning, Types of Industrial Fatigue, Causes of Fatigue, Contents, Fatigue Symptoms, Industrial Studies on Fatigue, Causes and Remedies of Industrial Fatigue, Effects of Industrial Fatigue

Industrial Boredom: Introduction, Concept and Meaning, Causes and Remedies of Boredom, Effects of Boredom, Reducing Boredom

Unit 3	**Performance Management**

Performance Management: Introduction, Concept and Meaning, Objectives of Performance Management, Process of Performance Management, Approaches to Performance Development, Methods of Performance Management

Relevance of Leadership and supervision, Recruitment, Time and Stress Management, Occupational Health and Safety. Implication of Motivation Theories in Workplace, Factors Influencing Job Satisfaction, Reducing Dissatisfaction

Unit 4	**Organizational Behavior: Introduction**

Concept of organization & organizational behavior, Organizational structure, factors affecting behavior in organizations, Theories of Organization - Classic Organizational Theory, Human Relations Theory, Contingency Theories, Models and Approaches of Organizational Behavior.

Ethics and ethical behavior in organizations, Learning: meaning and definition, process and theories of learning, Understanding a social-system, Organizational Behavior in an Engineering Sector Organization

Unit 5	**Group Behavior and Interpersonal Relationships**

Group Behavior: Groups: Concept and Classification, Stages of Group Development, Group Structure, Roles and Norms, Premise and Issues. Group Decision-Making: Group vs Individual, Groupthink and Groups Shift, Group Decision Making Techniques and Process

Team work: meaning, concept, types, creating, an effective team

Leadership: Functions and approaches; trait, behavioral and contingency models; characteristics of successful leaders; role of power in leadership

Interpersonal Relationships: Understanding Self and Others, Developing Interpersonal

Relationships, Transactional Analysis, Johari Window

Conflict Management: Concept, Causes, Types, Stages, Effects, Management of Conflicts

Unit 6	**Organizational Culture, Change Management and Organizational Development**

Organizational Culture: Concept, Dominant Culture, Strong vs Weak Cultures, Creating and Sustaining Culture, Employees Learning of the Culture, Creating a Customer-Responsive Culture.

Organizational Changes: Concept and Forces for Change, Managing Planned Changes, Resistance to Change, Approaches to Manage Organizational Change, Organizational Development, Culture-Boundedness of Managing the Change.

Organizational theory and development:
Organizational Theory: Classical organizational THEORY, Humanistic Theory, Open-System Theory
Organizational development: Need, models of Organizational change, Organizational development interventions

Books and other resources

Text Books:

1. Vikram Bisen and Priya, Indistrial Psychology, New Age Publication, 2010.
2. Michael Aamodt, Organizational/ Industrial Psychology, Wadsworth Cengage Learning, 2010
3. Robbins, S.P. Organizational Behaviour. Prenctice-Hall, latest edition.
4. Spector, P.E. Industrial and Organizational Psychology: Research and Practice. International Student Version. Latest Edition. Wiley.
5. Davis K. & Newstrom J.W., Human Behaviour at work, Mcgraw Hill International, 1985
6. Stephen P. Robbin & Seema Sanghi, Organizational behavior, Pearson, 2011
7. L.M. Prasad, Organizational behavior, S Chand & sons

References Books:

1. Blum M.L. Naylor J.C., Horper & Row, Industrial Psychology, CBS Publisher
2. Luthans Fred, Organizational Behaviour, McGraw Hill International.
3. Morgan C.t., King R.A.,John Rweisz & John Schoples, Introduction to Psychology, McHraw Hill, 1966
4. Schermerhorn J.R.Jr., Hunt J.G &Osborn R.N., Managing, Organizational Behaviour, John Willy
5. Arnold J., Robinson, Iran, T. and Cooper, Cary L, Work Psychology, Macmillan IndiaLtd.
6. Muchincky (2009). Psychology applied to work. New Delhi: Cengage.
7. Griffin, Ricky W: Organizational Behaviour, Houghton Mifflin co., Boston.
8. Ivancevich; John and Micheeol T. Matheson, Organizational Behaviour and Management, Tata McGraw-Hill, New Delhi.
9. Newstrom, John W. and Keith Davis: Organizational Behavior: Human Behavior at Work, Tata McGraw-Hill, New Delhi.
10. Steers Richard m. and J. Stewart black: Organizational Behavior, Hrper Collins college

Publishers, New York.
11. Sukla, Madhukar: Understanding Organizations: Organization Theory and Practice in India, Prentice Hall, New Delhi.

Web References:

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3. http://nptel.ac.in/cour ses/110105034/12
4. http://nptel.ac.in/cour ses/110105034/8
5. http://nptel.ac.in/cour ses/110105034/14
6. http://nptel.ac.in/course s/110105034/23
7. http://nptel.ac.in/course s/110105034/26
8. http://nptel.ac.in/course s/110105034/27
9. http://nptel.ac.in/cour ses/110105034/34
10. http://nptel.ac.in/cour ses/110105034/2
11. http://nptel.ac.in/cour ses/110105034/40

Savitribai Phule Pune University

Board of Studies - Mechanical and Automobile Engineering

Undergraduate Program – Final Year Mechanical Engineering (2019 pattern)

402051E: Electric and Hybrid Vehicle					
Teaching Scheme		**Credits**		**Examination Scheme**	
Theory	**3 Hrs./Week**	**Theory**	**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 and **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/

402052: Mechanical Systems Analysis Laboratory					
Teaching Scheme		**Credits**		**Examination Scheme**	
Practical	**02 Hrs.**	**Practical**	**01**	**Term Work**	**25 Marks**
				Oral	**25 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**:

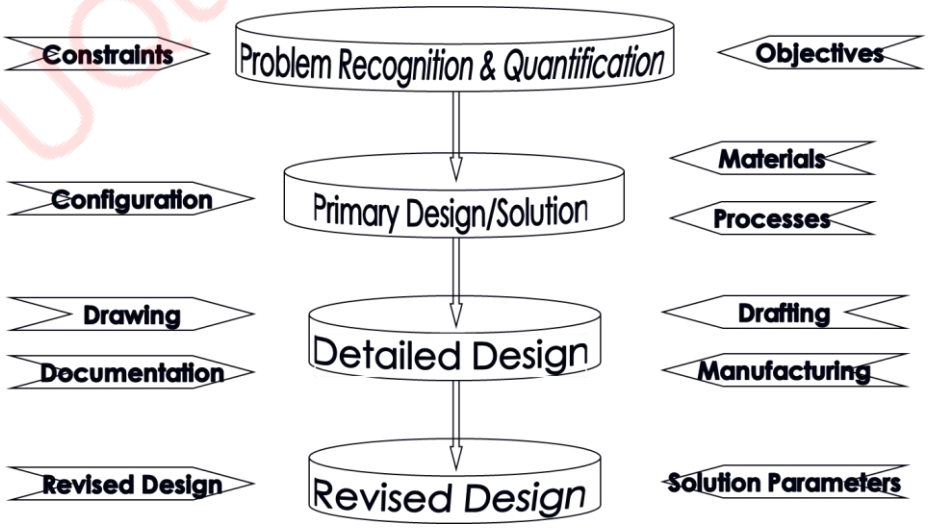
A] Product based Case study

- **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.

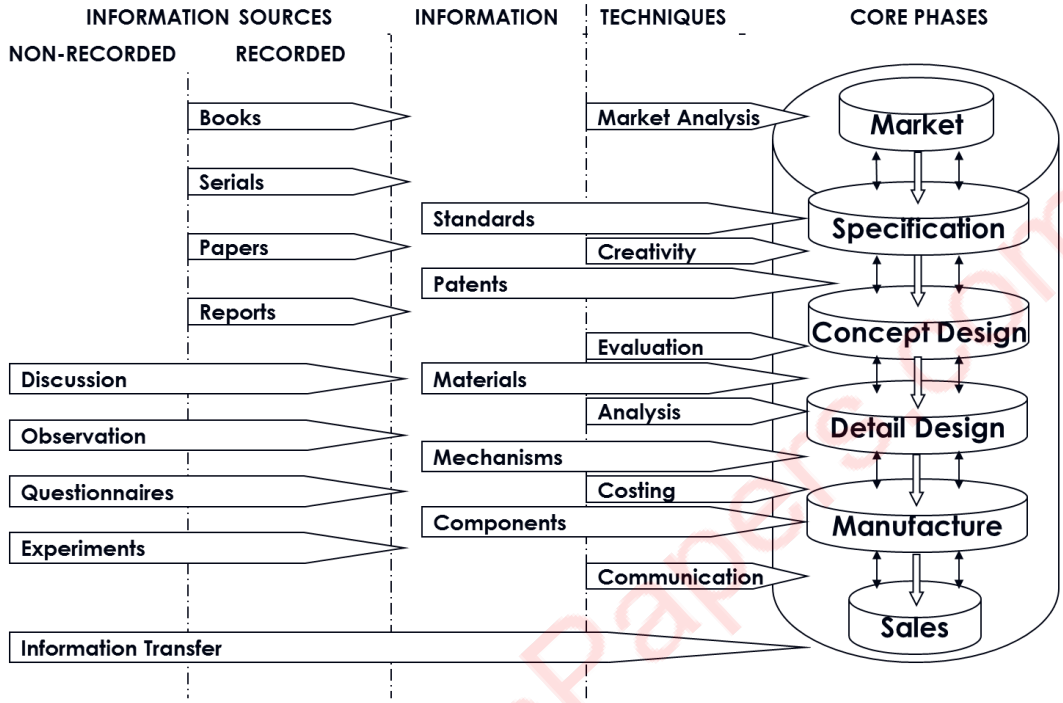
- The product can be but not limited to: any household product, Utility products, Hand/Process Tools/Equipments, Thermal Systems like, Heat exchangers, Mass production jigs/fixtures, robotics and automation products, etc.

- 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.

402053: Project (Stage II)					
Teaching Scheme		**Credits**		**Examination Scheme**	
Practical	**10 Hrs./Week**	**Practical**	**5**	**Term Work**	**100 Marks**
				Oral	**50 Marks**

Prerequisites: Project Based Learning, Internship/Mini Project, Laboratory works, Skill Development, Audit Courses, Industrial Visits, Project (Stage I)

Project Stage II is the extension of Project Stage I.

Course Objectives, Course Outcomes, Course Contents and Guidelines for Project Execution are same as that of Project Stage I

Term Work Evaluation

1. In Project Stage II, two reviews shall be taken for total 100 marks (50 marks each)
2. Review III shall be based on the approximate end of fabrication / design validation etc. in front of an expert panel from the department.
3. Review IV shall be third party evaluation by Faculty/Student/Industry person/Alumni
4. Evaluation committee shall consist of Guide, One Industry person and One Faculty appointed by the Institution.
5. Students shall be encouraged to publish a research paper/patent/technical note. Their credential shall be considered while term work evaluation.

Examination Scheme

1. Examination committee shall consist of Internal Examiner and External Examiner appointed by University. (External Examiner shall be a competent Industry/Research/Laboratory person. A list shall be provided by Board of Studies)
2. Well in advance soft copies of the project shall be shared with examination committee.

Presentation of Project Work

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

Project Report

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

Certificate

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

Index of Report

1. Title Sheet
2. Certificate (Institution)
3. Certificate (Company, if sponsored by company)
4. Acknowledgement
5. Abstract of the Project
6. List of Figures
7. List of Photographs / Plates
8. List of Tables
9. Table of Contents
10. Introduction
11. Literature Survey / Theory
12. Design / Experimentation / Fabrication / Production / Actual work carried out for the same
13. Observation Results
14. Discussion on Result and Conclusion
15. Student and Guide details. (A common photograph with project)

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.