

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
	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
		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									

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**.

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 behaviour 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
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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
Pre-requisites: 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 Multi stage 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 DESCRIBES 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 Systems
Multistage or compound system: Need of multi staging, Two stage compression with flash gas removal, flash intercooler and complete multistage compression system Multi evaporator system: 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.	
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 control of 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 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 all year round AC systems, all air system, all water system, air water system, variable refrigerant flow and variable air volume systems, unitary and central air conditioning	
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	
Text Books: 1. Arora C. P., Refrigeration and Air Conditioning, Tata McGraw-Hill. 2. Manohar Prasad, Refrigeration and Air Conditioning, Willey Eastern Ltd, 1983. 3. McQuiston, - Heating Ventilating and air Conditioning: Analysis and Designl 6th Edition, Wiley India. 4. Arora and Domkundwar, Refrigeration & Air Conditioning, Dhanpatrai & Company, New Delhi. 5. Khurmi R.S. and Gupta J.K., Refrigeration and Air conditioning, Eurasia Publishing House Pvt.Ltd, New Delhi,1994. 6. Ballaney P.L., Refrigeration and Air conditioning, Khanna Publishers, New Delhi, 1992. 7. S.N.Sapali , Refrigeration and Air conditioning, Eastern Economy Edition. 8. 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. Threlkeld J.L, Thermal Environmental Engineering, Prentice Hall Inc., New Delhi. 4. Aanatnarayan, Basics of refrigeration and Air Conditioning, Tata McGraw Hill Publications. 5. Roger Legg, Air Conditioning System Design, Commissioning and Maintenance. 6. ASHRAE Handbook (HVAC Equipments) & ISHRAE handbook. 7. Shan Wang, Handbook of Refrigeration and Air Conditioning, McGraw Hill Publications. 8. Wilbert Stocker, Industrial Refrigeration, McGraw Hill Publications. 9. 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 are compulsory)	

1. Test on Ice plant test rig.
2. Performance Simulation of Central Air-conditioning plant using Newton Raphson Method.
3. Test on air-conditioning system for cooling load estimation
4. Performance analysis of Counter flow or cross flow cooling tower. (Theoretical/Practical)
5. Building heat load simulation using suitable software (Trace 700, Energy plus etc.)
6. Design of cold storage with process layout.
7. Analysis of VCC by Cool pack 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

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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, Stability of a two wheel vehicle taking a turn, 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. 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.	
Unit 4	Single Degree of Freedom Systems - Forced Vibrations
Forced vibrations of longitudinal and torsional systems, Frequency Response to harmonic excitation, excitation due to rotating and reciprocating unbalance, base excitation, magnification factor, Force and Motion transmissibility, Quality Factor. Half power bandwidth method, Critical speed of shaft having single rotor of un-damped systems.	
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, Combined rectilinear and angular motion, Vibrations of Geared systems.	
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. William 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 Bhawe, 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 its 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
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
				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; CO 1: VALIDATE impulse moment principle using flat, inclined and curved surfaces and INVESTIGATE performance characteristics of hydraulic turbines. CO 2: DETERMINE performance parameters of impulse and reaction steam turbine along with discussion of nozzles, governing mechanism & losses. CO 3: MEASURE performance parameters of single & multistage centrifugal pumps along with discussion of cavitation and selection. CO 4: 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, Velocity triangles 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 its 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 operating characteristics.
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, performance characteristics 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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402044A: Automobile Design					
Teaching Scheme		Credits		Examination Scheme	
Theory	3 Hrs./Week	Theory	3	In-Semester	30
				End-Semester	70
Prerequisites: Engineering Mathematics-I and II, Systems in Mechanical Engineering, Engineering Mechanics, Theory of Machines, Automobile Engineering , Design of Machine Elements					
Course Objectives: To understand, design and develop modern automobile and e-vehicles.					
Course Outcomes: On completion of the course the learner will be able to; CO1: DESIGN of Principal Engine Components CO2: DESIGN of Drive train CO3: DESIGN of brakes and Suspension					
Course Contents					
Unit 1	Design of Principal Engine Components				
Design of piston, piston ring, piston pin, connecting rod, crankshaft, flywheel, Design of cooling system, Design of fuel system for CI engine, Governor design, Design of carburetor, Design of intake and exhaust system Engine friction and wear, Selection of lubricant, lubricating system, pump and filters.					
Unit 2	Design of Drive train, Axel and Steering				
Design of Drive train: Design of propeller shaft and U-joints, Design of propeller shaft, criteria, failure theories, u-joint design, Design of Final drive and differential, Design of bevel, worm and hypoid type of final drive, differential. Design of axel and Steering: Axle and shaft design, design of fully floating, half floating axle and dead axle, Steering gear and steering mechanism design, geometry for correct steering, linkages.					
Unit 3	Design of brakes and Suspension				
Internal expanding shoe brake, braking condition, friction lining material, mechanical and hydraulic braking system, leaf spring, coil spring, materials, suspension system and linkages, independent suspension.					
Unit 4	Introduction to Hybrid and Electric Vehicles				
Types of EVs, Hybrid Electric Drive-train, Tractive effort in normal driving.					

Electric Drives: Energy consumption Concept of Hybrid Electric Drive Trains, Architecture of Hybrid Electric Drive Trains, Series Hybrid Electric Drive Trains, Parallel hybrid electric drive trains, Electric Propulsion unit, Configuration and control of DC Motor drives, Induction Motor drives, Permanent Magnet Motor drives, switched reluctance motor.	
Unit 5	Energy Source-Battery
Energy Source-Battery: Battery Basics, Different types, Cell Discharge Operation, Cell Charge Operation, Construction, Alternative Batteries, Battery Parameters, Battery Capacity, Discharge Rate, State of Charge, State of Discharge, Depth of Discharge, Technical Characteristics, Practical Capacity, Capacity Redefined, Battery Energy, Constant Current Discharge, Specific Energy, Battery Power, Specific Power, Battery Pack Design, Ragone Plots, Targets and Properties of Batteries, Battery Modeling, Constant Current Discharge Approach, Fractional Depletion Model, Standard Driving Cycles , Power Density Approach. Design and Application of the Battery Management System: The Functions and Architectures of a Battery Management System, Architecture of the Battery Management System, High-voltage battery management systems (BMS) for electric vehicles, Cell balancing, battery state estimation, and safety aspects of battery management systems for electric vehicles, Thermal management of batteries for electric vehicles.	
Unit 6	Fuel Cell Vehicles
Operating Principles of Fuel Cells, Fuel Cell Technologies, Fuel Supply, Nonhydrogen Fuel Cells, Fuel Cell Hybrid Electric Drive Train Design, Configuration, Control Strategy, Parametric Design.	
Books	
Text Books: 1. Thomas D. Gillespie, "Fundamentals of Vehicle Dynamics", 2013, Society of Automobile Engineers Inc., 2. Engine Design – Giles J. G., Liffle Book Ltd. 3. Engine Design – Crouse, Tata McGraw Publication, Delhi. 4. Design of Automotive Engine – A. Kolchin and V. Demidov 5. Modern Electric, Hybrid Electric, and Fuel Cell Vehicles, Muhammad H. Rashid, Series Editor University of West Florida	
References Books: 1. Emadi, A. (Ed.), Miller, J., Ehsani, M., “Vehicular Electric Power Systems” Boca Raton, CRC Press, 2003, 2. Husain, I. “Electric and Hybrid Vehicles” Boca Raton, CRC Press, 2010. 3. Larminie, James, and John Lowry, “Electric Vehicle Technology Explained” John Wiley and Sons, 2012. 4. Tariq Muneer and Irene IllescasGarcía, “The automobile, In Electric Vehicles: Prospects and Challenges”, Elsevier, 2017. 5. Sheldon S. Williamson, “Energy Management Strategies for Electric and Plug-in Hybrid Electric Vehicles”, Springer, 2013	

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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, Design 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>

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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>

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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, CRC Press, 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>

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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 ₂ M) communications, Cyber-Physical-Systems (CPS)), IoT Vs M ₂ M, 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, I₂C), 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 M₂M in IoT, M₂M Value Chains, IoT Value Chains, M₂M 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 Expressif 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>

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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>

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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.	

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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. Thermo 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, Merritt, 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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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. Amit Bandyopadhyay, Susmita Bose, “Additive manufacturing”, CRC Press, Taylor & Francis Group, 2016 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, Filemon Schöffner & 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 Schöffner & 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. Sajan Kapil, 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”, Dr. Janakarajan Ramkumar Prof. Amandeep Singh, https://onlinecourses.nptel.ac.in/noc20_me50/preview	

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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 Criteria, 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/>

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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>

Savitribai Phule Pune University
Board of Studies - Mechanical and Automobile Engineering
Undergraduate Program – Final Year Mechanical Engineering (2019 pattern)

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: <i>Predictive Analytics:</i> 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.

Savitribai Phule Pune University
Board of Studies - Mechanical and Automobile Engineering
Undergraduate Program – Final Year Mechanical Engineering (2019 pattern)

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

4. Study projects are strictly allowed.
Project Lab
- There has to be a Project Lab in the department. - It consists of necessary tools required to do a project. - Previous projects and their components. - Common measuring instruments. - Previous years' project reports. - Project related books and Publications. - Proper linkage with central workshop and various laboratories. - Safety measures. - All the project activities must be handled with a digital platform which is developed in the department according to the policies laid down by the institution. Respective authority levels created to maintain the transparency and confidentiality.
Books and other resources
References Books: Dissertations and Project Reports: A Step by Step Guide by Dr Stella Cottrell.
Web References: - SWAYAM-NPTEL Course. - MOOCs' Courses.
Guidelines for Project Execution:
At the end of the 6th Semester - Students will make groups according to their suitability. - Department faculty will float prospective Project Titles through Project Coordinator. - Department will take care of a list of titles at least two times of the groups. - Students will interact with guides for scope and outline of the project. - Maximum of two groups will be given to a guide. - Guide and Project groups will be finalized at the end of sixth semester so that project work can be started at the start of Seventh semester. During the 7th Semester - Project work is expected to be done in the Project Lab. - Projects must be executed in association with industrial experts/facilities. - Progress of project work is monitored regularly on weekly project slots/project day. - Regular interval presentations are to be arranged to review and assess the work. - Project work is monitored and continuous assessment is done by guide and authorities.
Term Work:
- The student shall prepare the duly certified final report of project work in standard format for satisfactory completion of the work by the concerned guide and head of the Department/Institute. - Recommended performance measure parameters may Include-Problem definition and scope

of the project, Literature Survey, Appropriate Engineering approach used, Exhaustive and Rational Requirement Analysis, ● Comprehensive Implementation - Design, modeling, documentation, Usability, Optimization considerations (Time, Resources, Costing), Thorough Testing, Project Presentation and Demonstration (ease of use and usability), Social and environment aspects. ● The term work under project submitted by students shall include 1. Work Diary: Work Diary maintained by group and countersigned by the guide weekly. The contents of work diary shall reflect the efforts taken by project group for a. Searching suitable project work b. Brief report preferably on journals/ research or conference papers/ books or literature surveyed to select and bring up the project. c. Brief report of feasibility studies carried to implement the conclusion. d. Rough Sketches/ Design Calculations e. Synopsis ● The group should submit the synopsis in the following form. i. Title of Project ii. Names of Students iii. Name of Guide iv. Relevance v. Present Theory and Practices vi. Proposed work vii. Expenditure viii. References ● The synopsis shall be signed by each student in the group, approved by the guide (along with external guide in case of sponsored projects) and endorsed by the Head of the Department ● Presentation: The group has to make a presentation in front of the faculty of department at the end of semester.
Examination Scheme: ● During university examination Internal examiner (preferably the guide) and External examiners jointly, evaluate the project work. ● During the process of monitoring and continuous assessment & evaluation the individual and team performance is to be measured. ● The project term work shall be evaluated on the basis of reviews. In first semester two reviews are to be taken and evaluated for total 30 marks (15 marks each) ● Review 1 and 2 will be based on synopsis submission (team members, Title of the Project Work, abstract, Problem Definition, work done earlier, Objectives of the Project, Methodology of the Project, Application / Significance of the Project, Duration of 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 40 marks ○ 10 marks for presentation for group, ○ 15 marks for quality of the project work. ○ 15 marks for quality of the project report

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

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Board of Studies - Mechanical and Automobile Engineering
Undergraduate Program – Final Year Mechanical Engineering (2019 pattern)

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 ₂ M 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 beneficiation, 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
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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
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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
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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, 1 and 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.	

Savitribai Phule Pune University
Board of Studies - Mechanical and Automobile Engineering
Undergraduate Program – Final Year Mechanical Engineering (2019 pattern)

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 (Numericals): 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 Trigeration	
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
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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

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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-Hill
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/
6. https://onlinecourses.nptel.ac.in/noc22_ma44/

Savitribai Phule Pune University
Board of Studies - Mechanical and Automobile Engineering
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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., Hindmarsh, 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
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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>

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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 Multibody 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

References Books:

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

Web References:

- <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 fundamentals, 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 gimbaled, 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.

References Books:

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>

Web References:

India_2020_Energy_Policy

https://iea.blob.core.windows.net/assets/2571ae38-c895-430e-8b62-bc19019c6807/India_2020_Energy_Policy_Review.pdf

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

Savitribai Phule Pune University
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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 Transducers, 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/Eulerian/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:

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

Savitribai Phule Pune University
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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 its 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, Industrial Psychology, New Age Publication, 2010. 2. Michael Aamodt, Organizational/ Industrial Psychology, Wadsworth Cengage Learning, 2010 3. Robbins, S.P. Organizational Behaviour. Prentice-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. Robbins & 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 India Ltd. 6. Muchinsky (2009). Psychology applied to work. New Delhi: Cengage. 7. Griffin, Ricky W: Organizational Behaviour, Houghton Mifflin co., Boston. 8. Ivancevich; John and Micheel 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:

1. <http://nptel.ac.in/cour ses/110105034/1>
2. <http://nptel.ac.in/cour ses/110105034/6>
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
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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/>

Savitribai Phule Pune University
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 Undergraduate Program – Final Year Mechanical Engineering (2019 pattern)

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.

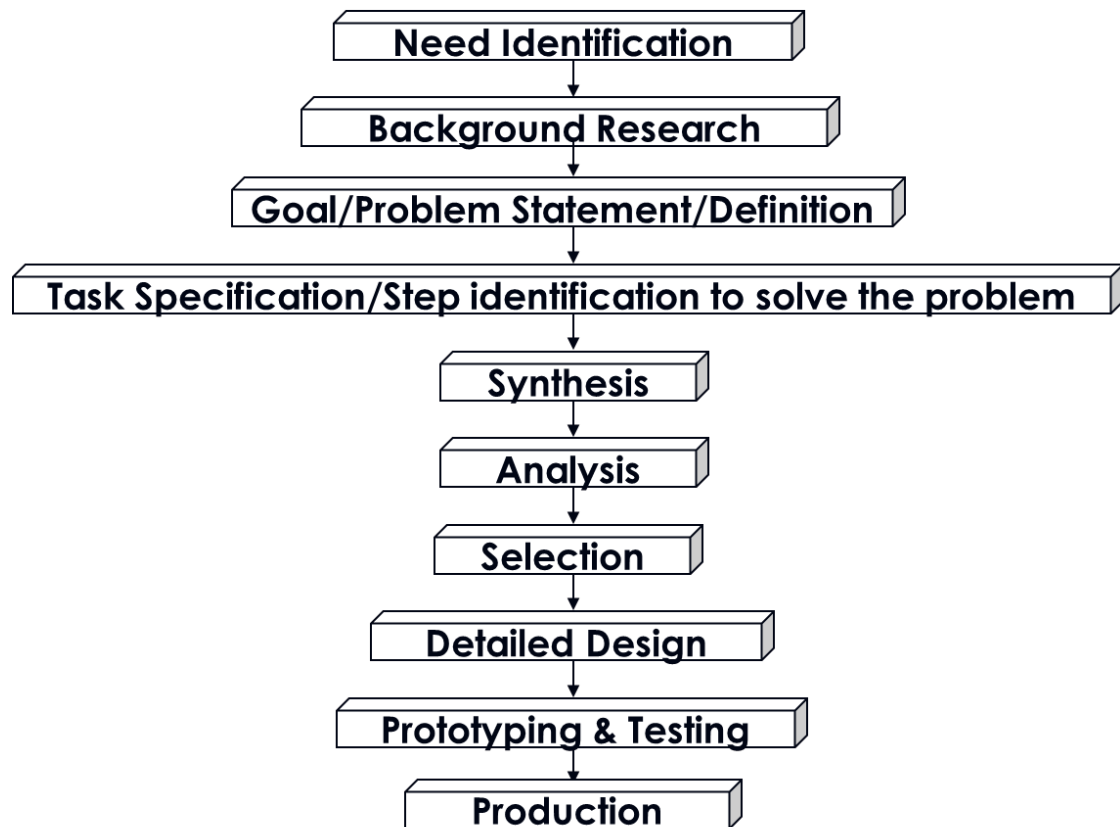
TERM WORK:

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

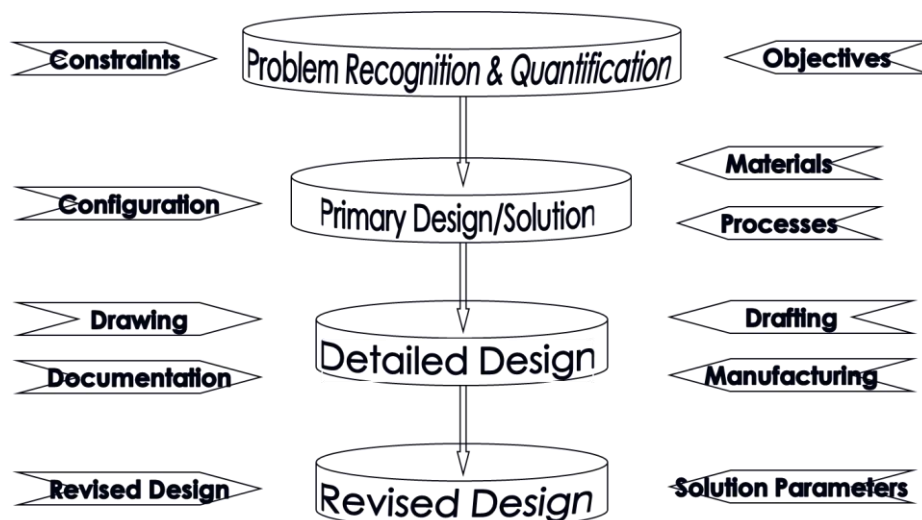
A) Product based Case study

- **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.

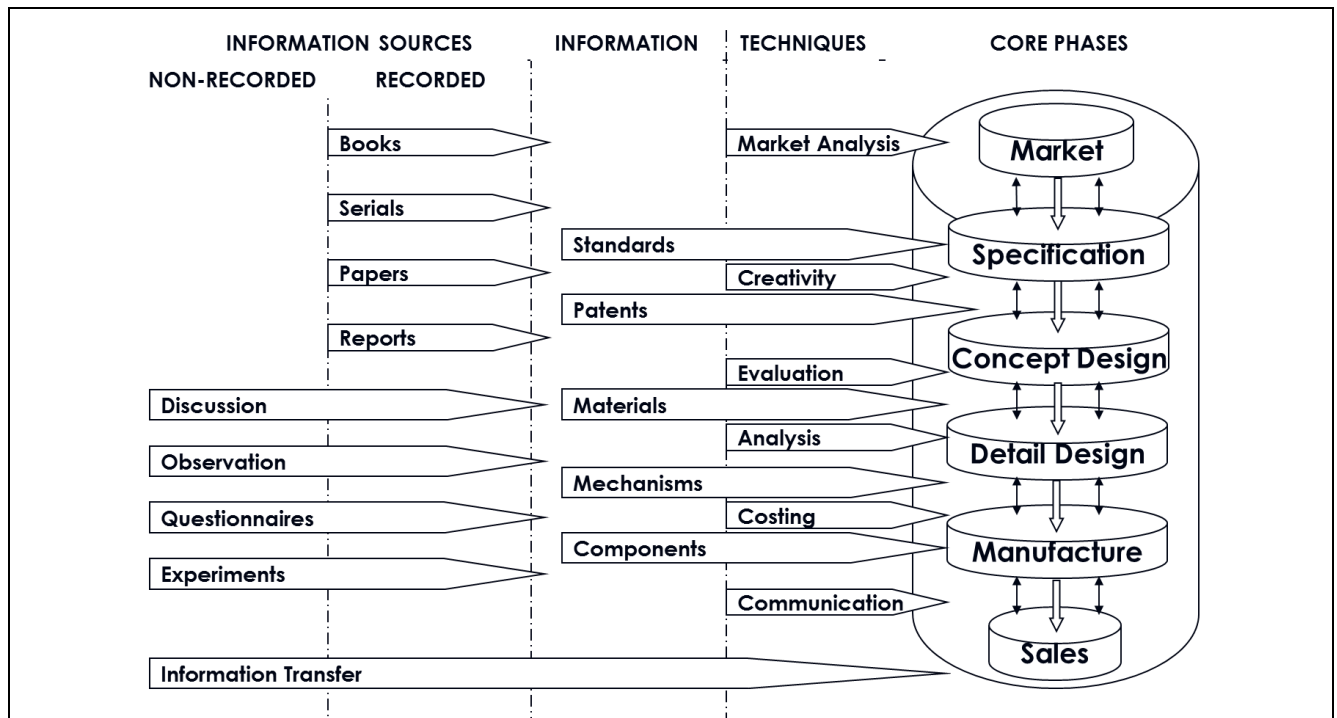
- Product Systems Analysis must follow following approach for developing the final prototype (Hardware, Software and Services).



- 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 (Blasius 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. Nikraves, 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.

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402053: Project (Stage II)					
Teaching Scheme		Credits		Examination Scheme	
Practical	12 Hrs./Week	Practical	6	Term Work	100 Marks
				Oral	50 Marks
Prerequisites: Project Based Learning, Internship/Mini Project, Project (Stage I)					
Course Objectives: 1. To provide an opportunity of designing and building complete system or subsystems based on areas where the student likes to acquire specialized skills. 2. To obtain hands-on experience in converting a small novel idea / technique into a working model / prototype involving multi-disciplinary skills. 3. To embed the skill in a group of students to work independently on a topic/ problem/ experimentation selected by them and encourage them to think independently on their own to bring out the conclusion under the given circumstances of the curriculum period in the budget provided with the guidance of the faculty. 4. To encourage creative thinking processes to help them to get confidence by planning and carrying out the work plan of the project and to successfully complete the same, through observations, discussions and decision making process. 5. To get visibility in industry to Project and Project group					
Course Outcomes: On completion of the course the learner will be able to; CO1. Implement systems approach. CO2. To conceptualize a novel idea / technique into a product. CO3. To think in terms of a multi-disciplinary environment. CO4. To take on the challenges of teamwork, and document all aspects of design work. CO5. To understand the management techniques of implementing a project.					
Course Contents					
Extended part of Project Stage I					
Guidelines for Project Execution					
1. Refer Project stage I guidelines.					
Term Work Evaluation					
1. In Project Stage II, two reviews are to be taken for total 80 marks (40 marks each) 2. Review III shall be based on the approximate end of fabrication / design validation etc. in front of an expert panel from the department.					

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

Examination Scheme

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

Presentation of Project Work

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

Project Report

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

Certificate

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

Index of Report

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