UNIVERSITY OF MUMBAI

Bachelor of Engineering

in

Production Engineering

Second Year with Effect from AY 2020-21

Third Year with Effect from AY 2021-22

Final Year with Effect from AY 2022-23

(REV- 2019 'C' Scheme) from Academic Year 2019 – 20

Under

FACULTY OF SCIENCE & TECHNOLOGY

(As per AICTE guidelines with effect from the academic year 2019–2020)

AC- 29/06/2021
Item No. 6.6

UNIVERSITY OF MUMBAI

Syllabus for Approval

Sr. No.	Heading	Particulars
1	Title of the Course	Third Year B.E. Production Engineering
2	Eligibility for Admission	After passing second year Engineering as per Ordinance 0.6243
3	Passing Marks	40%
4	Ordinances / Regulations (if any)	Ordinance 0.6243
5	No. of Years / Semesters	8 semester
6	Level	U.G.
7	Pattern	Semester
8	Status	Revised
9	To be implemented from Academic Year	With effect from Academic Year: 2021-22

Dr. S. K. Ukarande
Associate Dean
Faculty of Science and Technology
University of Mumbai

Dr. Anuradha Muzumdar
Dean
Faculty of Science and Technology
University of Mumbai

Preamble

To meet the challenge of ensuring excellence in engineering education, the issue of quality needs to be addressed, debated and taken forward in a systematic manner. Accreditation is the principal means of quality assurance in higher education. The major emphasis of accreditation process is to measure the outcomes of the program that is being accredited. In line with this Faculty of Science and Technology (in particular Engineering)of University of Mumbai has taken a lead in incorporating philosophy of outcome based education in the process of curriculum development.

Faculty resolved that course objectives and course outcomes are to be clearly defined for each course, so that all faculty members in affiliated institutes understand the depth and approach of course to be taught, which will enhance learner's learning process. Choice based Credit and grading system enables a much-required shift in focus from teacher-centric to learner-centric education since the workload estimated is based on the investment of time in learning and not in teaching. It also focuses on continuous evaluation which will enhance the quality of education. Credit assignment for courses is based on 15 weeks teaching learning process, however content of courses is to be taught in 12-13 weeks and remaining 2-3 weeks to be utilized for revision, guest lectures, coverage of content beyond syllabus etc.

There was a concern that the earlier revised curriculum more focused on providing information and knowledge across various domains of the said program, which led to heavily loading of students in terms of direct contact hours. In this regard, faculty of science and technology resolved that to minimize the burden of contact hours, total credits of entire program will be of 170, wherein focus is not only on providing knowledge but also on building skills, attitude and self learning. Therefore in the present curriculum skill based laboratories and mini projects are made mandatory across all disciplines of engineering in second and third year of programs, which will definitely facilitate self learning of students. The overall credits and approach of curriculum proposed in the present revision is in line with AICTE model curriculum.

The present curriculum will be implemented for Third Year of Engineering from the academic year 2021-22. Subsequently this will be carried forward for Final Year Engineering in the academic year 2022-23.

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Incorporation and implementation of Online Contents from NPTEL/ Swayam Platform

The curriculum revision is mainly focused on knowledge component, skill based activities and project based activities. Self learning opportunities are provided to learners. In the revision process this time in particular Revised syllabus of 'C ' scheme wherever possible additional resource links of platforms such as NPTEL, Swayam are appropriately provided. In an earlier revision of curriculum in the year 2012 and 2016 in Revised scheme 'A' and 'B' respectively, efforts were made to use online contents more appropriately as additional learning materials to enhance learning of students.

In the current revision based on the recommendation of AICTE model curriculum overall credits are reduced to 171, to provide opportunity of self learning to learner. Learners are now getting sufficient time for self learning either through online courses or additional projects for enhancing their knowledge and skill sets.

The Principals/ HoD's/ Faculties of all the institute are required to motivate and encourage learners to use additional online resources available on platforms such as NPTEL/ Swayam. Learners can be advised to take up online courses, on successful completion they are required to submit certification for the same. This will definitely help learners to facilitate their enhanced learning based on their interest.

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Preface By BoS

Engineering education in India is changing fast and is set to face multiple challenges in the near future. Academic institutes are expected to prepare good quality engineers and Industries are expected to come goodwith the wealth generation activity. Manufacturing, among the industry sectors, is currently emerging as oneof the high growth sectors in India. Government of India (GOI) has launched the 'Make in India' program to place India on the world map as a manufacturing hub. The GOI has set an ambitious target of increasing the contribution of manufacturing output to 25% of GDP by 2022, from the current 16 %. In this context, the major challenge is to ensure high quality in all aspects related to education & industry practices. Accreditation of the program is one of the principal ways, by which the quality can be assured. The major emphasis of the accreditation process is to measure the outcomes of the program that is being accredited. Program outcomes are essentially a range of skills and knowledge that a student will have at the time of graduation. Keeping this in mind, the Faculty of Science and Technology of the University of Mumbai has taken the lead in ensuring that the outcome based education is stressed upon in the curriculum development.

At the Board of Studies (Adhoc) in Production Engineering of the University of Mumbai, we are happy to statethat, the Program Educational Objectives (PEOs) of the UG Program in Production Engineering, were discussed in detail and finalized during the multiple brain storming sessions, attended by more than 20 members from different colleges affiliated to the University of Mumbai. Experts from the industry were also invited for their inputs and suggestions. Thus the PEOs were finalized as follows:

To prepare the Learner with sound foundation in STEM subjects, related to Manufacturing and its strategies.

To motivate the Learner for self-learning and to use modern tools for solving real life problems.

To inculcate a professional and ethical attitude, good leadership qualities and commitment to social responsibilities in the Learner's thought process.

To prepare the learner to face industrial challenges through practical exposure in an industrial environment.To prepare the Learner for a successful career in Indian and Multinational Organizations.

In addition to PEOs, for each course of the program, objectives and expected outcomes from a learner's point of view are also included in the curriculum to achieve the goal of outcome based education. We hopeto achieve the desired goals in our efforts to prepare high quality Production Engineers. Thank you very much.

Board of studies (Adhoc) in Production Engineering
Dr. Hari Vasudevan – Chairman
Dr. Arun Rane – Member
Dr. Yogesh Padia – Member
Dr. K. H. Inamdar

Semester VI

Course Code	Course Name	Teaching Scheme (Contact Hours)		Credits Assigned		
		Theory	Pract. Tut.	Theory	Pract.	Total
PEC601	Process Engineering	3	--	3	--	3
PEC602	Machine Design - II	3	--	3		3
PEC603	Industrial Engineering	3	--	3	--	3
PEC604	Operation Research	3	--	3	--	3
PEDO601X	Department Optional Course – 2	3	--	3	--	3
PEL601	Process Engineering lab.	--	2	--	1	1
PEL602	Machine Design - II Lab.	--	2	--	1	1
PEL603	Additive Manufacturing Lab.	--	2	--	1	1
PEL604	Data Analytics Lab.		2	--	1	1
PEM601	Mini Project – 2 B	--	4$	--	2	2
Total		**15**	**12**	**15**	**06**	**21**

Course Code	Course Name	Examination Scheme							
		Theory					Term Work	Prac /oral	Total
		Internal Assessment			End Sem Exam	Exam. Duration (in Hrs)			
		Test1	Test2	Avg					
PEC601	Process Engineering	20	20	20	80	3	--	--	100
PEC602	Machine Design - II	20	20	20	80	3	--	--	100
PEC603	Industrial Engineering	20	20	20	80	3	--	--	100
PEC604	Operation Research	20	20	20	80	3	--	--	100
PEDO6PEX	Department Optional Course – 2	20	20	20	80	3	--	--	100
PEL601	Process Engineering lab.	--	--	--	--	--	25	25	50
PEL602	Machine Design - II Lab.	--	--	--	--	--	25	25	50
PEL603	Additive Manufacturing Lab.	--	--	--	--	--	25	--	25
PEL604	Data Analytics Lab.	--	--	--	--	--	25	--	25
PEM601	Mini Project – 2 B	--	--	--	--	--	50	--	50
Total		**--**	**--**	**100**	**400**	**--**	**150**	**50**	**700**

$ indicates work load of Learner (Not Faculty) for Mini Project.

Students group and load of faculty per week.

Mini Project 2B:
Students can form groups with minimum 2 (Two) and not more than 4 (Four).
Faculty Load: 1 hour per week per four groups.

PEDO601X	**Department Optional Course – 2**
PEDO6011	Internal Combustion Engineering
PEDO6012	Refrigeration & Air Conditioning
PEDO6013	Rapid prototyping & Manufacturing
PEDO6014	Logistics and Supply Chain Management
PEDO6015	Maintenance Engineering.

Course Code	Course Name	Credits
PEC 601	Process Engineering	03

Objectives

1. To familiarize with the significance of process engineering with its relevance to manufacturing operations.
2. To prepare a skills in preparing machining sequence and estimate manufacturing time.
3. To acquaint with the significance and control of tolerance in design & manufacturing.
4. To appraise with basics of process and operation planning.

Outcomes: Learner will be able to:

1. Determine machine sequences to cater to the manufacturing requirements.
2. Analyse part prints.
3. .Prepare tolerance control charts with its balancing.
4. Design work holding devices for consistent positioning of work piece in relation to the tool.
5. Prepare process picture, process routing/process sheets.
6. Design cams for part production on single spindle automats.

Detailed Syllabus: (Module wise)		
Module No.	**Description**	**Duration**
01	**Process Engineering** Differentiation between Product Engineering and Process Engineering. Role of process engineering in a manufacturing setup, organization chart, functions of process engineering. Determining machining sequences - criteria and manufacturing sequence.	**04**
02	**2.1Preliminary Part Print Analysis** General characteristics, determining the principal processes, alternate processes, functional surfaces of the work piece, areas for processing, nature of work to be performed, finishing and identifying operations, case study for understanding preliminary part print analysis. **2.2 Work piece control** Causes of work-piece variations, variables influencing work-piece control, work piece control techniques - Equilibrium theories, concept of location, geometric control, dimensional control, mechanical control, alternate location theory.	**08**
03	**Tolerance Design** **Dimensional Analysis:** Types of dimensions, concept of baseline dimension, basic geometric dimensioning and tolerance (GD & T). **Tolerance Analysis**: Rules for adding and subtracting tolerance, tolerance stacks, design and process tolerance stacks, tolerance chart, purpose and use of tolerance chart, definitions and symbols, determining lay−out of tolerance chart, stock removal, constructing and balancing of tolerance chart.	**06**

04	**Process planning** 4.1 Classifying operations (Study of Basic Processes Operations, Principal Processes and Auxiliary Processes, identification of major, critical, qualifying, re-qualifying and supporting operations), product and process critical area, selection of equipment and Tooling. **4.2 Computer Aided Process Planning (CAPP):** CAPP -variant approach and generative approach.(Detail)	**06**
05	**5.1 Operation Planning** Process plan sheet design for complete manufacturing part with details of sequence of operations, machine or equipment used, Process pictures, machining parameters i.e. cutting speed, feed, depth of cut, tooling and gauge details, cutting tools specifications and gauge details, machining time calculations. Tool layout for turning on production lathe. **5.2 Other aspects of Process Engineering** Introduction to high speed machines, SPM, transfer line and other mass production machines-Elementary treatment only, in-process gauging and multiple gauging. ERP SOFTWARE (PPC module -only introduction).	**09**
06	**Cam Design for Automat** Automats major classification and types, tools and tool holders. Single spindle automats and its tooling, tool layout and cam design for part production on Single spindle automat.	**06**

Assessment:
Internal Assessment for 20 marks:
Consisting **Two Compulsory Class Tests**

1. First test based on approximately 40% of curriculum contents and second test based on remaining contents (approximately 40%, but excluding contents covered in Test I).
2. Total duration allotted for writing each of the paper is 1 hr.
3. Average of the marks scored in both the two tests will be considered for final grading.

End Semester Examination:
Weightage of each module in end semester examination will be proportional to the number of respective lecture hours mentioned in the curriculum.

1. Question paper will comprise of total **six questions**, **each carrying 20 marks.**
2. **Question 1** will be **compulsory** and should **cover maximum contents of the curriculum.**
3. **Remaining questions will be mixed in nature** (for example if Q.2 has part (a) from module 3 then part (b) will be from any module other than module 3).
4. Only **Four questions need to be solved.**

Reference Books:

1. Process Engineering for Manufacturing, Donald F. Eary and Gerald E. Johnson, Prentice-Hall, Inc
2. Production Technology, HMT.
3. Manufacturing Engineering. Danilevsky, Mir publication.
4. Tolerance Design and Analysis, Wade.
5. Fundamentals of Manufacturing Engineering, V.M. Kovan et al, Mir Publications.
6. HSS and Carbide Tool Catalogues for Turning, Drilling, Milling etc. from Tool manufacturer.
7. Westerman Tables for the Metal Trade, Wiley, Eastern Limited.
8. PMT Catalogue Traub Automat.

Course Code	Course Name	Credits
PEC 602	Machine Design - II	03

Objectives:

1. To familiarize with the constructional & design features of machine tool structures like bed, columns, slide ways/guideways and mechanical drives.
2. To prepare for skills in designing variable speed gear boxes, bearings, power screws, clutches etc. used in machine tools.
3. To acquaint with the usage of standards & hand books and retrieve relevant data from these for designing/selection of machine tool components.
4. To appraise about safety and safety standards pertaining to machine tools.
5. To acquaint with the recommended procedure of carrying out acceptance tests on machine tools & their significance.

Outcomes: Learner will be able to:

1. Design machine tool structures, drive elements/drives.
2. Design speed and feed gear boxes.
3. Design power screws and clutches.
4. Design bearings.
5. Demonstrate the requirements like maintaining of expected accuracy levels, parametric optimization, managing wear and tear problems.
6. Illustrate the safety aspects/ acceptance tests in machining tools.

Detailed Syllabus: (Module wise)		
Module No.	**Description**	**Duration**
01	**ELEMENTS OF MACHINE TOOLS** **1.1**Types and capabilities of various machine tools. General purpose and special purpose machine tools. Design requirements of machine tools. **1.2. Design of machine tool structures :-** **1.2.1Bed and Columns**- Design criteria for machine tool structures, Materials of construction, Profiles, Factors affecting Static and dynamic stiffness. Methods of enhancing rigidity. Design considerations for beds. .Machine tool bed cross-sections like lathe bed. Design considerations for columns, column sections. **1.2.2 Machine tool guideways** - Classification of guideways, Materials of construction, Slideway profiles, Clearance adjustment and wear compensation techniques, Fundamentals of hydrostatic guideways. Types of antifriction guideways. Design of guideways for wear and stiffness. **1.3 Design of Power Screws** Design of power screws- Materials of construction, power screw profiles and selection, backlash adjustments, design of machine tool power screws based on strength, buckling and stiffness, power requirements and efficiency, mounting of power screws, Elementary treatment on ball recirculating power screws.	**08**

02	**DESIGN OF MECHANICAL DRIVES:** **2.1 Design of belt drives** - Design of belts, belt materials, belt types:- specification and selection, types of pulleys and design of pulleys. *(Only design procedure)* **2.2 Design of gear drives** - Types of gears, materials, application, and selection. Design of spur gears - Design on the basis of beam strength (Lewis's equation), Design on the basis of wear and fatigue (Buckingham's Equation) **2.3 Design of chain drives**- Types of chains and sprockets. Principles of designing sprockets and roller chains. Design of chain drives- Types of chains and sprockets. Principles of designing sprockets and roller chains. *(Only design procedure)*	**06**
03	**DESIGN OF SPEED AND FEED BOXES** **3.1 Design of gear boxes**: Stepped and Stepless speed outputs, selection of spindle speed ranges, construction of structural, speed, gearing & deviation diagrams, layout of speeds on geometric progression, kinematic advantages of geometric progression series, selection of values of common ratio, Design of gear boxes for feed and speeds having 2−3 stages and 4−12 speeds. **3.2 Stepless drives** : Mechanical stepless drives − single disc, double disc and cone disc transmissions, speed regulation by epicyclic gear train, positive infinitely variable drives (PIV drives) − Kopp's , Meander and Svetozarav'sdrives. **3.3 Feed boxes**: Quadrant change gear mechanism, speed boxes with gear cone and sliding key, Norton gear drive, Meander gear drives, gear boxes with clutched drive, Schopke drive and Ruppert drive.	**12**
04	**DESIGN OF CLUTCHES** Design considerations, materials of clutch plates & linings. Running conditions- wet & dry. Design of plate clutches. Single and multi-plate clutches involving design of clutch plates, springs & operating lever.	04
05	**DESIGN OF MACHINE TOOL BEARINGS** Bearing materials & their characteristics. Types of bearings- selection & application. **5.1 Design of ball & roller bearings**: Bearing designation (ISI, ISO, SAE, and SKF). Calculation of equivalent load, cubic mean load, static & dynamic load bearing capacities. Selection of ball & roller bearing from handbook. Mounting & maintenance of bearings. **5.2 Design of journal bearings:** Terminology. Theory of lubrication, bearing characteristic Number, Sommerfield Number, calculations involving bearing dimensions, clearance, coefficient of friction, heat generated, and heat dissipated and power lost in friction. Mounting & maintenance of bearings.	**06**
06	**SAFETY OF MACHINE TOOLS & ACCEPTANCE TESTS** **6.1Safety of machine tools:** Concepts, various safety devices incorporated in machine tools to safeguard safety of man, tools and equipment. Interlocked, fool proof safety systems. Introduction to safety standards. **6.2 Acceptance tests on machine tools:** Significance, performance and geometrical tests on machine tools. **6.3 Vibrations in machine tools:** Elementary concepts about factors contributing to vibrations, vibration detection and measurement, remedial approaches	**03**

NOTE: Use of standard design data books like PSG Data Book or Design Data book by Mahadevan is permitted at the examination and shall be supplied by the college

Assessment:

Internal Assessment for 20 marks:
Consisting **Two Compulsory Class Tests**

1. First test based on approximately 40% of curriculum contents and second test based on remaining contents (approximately 40%, but excluding contents covered in Test I).
2. Total duration allotted for writing each of the paper is 1 hr.
3. Average of the marks scored in both the two tests will be considered for final grading.

End Semester Examination:
Weightage of each module in end semester examination will be proportional to the number of respective lecture hours mentioned in the curriculum.

1. Question paper will comprise of total **six questions**, **each carrying 20 marks.**
2. **Question 1** will be **compulsory** and should **cover maximum contents of the curriculum.**
3. **Remaining questions will be mixed in nature** (for example if Q.2 has part (a) from module 3 then part (b) will be from any module other than module 3).
4. Only **Four questions need to be solved.**

Reference Books:

1. Principles of machine tools, Sen and Bhattacharya, New Central Book Agency.
2. Machine tool design and Numerical Control, N. K. Mehta, Tata McGraw Hill.
3. Machine tool Engineering, G R Nagpal, Khanna Publishers.
4. Design of Machine tool, S.K. Basu and D. K. Pal, Oxford and IBH publishing Co.
5. The design and construction of machine tools, H. C. Town.
6. Machine tool design hand book: Central Machine Tool Research Institute, Bangalore. Tata McGraw Hill.
7. PSG Design Data book: PSG College of engineering and technology, Coimbatore.
8. Machine Tool Design (Volume 3), (English, Paperback, V. Vermakov, N. Acherkan, Nicholas Weinstein).
9. Machine Tool Structures: Vol.1, by F. Koenigsberger, J. Tlusty .

Course Code	Course Name	Credits
PEC 603	Industrial Engineering	03

Objectives:

1. To prepare for understanding of the role of Industrial Engineering in the overall business strategy of the firm.
2. To prepare for understanding of the interdependence of the operating system with other key functional areas of the firm.
3. To familiarize with the key factors and interdependence of these factors in the design of effective operating systems.
4. To prepare for identification and evaluation of tools appropriate for analysis of operating systems of the firm.
5. To familiarize with the application of production and operations management policies and techniques to the service sector as well as manufacturing firms.

Outcomes: Learner will be able to...

1. Analyze implications of Industrial Engineering in industries.
2. Demonstrate the role of Production Management in creating competitive advantage for business organizations.
3. Analyze various constituents of production operations in manufacturing and service.
4. Plan and control various production related activities.
5. Illustrate various inventory management procedures with the tools employed there in.
6. Demonstrate role of JIT, MRP, and ERP with their contribution towards Industrial Engineering.

Detailed Syllabus: (Module wise)		
Module No.	**Description**	**Duration Hrs**
01	**Introduction to Industrial Engineering:** Industrial Engineering in the modern world, techniques and objectives of Industrial Engineering. **Production and Productivity:** Definition and comparison, productivity measurements, factors influencing productivity. Productivity Improvement techniques likes 5s, Poka-Yoke, Kaizen, Kanban, Quality Improvement Techniques like QFD, FMEA, Ishikawa diagram, SMED, SQC tools.	**05**
02	**Work System Design:** Inter disciplinary nature of ergonomics, modern ergonomics, human performance, information processing, factors affecting human performance, physical workload and energy expenditure. Workspace Design, Anthropometry, workspace design for standing and seated workers, Arrangements of components within a physical space, Application of Ergonomics in automobiles **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.	**07**
03	**Value Engineering and Value Analysis:** Distinction between value engineering & value analysis and their Significance. Steps in value engineering & analysis, function analysis system techniques- FAST diagram with Case studies.	**06**
04	**Facility Location:** The need for location decision, Procedure for making location decisions, Factors affecting location decisions, Methods of evaluating location decisions. **Facility Layout / Plant Layout:** Types of Layout, Significance and Factors influencing layout choices, Principles of Plant layout, Concepts of Group Technology and Cellular Manufacturing, Computerized Layout Techniques.	**07**

	Materials Handling: Function, Importance and Objectives of Material Handling, Material handling Principles, Types of Material Handling Systems, Selection of Material Handling Equipment.	
05	**Inventory Management:** Nature, Importance, Classification and Functions of Inventory, Inventory Costs, Importance of Inventory Management, Inventory Control System for Dependent Demand and Independent Demand, Inventory Ordering Systems. Inventory Control subject to Known Demand. The EOQ Model, Extension to Finite Production Rate, Quantity Discount Model**.**	**08**
06	Material Requirement Planning (MRP), Manufacturing Resource Planning (MRP II), Enterprise Resource Planning (ERP), Just in Time Manufacturing, Lean Production, Agile Manufacturing, Line Balancing, Sustainable Production and Green Manufacturing.	**06**

Assessment:
Internal Assessment for 20 marks:
Consisting **Two Compulsory Class Tests**

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1. Question paper will comprise of total **six questions**, **each carrying 20 marks.**
2. **Question 1** will be **compulsory** and should **cover maximum contents of the curriculum.**
3. **Remaining questions will be mixed in nature** (for example if Q.2 has part (a) from module 3 then part (b) will be from any module other than module 3).
4. Only **Four questions need to be solved.**

Reference Books:

1. *Production and Operations analysis by Steven Nahmia , McGraw-Hill / Irwin publication*
2. *Facilities Planning* 4th Edition by James A. Tompkins, John Wiley and Sons Inc.
3. *Elements Of Production Planning And Control* by Eilon, Samuel, New York: Macmillan
4. Production Planning and Control by Prof. Jhamb L.C. by Everest Publishing House
5. *Production (Operations) Management* by Prof. Jhamb L.C. by Everest Publishing House
6. *Inventory Management* Prof. Jhamb L.C. by Everest Publishing House
7. *Operations Management*- an Integrated Approach 5th Edition by R. Dan Reid, Wiley
8. *Production and Operations Management* by R. Panneer selvam, Prentice-Hall Of India
9. *Operations Management for Competitive Advantage* by Richard B. Chase, MGH
10. *Orlicky's Material Requirements Planning*, by Carol Ptak, McGraw Hill.
11. *Enterprise resource planning*: *concepts and practice* by Vinod kumar Garg PHI Learning
12. *Lean Thinking: Banish Waste and Create Wealth in Your Corporation*, by James P. Womack, Free Press
13. *Toyota Production System: An Integrated Approach to Just-In-Time,* by Yasuhiro Monden ,CRC PRESS

Course Code	Course Name	Credits
PEC 604	Operation Research	03

Objectives:

1. To familiarize the students with various tools of optimization for management of various resources.
2. To acquaint the students with various simulation tools for optimization for various resources.

Outcomes: Learner will be able to:

1. Utilize the resources in various industries optimally.
2. Apply the concept of linear programming for solving specialized problems on transportation, assignments & sequencing.
3. Apply principles of queuing, replacement & game theory models to solve real life problems.
4. Demonstrate the concept of dynamic programming in modeling and solving problems.
5. Illustrate different types of simulation models applicable to Inventory/queuing.
6. Acquire skills in identifying & applying cost effective strategies in managing of manufacturing projects.

Detailed Syllabus: (Module wise)		
Module No.	**Description**	**Duration**
01	**Linear Programming:** Linear Programming Problem: Formulation, Graphical solution, Simplex method, Big−M method, Two−phase method, Principle of Duality, Dual Simplex, and Sensitivity Analysis. **Transportation problem:** Formulation - Optimal solution, Degeneracy. **Assignment problem:** Formulation - Optimal solution, Traveling Salesman problem. **Sequencing:** Introduction – Flow Shop sequence. Sequencing – n jobs through two machines - n jobs through three machines – Job shop sequencing - two jobs through 'm' machines.	**13**
02	**Queuing Models:** Introduction - Single Channel - Poisson arrivals - exponential service times - with infinite population and finite population models – Multichannel - Poisson arrivals – exponential service times with infinite population single channel Poisson arrivals. **Replacement**: Introduction - Replacement of items that deteriorate with time- when money value is not counted and counted -Replacement of items that fail completely, group replacement	**06**
03	**Game Theory**: Introduction - Minimax (Maximin) - Criterion and optimal strategy Solution of games with saddle points – Rectangular games without saddle points 2 X 2 games - dominance principle – m X2 & 2 X n games, Graphical method	**05**
04	**Dynamic programming**: Introduction – Bellman's Principle of optimality - Applications of dynamic programming- capital budgeting problem - Shortest Path problem – Minimum Spanning Tree.	**04**
05	**Simulation**: Definition - Types of simulation models - phases of simulation - applications of simulation - Inventory and Queuing problems - Advantages and Disadvantages - Simulation Languages.	**04**
06	**Project Management:** Programme Evaluation and Review Technique, Critical Path Method, Network Updating, Crashing of Network and Resources leveling.	**07**

Assessment:

Internal Assessment for 20 marks:

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2. **Question 1** will be **compulsory** and should **cover maximum contents of the curriculum.**
3. **Remaining questions will be mixed in nature** (for example if Q.2 has part (a) from module 3 then part (b) will be from any module other than module 3).
4. Only **Four questions need to be solved.**

Reference Books:

1. *Operations Research*: Principle and Practices, A. Ravindran, D. Phillips, Wiley India.
2. *Operations Research*, S. D. Sharma, Kedar Nath, Ram Nath-Meerut.
3. *Operations Research*, R. Panneerselvam, PHI Publications.
4. *Operations Research*, Kanti Swarup, P. K. Gupta and Man Mohan, Sultan Chand & Sons.
5. *Operations Research*, A. M. Natarajan, P. Balasubramani, A. Tamilarasi, Pearson Education.
6. *Operations Research*, An Introduction, Hamdy A. Taha, Pearson Education
7. *Operations Research*: Methods and Problems, Maurice Saseini, Arhur Yaspan and Lawrence Friedman.
8. *Introduction to O.R*, Hiller & Libermann (TMH).

Course Code	Course Name	Credits
PEDO6011	Internal Combustion Engine	03

Objectives:

1. To understand the working and basic components of IC engine.
2. To understand the basis performance measuring parameters of IC engine.

Outcomes: learner will be able to:

1. Understand the working concept of IC Engine and its classifications.
2. Understand the working of fuel supply system of Spark Ignition Engine.
3. Understand the working of fuel supply system of Compression Ignition Engine.
4. Understand the lubrication and cooling system of SI and CI Engine.
5. Analyze the performance parameters like Indicated power, brake power and fuel consumption of the engine.
6. Understand the use of non-conventional fuel like Alcohol - Hydrogen - Natural Gas and Liquefied Petroleum Gas – Biodiesel- Biogas and its merits and demerits as fuels.

Detailed Syllabus: (Module wise)

Module No.	Description	Duration Hrs
01	**Introduction** Classification of I.C. Engines; Parts of I.C. Engine and their materials, Cycle of operation in Four stroke and Two-stroke IC engines and their comparative study; Fuel air cycles and their analysis, Actual working cycle, Valve Timing Diagram. LHR Engines, Homogeneous charge compression Ignition, Rotary engine-Six stroke engine concept	06
02	**S.I. Engines** **Fuel Supply System**: Spark ignition Engine mixture requirements, Fuel-Air ratio, Simple carburettor and auxiliary circuits (excluding mathematical analysis of carburetors). **Injection systems:** Single-point and Multipoint injection, Gasoline Direct Injection. Ignition System: Battery Ignition System, Magneto Ignition System, Functions and working of ignition coil, spark plug, contact breaker point, Requirements and working of Ignition advance mechanisms; mechanical and vacuum, Electronic Ignition Systems; Capacitor Discharge Ignition System, Transistorized Coil Assisted Ignition System, Transistor Ignition system with contactless breaker. **Combustion :** Combustion phenomenon in SI Engines, Ignition delay, Flame propagation, Pressure Crank angle diagram, Abnormal combustion, Auto ignition, Detonation and Knocking, Factors affecting combustion and detonation, Types of combustion chambers	07
03	**Compression Ignition Engines** **Fuel Injection Systems:** Air injection systems, Airless/solid injection systems, Common rail, individual pump, distributor and unit systems. Injection pumps, Fuel injector, Types of nozzle, Electronically controlled unit fuel injection system. **Combustion:** Combustion phenomenon in C I engines, Stages of combustion, Delay period, Knocking, Pressure-Crank angle diagram, Factors affecting combustion and knocking, Types of combustion chambers.	07
04	**Engine lubrication:** Types of lubricants and their properties, SAE rating of lubricants, Types of lubrication systems.	06

	Engine Cooling: Necessity of engine cooling, disadvantages of overcooling, Cooling systems and their comparison: Air cooling, Liquid cooling. **Supercharging/Turbo-charging:** Objectives, Limitations, Methods and Types, Different arrangements of turbochargers and superchargers.	
05	**Engine Testing and Performance** Measurement of Brake Power, Indicated Power, Frictional Power, Fuel Consumption, Air flow, BMEP, Performance characteristic of SI and CI Engine Effect of load and speed on Mechanical, Indicated Thermal, Brake Thermal and Volumetric efficiencies, Heat balance sheet. **Engine Exhaust Emission and its control** Constituents of exhaust emission at its harmful effect on environment and human health, Formation of NOx, HC, CO and particulate emissions, Methods of controlling emissions; Catalytic convertors, particulate traps, Exhaust Gas Recirculation, EURO and BHARAT norms.	**07**
06	**Alternative Fuels** Alcohol - Hydrogen - Natural Gas and Liquefied Petroleum Gas – Biodiesel- Biogas - Producer Gas - Properties - Suitability - Engine Modifications - Merits and Demerits as fuels. **Basics of Electronic Engine Controls:** Electronic Control module (ECM), Inputs required and output signals from ECM, Sensors: Throttle Position, Inlet Air Temperature, Coolant Temperature, Crankshaft Position, Camshaft Position, Mass Air flow and Exhaust Gas Oxygen sensors, their construction and importance in ECM. Electronic Spark control, Air Management system, Idle speed control.	**06**

Assessment:
Internal Assessment for 20 marks:
Consisting **Two Compulsory Class Tests**

1. First test based on approximately 40% of curriculum contents and second test based on remaining contents (approximately 40%, but excluding contents covered in Test I).
2. Total duration allotted for writing each of the paper is 1 hr.
3. Average of the marks scored in both the two tests will be considered for final grading.

End Semester Examination:
Weightage of each module in end semester examination will be proportional to the number of respective lecture hours mentioned in the curriculum.

1. Question paper will comprise of total **six questions**, **each carrying 20 marks.**
2. **Question 1** will be **compulsory** and should **cover maximum contents of the curriculum.**
3. **Remaining questions will be mixed in nature** (for example if Q.2 has part (a) from module 3 then part (b) will be from any module other than module 3).
4. Only **Four questions need to be solved.**

Books Recommended:

Text books:

1. Internal Combustion Engine, Mathur and Sharma.
2. Internal Combustion Engines, Shyam Agrawal, New Age International.
3. Internal Combustion Engine by Domkundwar.

Reference Books:

1. Internal Combustion Engines, Willard W. Pulkrabek, Pearson Education.
2. Internal Combustion Engines, Mohanty, Standard Book House.
3. Internal Combustion Engine, Gills and Smith.
4. Internal Combustion Engines Fundamentals, John B. Heywood, Tata McGraw Hill.
5. Internal Combustion Engines, Gupta H N, 2nd ed, PHI.
6. Internal Combustion Engine, V Ganesan, Tata McGraw Hill.
7. Introduction to Internal Combustion Engines, Richard Stone, Palgrave Publication, 4th Edition.
8. Internal Combustion Engine, S.L. Beohar.

Course Code	Course Name	Credits
PEDO6012	Refrigeration and Air-conditioning	03

Objectives:

1. To familiarize with the working and operating principles of Vapour Compression and Vapour Absorption systems.
2. To familiarize with the components of refrigeration and air conditioning systems.
3. To familiarize with the design air conditioning systems using cooling load calculations.

Outcomes: Learner will able to:

1. Demonstrate fundamental principles of refrigeration and air conditioning.
2. Locate various important components of the refrigeration and air conditioning system.
3. Illustrate the properties of refrigerants.
4. Use psychometric chart.
5. Design and analyze complete air conditioning systems.
6. Design ducts for conditioning system.

Detailed Syllabus: (Module wise)		
Module No.	**Description**	**Duration**
1	**Introduction to Refrigeration:** Methods of refrigeration, First and Second Law applied to refrigerating machines, Carnot refrigerator, Carnot heat pump, unit of refrigeration, Coefficient of Performance, Energy Efficiency Ratio (EER), BEE star rating.	3
2	**Vapour Compression Refrigeration System:** Simple vapour compression cycle, Effect of liquid sub cooling & superheating, effect of evaporator and condenser pressures, methods of sub cooling, use of P-h charts, Actual VCR cycle. Types of condensers, evaporators, expansion devices and Compressors. Use of enhanced surface tubes in Heat Exchangers. **Refrigerants-** Desirable properties of refrigerants, ASHRAE numbering system for refrigerants. Thermodynamic, Chemical and Physical properties. Secondary refrigerants, ODP and GWP, Montreal protocol and India's commitment, Recent substitutes for refrigerants.	10
3	**Vapour Absorption Refrigeration:** Importance of VAR system, COP of ideal VAR system, Ammonia-water VAR system, Lithium Bromide – Water VAR system. **Nonconventional Refrigeration Systems:** Thermoelectric Refrigeration, Thermoacoustic Refrigeration, Vortex Tube Refrigeration.	4
4	**Psychrometry**: Need for air conditioning, Principle of psychromerty, Psychometric properties, chart and processes, air washers, requirements of comfort air conditioning, summer and Winter Air conditioning.	6
5	**Cooling load calculations and design of air-conditioning systems:** Different Heat sources,- Adiabatic mixing of two air streams, Bypass factor, sensible heat factor, RSHF, GSHF, ERSHF, Room apparatus dew point and coil apparatus dew	10

	point, Ventilation and infiltration, Inside and Outside Design condition, Cooling Load estimation. **Requirements of comfort air-conditioning**: Human Comfort, Thermal exchange of body with environment, Effective temperature, Comfort chart, Comfort zone.	
6	**Applications of Refrigeration and Air-conditioning Systems:** Introduction to Unitary Products viz. Room/Split and Packaged Air Conditioners, Introduction to recent developments viz. Variable Refrigerant Flow systems, VAV control systems, Inverter Units. Applications Refrigeration & A/C Ice plant – food storage plants – dairy and food processing plants, Food preservation, Freeze Drying, A/c in textile, printing pharmaceutical industry and Hospitals.	6

Assessment:
Internal Assessment for 20 marks:
Consisting **Two Compulsory Class Tests**

1. First test based on approximately 40% of curriculum contents and second test based on remaining contents (approximately 40%, but excluding contents covered in Test I).
2. Total duration allotted for writing each of the paper is 1 hr.
3. Average of the marks scored in both the two tests will be considered for final grading.

End Semester Examination:
Weightage of each module in end semester examination will be proportional to the number of respective lecture hours mentioned in the curriculum.

1. Question paper will comprise of total **six questions**, **each carrying 20 marks.**
2. **Question 1** will be **compulsory** and should **cover maximum contents of the curriculum.**
3. **Remaining questions will be mixed in nature** (for example if Q.2 has part (a) from module 3 then part (b) will be from any module other than module 3).
4. Only **Four questions need to be solved.**

Reference Books:

1. *Refrigeration and air-conditioning* – C P Arora, Tata McGraw Hill.
2. *Principles of refrigeration* – R J Dossat, Willey Eastern Publication.
3. *Refrigeration and air-conditioning* – W F Stoker and J W Jones, Tata McGraw Hill.
4. *Modern Air-conditioning practice* – C P Arora, Tata McGraw Hill.
5. *Refrigeration and air-conditioning*- Manohar Prasad, New Age Int (P) Ltd.
6. *Basic Refrigeration and air-conditioning*- P.Ananthanarayana, Tata McGraw Hill.
7. *Refrigeration and air-conditioning*- V. M. Domkundwar.

Course Code	Course/Subject Name	Credits
PEDO6013	Rapid Prototyping and Manufacturing	03

Objectives:

1. To acquaint with various rapid prototyping and additive manufacturing technologies.
2. To familiarize with the concept of Direct Digital Manufacturing.
3. To familiarize with the various Rapid tooling and Reverse engineering techniques.
4. To introduce the concept of Digital Manufacturing.

Outcomes: Learner will be able to:

1. Demonstrate an importance of rapid prototyping/additive manufacturing techniques.
2. Design and develop of products using rapid manufacturing technology.
3. Design and develop of products using additive manufacturing technology.
4. Illustrate the concept of Direct Digital Manufacturing.
5. Select appropriate Reverse engineering techniques for a particular case.
6. Select appropriate Rapid tooling techniques for a particular case.

Detailed Syllabus: (Module wise)		
Module No.	**Description**	**Duration Hrs**
01	**Introduction to Rapid Prototyping (RP) and Additive Manufacturing (AM)** Prototype Fundamentals, Historical Development, Fundamentals of Rapid Prototyping, Advantages of Rapid Prototyping, Commonly Used Terms, Additive Manufacturing (AM) Definition, Applications of AM parts, The Generic AM process, Why use the term Additive Manufacturing, The Benefits of AM, Distinction Between AM and CNC Machining Other Related Technologies: Reverse Engineering, CAE, Haptic based CAD. Classifications of AM / RP System: Liquid polymer Systems, Discrete Particle Systems, Molten Material Systems, Solid Sheet Systems New AM Classification Schemes as per ASTM F42 and ISO TC 261: Vat photo polymerization, Powder bed fusion, Material extrusion, Material jetting, Binder jetting, Sheet lamination and Directed energy deposition	**06**
02	**Additive Manufacturing / Rapid Prototyping Systems** **Vat Photo Polymerization based AM / RP Systems**: Principle of operation, Process, materials advantages, disadvantages, and applications of 3D Systems' stereo lithography (SLA), CMET'S Solid Object Ultraviolet-Laser Printer (SOUP). **Powder Bed Fusion based AM / RP Systems**: Principle of operation, Process, materials, advantages, disadvantages, and applications of 3D Systems' Selective Laser Sintering (SLS), EOS's EOSINT Systems, ARCAM's Electron Beam Melting (EBM). **Material Extrusion based AM / RP Systems**: Principle of operation, Process, advantages, disadvantages and applications of STRATASYS' Fused Deposition Modeling (FDM). **Material Jetting based AM / RP Systems:** Principle of operation, Process, advantages, disadvantages and applications of 3D Systems' Multi-jet Modeling System (MJM). **Binder Jetting based AM / RP Systems**: Binder jetting principle, materials, Z Corporation's Three Dimensional Printing (3DP) machine, process benefits and drawbacks. **Sheet lamination based AM / RP Systems:** Principle of operation, Process, materials, advantages, disadvantages, and applications of CUBIC Technologies Laminated Object	**10**

	Manufacturing (LOM), CAM-LEM's (Computer Aided Manufacturing of Laminated Engineering Materials) CL 100. **Directed Energy Deposition based AM / RP Systems**: Principle of operation, Process, materials, advantages, disadvantages, and applications of OPTOMEC's Laser Engineered Net Shaping (LENS).	
03	**Direct Digital Manufacturing** Concept of Direct Digital Manufacturing (DDM), Application Case Studies, DDM Drivers, Manufacturing Versus Prototyping, Cost Estimation: Cost Model, Build Time Model, Life-Cycle Costing, 3.6 Future of DDM	**05**
04	**Design for Additive Manufacturing** **AM Unique Capabilities**: Shape Complexity, Hierarchical Complexity, Functional Complexity, And Material Complexity. **Core DFAM Concepts and Objectives:** Complex Geometry, Integrated Assemblies, Customized Geometry, Multifunctional Designs, Elimination of Conventional DFM Constraints	**05**
05	**Rapid Tooling** Introduction to Rapid Tooling, Indirect Rapid Tooling Processes, Direct Rapid Tooling Processes, Emerging Trends in Rapid Tooling **Reverse Engineering (RE):** Introduction, RE generic process, RE hardware and software, Integration of RE and RP for Layer-based Model Generation, Applications and case studies of RE in automotive, aerospace and medical device industry, Barriers for adopting RE.	**06**
06	**Digital Manufacturing** Definition of digital manufacturing, Digital manufacturing idea taking control for center, Digital manufacturing idea taking design for center, Digital manufacturing idea taking management as its center, The 10 disruptive principles of digital manufacturing processes. **Key Technologies of Digital Manufacturing**: Various Digital Technologies in Product Life Cycle, Resource and Environment, Management, Control and Product Recognition.	**07**

Assessment:

Internal Assessment for 20 marks:

Consisting **Two Compulsory Class Tests**

1. First test based on approximately 40% of curriculum contents and second test based on remaining contents (approximately 40%, but excluding contents covered in Test I).
2. Total duration allotted for writing each of the paper is 1 hr.
3. Average of the marks scored in both the two tests will be considered for final grading.

End Semester Examination:

Weightage of each module in end semester examination will be proportional to the number of respective lecture hours mentioned in the curriculum.

1. Question paper will comprise of total **six questions**, **each carrying 20 marks.**
2. **Question 1** will be **compulsory** and should **cover maximum contents of the curriculum.**
3. **Remaining questions will be mixed in nature** (for example if Q.2 has part (a) from module 3 then part (b) will be from any module other than module 3).
4. Only **Four questions need to be solved.**

Reference Books:

1. *Fundamentals of Digital Manufacturing Science*, Zude Zhou, Shane (Shengquan) Xie, Dejun Chen, Springer, 2012.

2. *Rapid Manufacturing: An Industrial Revolution for the Digital Age,* N. Hopkinson, R.J.M. Hague and P.M. Dickens (Eds.), John Wiley & Sons, 2006.

3. *Rapid Tooling: Technologies and Industrial Applications*, Peter D. Hilton and Paul F. Jacobs (Eds.), Marcel Dekker, 2000.

4. *Collaborative Design and Planning for Digital Manufacturing* Lihui Wang, Andrew Y.C. Nee. (Eds.), Springer, 2009.

5. *Rapid Prototyping Principles and Applications*, Chua C.K., Leong K.F., and Lim C.S 2nd Edition, World Scientific, 2003.

6. *Additive Manufacturing Technologies*, Ian Gibson, D.W. Rosen, and B. Stucker, 2nd Edition, Springer, 2015.

7. *Rapid Prototyping Theory and Practice*, Ali Kamrani, and EmadAbouel Nasr (Eds.), Springer, 2006.

8. *Understanding Additive Manufacturing*, Andreas Gebhardt, Hanser, 2011.

9. *Rapid Manufacturing: The Technologies and Applications of Rapid Prototyping and Rapid Tooling*, D. T. Pham and S.S. Dimov, Springer, 2001.

10. *Rapid Prototyping Technology Selection and Application*, Kenneth G. Cooper, Marcel Dekker Inc, 2001.

11. Reverse Engineering: An Industrial Perspective, Vinesh Raja and Kiran J. Fernandes (Eds.), *Springer*, 2008.

Course Code	Course Name	Credits
PEDO6014	Logistics and Supply Chain Management	03

Objective:

1. To acquaint with concepts, analytical and problem solving skills and design skills to develop an understanding of information technology in supply chain optimization.
2. To acquaint with the complexity of inter-firm and intra-firm coordination in implementing programs such as e-collaboration, quick response, jointly managed inventories and strategic alliances.

Outcomes: Learner will be able to:

1. Demonstrate the functional strategy map of supply chain management.
2. Design supply chain strategy of a firm.
3. Demonstrate concepts and ideas related to Materials management.
4. Illustrate various aspects pertaining to logistics and analysis of logistic systems.
5. Demonstrate activities of warehouse and transport management.
6. Demonstrate the use of emerging technology in logistics and supply chain management.

Detailed Syllabus: (Module wise)		
Module No.	**Description**	**Duration Hrs**
01	**Supply Chain & Framework** Objective of a Supply Chain, Decision Phases in a Supply Chain, Process Views of a Supply Chain, Examples of Supply Chains **Supply Chain Strategic Fit** Competitive and Supply Chain Strategies, Achieving Strategic Fit, Expanding Strategic Scope, Challenges to Achieving and Maintaining Strategic Fit, Drivers of Supply Chain Performance, Framework for structuring drivers: inventory, transportation facilities, information, sourcing, pricing, Obstacles to achieving fit.	**05**
02	**Supply Chain Network** Role of Network Design in the Supply Chain, Factors Influencing Network Design Decisions, Framework for Network Design Decisions.	**05**
03	**Materials Management** Scope, Importance, Classification of materials, Procurement, Purchasing policies, Vendor development and evaluation, Inventory control systems of stock replenishment, Cost elements, EOQ and its derivative modules.	**05**
04	**Dimensions of Logistics** Macro and Micro Dimensions of logistics, Logistics and interfaces with other areas, Approach to analyzing logistics system, Techniques of logistics system analysis, Factors affecting the cost and Importance of logistics.	**06**
05	**Warehouse and Transport Management** Warehouse functionality, Warehouse operating principles, Developing warehouse resources, Material handling and packaging in warehouses, Transportation Management, Transport functionality and principles, Transport infrastructure, Transport economics and Pricing, Transport decision making	**06**

06	**IT in Supply Chain** The Supply Chain IT Framework, Customer Relationship Management(CRM), Internal Supply chain management(ISCM), Supplier Relationship Management(SRM), Transaction management, Risk Management in IT **Coordination in A Supply Chain** Lack of supply chain coordination and the Bullwhip effect, Obstacle to coordination, Managerial levers to achieve coordination, Building partnerships and trust, **Emerging Trends and Issues** Vendor managed inventory (VMI), Co-managed Inventory (CMI), Third- and Fourth-Party Logistics Providers (3PL-4PL), Reverse logistics: Reasons, Role and activities of RFID systems in Supply chain: Lean supply chain, Implementation of Six Sigma in supply chain, Green supply chain.	**12**

Assessment:
Internal Assessment for 20 marks:
Consisting **Two Compulsory Class Tests**

1. First test based on approximately 40% of curriculum contents and second test based on remaining contents (approximately 40%, but excluding contents covered in Test I).
2. Total duration allotted for writing each of the paper is 1 hr.
3. Average of the marks scored in both the two tests will be considered for final grading.

End Semester Examination:
Weightage of each module in end semester examination will be proportional to the number of respective lecture hours mentioned in the curriculum.

1. Question paper will comprise of total **six questions**, **each carrying 20 marks.**
2. **Question 1** will be **compulsory** and should **cover maximum contents of the curriculum.**
3. **Remaining questions will be mixed in nature** (for example if Q.2 has part (a) from module 3 then part (b) will be from any module other than module 3).
4. Only **Four questions need to be solved.**

References

1. *Supply Chain Management Strategy, Planning, and operations*, Sunil Chopra and Peter Meindl.
2. *Materials Management & Purchasing*, Ammer D.S. Taraporawala.
3. *Designing & Managing Supply chain*, David Simchi Levi, Philip Kaminsky & Edith Smichi Levi.
4. *Supply Chain Redesign: Transforming Supply Chains into Integrated Value Systems*, Robert B Handfield, Ernest L Nicholas.
5. *The Management of Business Logistics: A Supply Chain Perspective*, Coyle, Bardi, Langley.

Course Code	Course Name	Credits
PEDO6015	Maintenance Engineering	03

Objectives

1. To acquaint with various principles, functions and practices adopted in industry for the successful management of maintenance activities.
2. To appraise with the importance of maintenance in productivity enhancement and cost reduction.
3. To make conversant with preventive maintenance and breakdown maintenance functions.
4. To appraise with modern approaches in the field of maintenance.

Outcomes: Learner will be able to:

1. Acquire awareness and interest about the significance of maintenance function.
2. Develop skills to diagnose and trace the faults.
3. Keep pace with the ongoing and emerging trends in the field of maintenance engineering.
4. Plan and implement maintenance management strategies & functions.

Detailed Syllabus: (Module wise)		
Module No.	**Description**	**Duration Hrs**
01	**Principles of Maintenance & Maintenance Planning** Introduction to maintenance, Types of maintenance, Basic Principles of maintenance planning, Objectives of planned maintenance activity, Importance and benefits of sound Maintenance systems, Reliability, Maintainability and machine availability trade off, concepts of MTBF, MTTR and MWT and factors of availability.	**06**
02	**Preventive Maintenance** Significance of Preventive maintenance, maintenance planning & schedules, repair cycle, Concepts of lubrication & lubricants, Types of lubricants & selection Techniques of lubrication.	**06**
03	**Breakdown Maintenance** Logical fault location methods, Sequential fault location, Repair methods for machine beds, columns, and slide and guide ways. Repair methods for drive elements like shafts, spindles, couplings, gears and gear box, lead screw, bearings, keys, belts, chains, sprockets etc. maintenance of pneumatic and hydraulic components values and actuators and similar drive elements.	**08**
04	**Condition Monitoring** Condition Monitoring, Cost comparison with and without condition monitoring, On load testing and offload testing, Methods and instruments for condition monitoring, Temperature sensitive tapes, Pistol thermometers and wear debris analysis	**06**
05	**Maintenance of Machine Tools & Material Handling Equipment** Maintenance of Material handling equipment like crane, fork lift and conveyors, Maintenance of machine tools like lathes, shaping, milling & drilling machines.	**06**
06	**Maintenance Management** Maintenance strategies, Types and techniques, planned and unplanned maintenance, Computer aided maintenance, maintenance scheduling, spare part management, inventory control, maintenance records and documentation. Concepts of Total Productive Maintenance (TPM).Predictive maintenance techniques.	**07**

Assessment:

Internal Assessment for 20 marks:

Consisting **Two Compulsory Class Tests**

1. First test based on approximately 40% of curriculum contents and second test based on remaining contents (approximately 40%, but excluding contents covered in Test I).
2. Total duration allotted for writing each of the paper is 1 hr.
3. Average of the marks scored in both the two tests will be considered for final grading.

End Semester Examination:

Weightage of each module in end semester examination will be proportional to the number of respective lecture hours mentioned in the curriculum.

1. Question paper will comprise of total **six questions**, **each carrying 20 marks.**
2. **Question 1** will be **compulsory** and should **cover maximum contents of the curriculum.**
3. **Remaining questions will be mixed in nature** (for example if Q.2 has part (a) from module 3 then part (b) will be from any module other than module 3).
4. Only **Four questions need to be solved.**

References

1. *Industrial Maintenance Management*, Srivastava S.K., S. Chand and Co.
2. *Installation, Servicing and Maintenance*, Bhattacharya S.N., S. Chand and Co.
3. *Maintenance Planning*, White E.N., I Documentation, Gower Press.
4. *Industrial Maintenance*, Garg M.R., S. Chand & Co.
5. *Maintenance Engineering Hand book*, Higgins L.R., McGraw Hill.
6. *Condition Monitoring*, Armstrong, BSIRSA.
7. *Handbook of Condition Monitoring*, Davies, Chapman &Hall.
8. *Advances in Plant Engineering and Management*, Seminar Proceedings–IIPE.

Course Code	Course Name	Credits
PEL 601	**Process Engineering Lab.**	**01**

Objectives:-

1. To familiarize with the significance of process engineering and its relevance to manufacturing operations.
2. To prepare for developing a skills in preparing machining sequence and estimating manufacturing time.
3. To acquaint with the significance and control of tolerance in design & manufacturing.
4. To appraise a basics of process and operation planning.

Outcomes: Learner will be able to…

1. Develop capability to prepare part prints.
2. Develop work piece control system.
3. Develop tolerance control charts and process sheets.
4. Develop tool layout for production Lathe.
5. Develop process picture, process routing, process sheets.
6. Design cams for part production on single spindle automats.

Sr. no	Design Exercise /Assignment.
01	Assignment on introduction to process engineering.
02	Assignment on Part print analysis.
03	Assignment on Work piece control.
04	Prepare Tolerance Chart Design for one component.
05	Design of Tool Layout for production lathe.
06	Design process planning sheet with process picture.
07	Design of Cams for Traub Automat.

Term Work

Term work shall consist of assignments based on the syllabus and exercises as mentioned in the table above as well as a detailed report, based on an Industrial visit to a manufacturing firm, covering few of the essential concepts mentioned in subject of Process Engineering and Tooling. The report should cover the importance of optimization of various resources like Time, Material etc. in today's manufacturing firms.
The distribution of marks for term work shall be as follows:

Design Exercise : 12 marks
Assignments : 05 marks
Industrial Visit Report : 03 marks
Attendance (Theory and Practical) : 05 marks

The final certification and acceptance of term work ensures the satisfactory performance of Laboratory work and minimum passing in the term work.

Practical/Oral Examination

Each student will be given a small exercise based on syllabus, which will be assessed /verified by examiners during the oral examination.

The distribution of marks for oral-practical examination shall be as follows:

Exercise	: 15 marks
Oral	: 10 marks

1. Evaluation of practical/oral examination to be done based on the performance of design task.
2. Student's work along with evaluation report to be preserved till the next examination.

Course Code	Course Name	Credits
PEL 602	Machine Design – II Lab.	01

Objectives:

1. To familiarize with the concept of design features of machine tool structures.
2. To acquaint with design principles of feed gear boxes, bearings, power screws, clutches etc. used in machine tools.
3. To acquaint with the standards & hand books to retrieve relevant data for designing/selection of machine tool components.
4. To acquaint with the acceptance tests on machine tools & their significance.

Outcomes: Learner will be able to:

1. Use codes and hand books to retrieve relevant data for design and selection.
2. Design machine tool structures.
3. Select drive elements and drives for machine tools.
4. Design feed gear boxes for a machine tool.
5. Design bearings and clutches for a machine tool.
6. Design power screws for a machine tool.

Sr. no	Design Exercise/ Assignment
01	Design of mechanical drives (At least one design and drawing)
02	Design and drawing of machine tool guide ways, slide ways profiles, wear compensation techniques.
03	Design and drawing of machine tool structure profiles.
04	Demonstration of acceptance test on at least one machine tool.
04	Assignment on power screws.
05	Assignment on clutches.
06	Assignment each on anti-friction bearing & journal bearing.

Term Work:

Term work shall consist of design exercises and assignments as per the list given above The distribution of marks for term work shall be as follows:

Laboratory work (Experiments/ design and drawings):	15 marks
Assignments:	05marks
Interest & involvement:	05marks
TOTAL:	25Marks**.**

The final certification and acceptance of term work ensures the satisfactory performance of laboratory work and minimum passing in the term work.

Oral Examination

1. Oral examination shall be conducted based on term work and syllabus content.
2. Examiners are expected to give a small task or ask questions either to evaluate understanding of basic fundamentals or to evaluate their capability of applying basic theory to practical applications.

Course Code	Course Name	Credits
PEL 603	Additive Manufacturing Lab.	01

Objective:

1. To acquaint with various rapid prototyping and additive manufacturing technologies.
2. To familiarize with the concept of Direct Digital Manufacturing.
3. To familiarize with the various Rapid tooling and Reverse engineering techniques.
4. To introduce the concept of Digital Manufacturing.

Outcomes: Learner will be able to:

1. Demonstrate an importance of rapid prototyping/additive manufacturing techniques.
2. Illustrate the concept of Direct Digital Manufacturing.
3. Select appropriate Rapid tooling techniques for a particular case.

Sr. no	Experiments
01	Basic Design / Modelling Introduction
02	Introduction to 3D Printing Machine and Software
03	Injection Mould Prototype - Modelling and Printing
04	Assembly Modelling and Printing (Separate Components)
05	Reverse Engineering of Model
06	Working Model Print
07	Study the workflow, material requirements, design consideration, post processing of Fused Deposition Modelling FDM 3D Printer.
08	Design for Additive Manufacturing: One or two experiments

Assessment:

Term Work:

Term work shall consist of any six experiments from Sr.No 1 to 8. In all total 6 experiments.

Experiments (1to 8): …… 10 marks

Assignments: ……10 marks

Attendance: ……05 marks

The final certification and acceptance of term work ensures the satisfactory performance of laboratory work and minimum passing in the term work.

Course Code	Course Name	Credits
PEL 604	**Data Analytics Lab.**	**01**

Objective: Students will try to learn:

1. To introduce students to the basic concepts and techniques Data Preparation.
2. To become familiar with regression methods, classification methods, clustering methods.
3. To become familiar with Model Comparison.

Outcomes: Learner will be able to:

1. Develop relevant programming abilities.
2. Demonstrate proficiency with statistical analysis of data.
3. Develop the ability to build and assess data-based models.
4. Apply data science concepts and methods to solve problems in real-world contexts and will communicate these solutions effectively.

Module No.	Detailed Contents
01	Introduction to Data Analytics, Data Summarization and Visual Analytics (At least two programs on Central tendency, depression and data visualization)
02	Data Preparation: Data Cleaning, Data Integration, Data Transformation and Data Reduction (One program which includes all the above. Consider an uncleaned dataset for the same.)
03	Data Modelling: Fundamentals of modelling (Creating Training and Validation data), Decision Tree (Construction of Decision Tree and assessing the results) and K nearest neighbour (Perform KNN with different K values and analyse the results). For result analysis: confusion matrix, accuracy, misclassification, precision, recall, F score, ROC curve. (At least two programs one on decision tree and another on KNN. Consider a categorical class label data set.)
04	Data Modelling: Linear regression for continuous class label data set and Logistic regression for binary class label dataset. (At least two programs one on linear regression and another on logistic regression)
05	Data Modelling: Artificial neural network and Support Vector machine for Non Linear dataset, Ensemble model: Boosting. (At least two programs one on Neural Network and another on Support Vector machine. One program can be implemented on Random Forest.)
06	Data Modelling: Introduction to Pattern Discovery for dataset without class labels. K means clustering. Model comparison for same data sets. (At least one program on K means clustering. One program can be a comparison of two or more models on same dataset.)

Assessment:

Term Work:

Distribution of Term work Marks

Laboratory work	20 Marks
Attendance	05 Marks

Reference Books:

1. Data Mining: Concepts and Hierarchy by ByJiawei Han, Jian Pei, Micheline Kamber, Maurgan Kaufmann publisher.
2. Machine Learning by Tom Mitchell, McGraw Hills publisher.
3. Data Mining and Predictive Analytics by Danial T Larose and Chantal D Larose, Wiley.
4. Python for Data Analysis by Wes McKinney, O'Reilly publisher.
5. R for Data Science by Hadley Wickham and Garrett Grolemund, O'Reilly publisher.

Course	Course Name	Credits
PEM601	Mini Project – 2B	02

Objectives

1. To acquaint with the process of identifying the needs and converting it into the problem.
2. To familiarize the process of solving the problem in a group.
3. To acquaint with the process of applying basic engineering fundamentals to attempt solutions to the problems.
4. To inculcate the process of self-learning and research.

Outcome: Learner will be able to:

1. Identify problems based on societal /research needs.
2. Apply Knowledge and skill to solve societal problems in a group.
3. Develop interpersonal skills to work as member of a group or leader.
4. Draw the proper inferences from available results through theoretical/ experimental/simulations.
5. Analyze the impact of solutions in societal and environmental context for sustainable development.
6. Use standard norms of engineering practices
7. Excel in written and oral communication.
8. Demonstrate capabilities of self-learning in a group, which leads to lifelong learning.
9. Demonstrate project management principles during project work.

Guidelines for Mini Project :

- Students shall form a group of 3 to 4 students, while forming a group shall not be allowed less than three or more than four students, as it is a group activity.
- Students should do survey and identify needs, which shall be converted into problems in consultation with faculty supervisor/head of department/internal committee of faculties.
- Students shall submit implementation plan in the form of Gantt/PERT/CPM chart, which will cover weekly activity of mini project.
- A log book to be prepared by each group, wherein group can record weekly work progress, guide/supervisor can verify and record notes/comments.
- Faculty may give inputs during mini project activity; however, focus shall be on self-learning.
- Students in a group shall understand problem effectively, propose multiple solution and select best possible solution in consultation with guide/ supervisor.
- Students shall convert best solution into working model using various components of their domain areas and demonstrate.
- The solution to be validated with proper justification and report to be compiled in standard format of University of Mumbai.

Guidelines for Assessment of Mini Project:

Term Work

- The review/ progress monitoring committee shall be constituted by head of departments of each institute. The progress of mini project to be evaluated on continuous basis, minimum two reviews in each semester.
- In continuous assessment focus shall also be on each individual student, assessment based on individual's contribution in group activity, their understanding and response to questions.

- Distribution of Term work marks for both semester shall be as below;
    - Marks awarded by guide/supervisor based on log book : 10
    - Marks awarded by review committee : 10
    - Quality of Project report : 05

- In this semester expected work shall be procurement of component's/systems, building of working prototype, testing and validation of results based on work completed in an earlier semester.
- First review is based on readiness of building working prototype to be conducted.
- Second review shall be based on poster presentation cum demonstration of working model in last month of the said semester.
- Term work shall be assessed by review/progress monitoring committee appointed by the Head of the Department/Institute of respective Programme.

Mini Project B shall be assessed based on following points

1. Innovativeness
2. Cost effectiveness and Societal impact
3. Full functioning of working model as per stated requirements
4. Effective use of skill sets
5. Effective use of standard engineering norms
6. Contribution of an individual's as member or leader
7. Clarity in written and oral communication

Guidelines for Assessment of Mini Project Practical/Oral Examination in Even semester:

- Report should be prepared as per the guidelines issued by the University of Mumbai.
- Mini Project shall be assessed through a presentation and demonstration of working model by the student project group to a panel of Internal and External Examiners approved by the University of Mumbai
- Students shall be motivated to publish a paper based on the work in Conferences/students competitions.

Mini Project shall be assessed based on following points;

1. Quality of problem and Clarity
2. Innovativeness in solutions
3. Cost effectiveness and Societal impact
4. Full functioning of working model as per stated requirements
5. Effective use of skill sets
6. Effective use of standard engineering norms
7. Contribution of an individual's as member or leader
8. Clarity in written and oral communication