**KALASALINGAM ACADEMY OF RESEARCH AND EDUCATION**
**(Deemed to be University)**
**Anand Nagar, Krishnankoil - 626 126**
**Srivilliputhur Taluk, Virudhunagar District, Tamil Nadu,**
**India**

# CURRICULUM AND SYLLABUS

*(2018-2019)*

CHOICE BASED CREDIT SYSTEM

## M. TECH.

## (MANUFACTURING ENGINEERING)

## Regulation 2018

## Proposed Structure for M.Tech - Manufacturing Engineering

| Sl.No. | Course Type | Credits Proposed | Credits |
|---|---|---|---|
| **1** | Core Theory Course | 15 | 15 |
| **2** | Lab Courses | 6-8 | 6 |
| **3** | Supportive Course | 4 | 4 |
| **4** | Program Specific Electives | 15 | 15 |
| **5** | Inter Disciplinary/ General Electives | 3 | 3 |
| **6** | Mini Project | 2 | 2 |
| **7** | Project Work | 26 | 26 |
| **8** | Audit Courses | - | - |
| | **Total** | **71 - 73** | **71** |

### SCHEME OF INSTRUCTION

### 1. Core Theory Courses

| Sl.No | Course Code | Course Name | Course Type | L | T | P | C |
|---|---|---|---|---|---|---|---|
| 1 | MFE18R5101 | Production and Operational Management | T | 3 | 0 | 0 | 3 |
| 2 | MFE18R5102 | Design for Manufacture, Assembly and Environment | T | 3 | 0 | 0 | 3 |
| 3 | MFE18R5103 | Maintenance Management | T | 3 | 0 | 0 | 3 |
| 4 | MFE18R5104 | Quality Control and Reliability Engineering | T | 3 | 0 | 0 | 3 |
| 5 | MFE18R6101 | Advanced Manufacturing Process | T | 3 | 0 | 0 | 3 |
| | | | | | | **Total** | **15** |

### 2. Lab Courses

| Sl.No | Course Code | Course Name | Course Type | L | T | P | C |
|---|---|---|---|---|---|---|---|
| 1 | MFE18R5181 | Composite Materials and Testing Lab | L | 0 | 0 | 3 | 2 |
| 2 | MFE18R6181 | Advanced Machining and Automation Lab | L | 0 | 0 | 3 | 2 |
| 3 | MFE18R6182 | CAD/CAM Lab | L | 0 | 0 | 3 | 2 |
| | | | | | | **Total** | **6** |

## 3. Supportive courses

| Sl.No | Course Code | Course Name | Course Type | L | T | P | C |
|---|---|---|---|---|---|---|---|
| 1 | MAT18R5002 | Statistics and Computational Techniques | SC | 3 | 0 | 0 | 3 |
| 2 | PGM18R5001 | Research Methodology | SC | 1 | 0 | 0 | 1 |
| | | | | | | **Total** | **4** |

## 4. Program Electives

| Sl.No | Course Code | Course Name | Course Type | L | P | T | C |
|---|---|---|---|---|---|---|---|
| 1 | MFE18R 5105 | Work Study and Ergonomics | **T** | **3** | **0** | **0** | **3** |
| 2 | MFE18R 5106 | Sustainable Manufacturing | **T** | **3** | **0** | **0** | **3** |
| 3 | MFE18R 5107 | Rapid prototyping and tooling | **T** | **3** | **0** | **0** | **3** |
| 4 | MFE18R 5108 | Diagnostic techniques | **T** | **3** | **0** | **0** | **3** |
| 5 | MFE18R 5109 | Advanced finite element methods | **T** | **3** | **0** | **0** | **3** |
| 6 | MFE18R 5110 | Non destructive evaluation | **T** | **3** | **0** | **0** | **3** |
| 7 | MFE18R6102 | Lean manufacturing systems and implementation | **T** | **3** | **0** | **0** | **3** |
| 8 | MFE18R 6103 | Fluid power control and automation | **T** | **3** | **0** | **0** | **3** |
| 9 | MFE18R 6104 | Industrial ergonomics | **T** | **3** | **0** | **0** | **3** |
| 10 | MFE18R 6105 | Computer Integrated Manufacturing | **T** | **3** | **0** | **0** | **3** |
| 11 | MFE18R 6106 | Green Supply Chain Management | **T** | **3** | **0** | **0** | **3** |
| 12 | MFE18R 6107 | Artificial intelligence and expert systems | **T** | **3** | **0** | **0** | **3** |
| 13 | MFE18R 6108 | Reliability and quality engineering | **T** | **3** | **0** | **0** | **3** |
| 14 | MFE18R7101 | Manufacturing Strategy | | | | | |
| 15 | MFE18R 7102 | Advanced tool design | **T** | **3** | **0** | **0** | **3** |
| 16 | MFE18R 7103 | Composite materials | **T** | **3** | **0** | **0** | **3** |
| 17 | MFE18R 7104 | Corrosion and surface engineering | **T** | **3** | **0** | **0** | **3** |
| 18 | MFE18R 7105 | Advances in casting and welding processes | **T** | **3** | **0** | **0** | **3** |

## 5. Inter Disciplinary Electives

| Sl.No. | Course Code | Course Name | Course Type | L | P | T | C |
|---|---|---|---|---|---|---|---|
| 1 | XXXXXXXXX X | Interdisciplinary Elective I | **IE** | **3** | **0** | **0** | **3** |
| | | | | | | **Total** | **3** |

## 6. Mini Project

| Sl.No. | Course Code | Course Name | Course Type | L | P | T | C |
|---|---|---|---|---|---|---|---|
| 1 | MFE18R6197 | Mini Project | **L** | **0** | **2** | **0** | **2** |
| | | | | | | **Total** | **2** |

## 7. Project Work

| Sl.No. | Course Code | Course Name | Course Type | L | P | T | C |
|---|---|---|---|---|---|---|---|
| 1 | MFE18R7191 | Project Work Phase I | | **0** | **20** | **0** | **10** |
| 2 | MFE18R7192 | Project Work Phase II | | **0** | **32** | **0** | **16** |
| | | | | | | **Total** | **26** |

## 8. Audit Courses

| Sl.No. | Course Code | Course Name | Course Type | L | P | T | C |
|---|---|---|---|---|---|---|---|
| 1 | XXXXXXXXX X | Audit Course I | **AC** | **2** | **0** | **0** | **0** |
| 2 | XXXXXXXXX X | Audit Course II | **AC** | **2** | **0** | **0** | **0** |
| | | | | | | **Total** | **0** |

## 9. List of Interdisciplinary Electives (Offered to Other Disciplines)

| Code | Name of the Subject | L | T | P | C |
|---|---|---|---|---|---|
| MFE18R 6117 | Industrial safety management | **3** | **0** | **0** | **3** |
| MFE18R 7111 | MEMS and nano technology | **3** | **0** | **0** | **3** |
| MFE18R 7112 | Testing, inspection and quality control of weldments | **3** | **0** | **0** | **3** |
| MFE18R 7114 | Vibration control and condition monitoring | **3** | **0** | **0** | **3** |
| MFE18R 7115 | Financial management and cost accounting | **3** | **0** | **0** | **3** |
| MFE18R 7116 | Logistics and Supply Chain Management | **3** | **0** | **0** | **3** |

## 10. List of General Electives

| CODE | Name Of The Subject | L | T | P | C |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| EEE18R5020 | Soft Computing Techniques | **3** | **0** | **0** | **3** |
| EEE18R6013 | Evolutionary Computation Techniques | **3** | **0** | **0** | **3** |
| EEE18R5021 | Optimization Techniques | **3** | **0** | **0** | **3** |
| CSE18R5051 | Cloud Computing | **3** | **0** | **0** | **3** |
| CSE18R5052 | IOT And Applications | **3** | **0** | **0** | **3** |
| CSE18R5053 | Big Data Analytics | **3** | **0** | **0** | **3** |

## 11. List of Audit Courses

| Sl. No | CODE | Name of The Subject | L | T | P | C |
|---|---|---|---|---|---|---|
| 1 | XXXXXXXX | English for Research Paper Writing | **2** | **0** | **0** | **0** **0** |
| 2 | XXXXXXXX | Disaster Management | **2** | **0** | **0** | **0** |
| 3 | XXXXXXXX | Sanskrit for Technical Knowledge | **2** | **0** | **0** | **0** |
| 4 | XXXXXXXX | Value Education | **2** | **0** | **0** | **0** |
| 5 | XXXXXXXX | Constitution of India | **2** | **0** | **0** | **0** |
| 6 | XXXXXXXX | Pedagogy Studies | **2** | **0** | **0** | **0** |
| 7 | XXXXXXXX | Stress Management by Yoga | **2** | **0** | **0** | **0** |
| 8 | XXXXXXXX | Personality development through Life Enlightenment Skill | **2** | **0** | **0** | **0** |

| MAT18R5002 | Statistics and Computational Techniques | L | T | P | C |
|---|---|---|---|---|---|
| | | 3 | 1 | 0 | 4 |

**PROBABILITY DISTRIBUTIONS**

Probability basic concepts - Binomial, Poisson, Geometric, Normal, Uniform, Exponential, Gamma and Weibull - distributions - Mean, Variance, Moment generating functions.

**CORRELATION AND REGRESSION ANALYSIS**:

Bivariate correlation – correlation in multivariate systems; Bivariate linear regression – statistical optimization – principle of least squares – reliability of the regression equation – reliability of point estimates of regression coefficients – confidence interval of the regression equation – correlation versus regression - Multiple Regression Analysis: Matrix solution of the standardized model - criteria for evaluating a multiple regression model – Analysis of residuals

**ESTIMATION THEORY**

Estimation of parameters - Principles of least squares - Maximum likelihood estimation - Method of moments - Interval estimation

**TESTING OF HYPOTHESIS**

Sampling distribution, Large sample tests - Mean and Proportion, Small sample tests - t - test, F- test and Chi-Square test.-Goodness of fit -Independence of attributes.

**DESIGN OF EXPERIMENTS**

Design of Experiments: Basic Designs, Factorial Design, ANOVA

**Text Book(s):**

1. Jay, L. Devore, Probability and Statistics for Engineering and Sciences, Brooks Cole Publishing Company, Monterey, California, 1982.
2. Gupta, S.C. and Kapoor, V.K, Fundamentals of Mathematical Statistics, Sultan Chand and Sons, New Delhi, 11th Edition.
3. Paul Mac Berthouex and Linfield C. Brown, “Statistics for Environmental Engineers”, Second Edition, Lewis Publishers, Washington D.C. , 2002

**References:**

1. Trivedi, K.S., Probability and Statistics with Reliability, Queuing and Computer Science Applications,PHI.
2. Kapur, J.N. and Saxena, H.C, Mathematical Statistics, S.Chand and Co. Ltd., 18th Revised Edition, 1997.
3. Douglas C. Montgomery, Design and analysis of experiments, John Wiley and sons, 7th edition, 2010.

| PGM18R5001 | RESEARCH METHODOLOGY | L | T | P | C |
|---|---|---|---|---|---|
| | | 1 | 0 | 0 | 1 |

**INTRODUCTION**

Definition and objectives of Research – Types of research, Various Steps in Research process, Mathematical tools for analysis, Developing a research question-Choice of a problem Literature review, Surveying, synthesizing, critical analysis, reading materials, reviewing, rethinking, critical evaluation, interpretation, Research Purposes, Ethics in research – APA Ethics code.

**QUANTITATIVE METHODS FOR PROBLEM SOLVING**

Statistical modeling and analysis, time series analysis probability distributions, Fundamentals of statistical analysis and interference, multivariate methods, concepts of correlation and regression, fundamentals of time series, analysis and spectral analysis, error analysis, applications of spectral analysis.

**DATA ANALYSIS**

Tables and graphs of frequency data of one variable, Tables and graphs that show the relationship between two variables, relation between frequency distributions and other graphs, preparing data for analysis.

**SOFT COMPUTING APPLICATION**

Computer and its role in research, Use of statistical software SPSS, GRETL etc in research. Introduction to evolutionary algorithms- fundamentals of genetic algorithms, simulated annealing, and neural network based optimization, optimization of fuzzy systems.

**REPORT WRITING**

Structure and Components of Research Report, Types of Report, Layout of Research Report, Mechanism of writing a research report, referencing in academic writing

**TEXT BOOKS**

1. C.R. Kothari, Research Methodology Methods and Techniques, 2/e, VishwaPrakashan, 2006
2. Donald H.McBurney, Research Methods, 5th Edition, Thomson Learning, ISBN:81-315-0047-0,2006

**REFERENCE BOOKS**

1. Donald R.Cooper, Pamela S.Schindler, Business Research Methods, 8/e, Tata McGraw Hill Co.Ltd. 2006.
2. Fuzzy Logic with Engg Applications, Timothy J.Ross, Wiley Publications, 2nd Ed[d].
3. Simulated Annealing: Theory and Applications (Mathematica and its applications, by P.J.VanLaarhoven&E.H.Aarts[e]
4. Genetic Algorithms in search, optimization and machine learning by David E Goldberg

# II - CORE COURSES

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| MFE18R 5101 | Production and Operational Management | L | T | P | C |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 3 |

**TRANSFORMATION PROCESS MODEL**
Inputs, process and outputs; Classification of operations; Responsibilities of Operations Manager; New Product Development, Selection and Design of Product / Services.

**PROCESS TYPES IN MANUFACTURING**
Project, jobbing, batch, line, mass, continuous; Process types in services: professional services, services shops, mass services; Plant location; Layout planning.

**PRODUCTION PLANNING & CONTROL**
Production planning techniques for various process choices, techniques of production control, aggregate planning techniques

**QUALITY MANAGEMENT: INTRODUCTION**
Meaning; Quality characteristics of goods and services; Tools and techniques for quality improvement: check sheet, histogram, scatter diagram, cause and effect diagram, Pareto chart, process diagram, statistical process control chart; Quality assurance; Total quality management (TQM) model; Service quality, concept of Six Sigma and its application.

**PRODUCTIVITY IMPROVEMENT TECHNIQUES**
Work study; Method study; Work measurement: time study: stop watch time study; Work sampling.
Maintenance: maintenance policies for facilities and equipment; Time of failure; Preventive versus breakdown maintenance; Procedure for maintenance, total productive maintenance (TPM)

***References:***
*1) Adam Jr Everetl E. R J – **Production and Operations Management** (Prentice-Hall, 1992), 2000*
*2) Chary- **Production and Operations Management** (Tata McGraw-Hill, 1997 9th ed.)*
*3) Hill T- **Operations Management** (Palgrave, 2000)*
*4) Johnston R et al – **Cases in Operations Management** (Pitman, 1993)*
*5) McGregor D – **Operations Management** (McGraw-Hill, 1960)*
*6) Morton- **Production and Operations Management** (Vikas)*
*7) Haleem A- **Production and Operations Management** (Galgotia books, 2004)*
*8) Shanker Ravi- **Industrial Engineering** ( Galgotia)*
*9) **Chase & Production and operation Management**, Richard Irwin London; 1995, 7th ed.*
*10) **Production & Operations Management**.- Kanishka Bedi, (Oxford University Press)*

| MFE18R 5102 | Design for Manufacture, Assembly and Environment | L | T | P | C |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 3 |

**INTRODUCTION**

General design principles for manufacturability –Factors influencing design-Systematic working plan for the designer-Types of problems to be solved-Possible solutions-Evaluation method- Process capability - Feature tolerances -Geometric tolerances - Assembly limits -Datum features - Tolerance stacks-Interchangeable part manufacture and selective assembly.

**FACTORS INFLUENCING FORM DESIGN**

Materials choice - Influence of basic design, mechanical loading, material, production method, size and weight on form design- form design of welded members and forgings.

**COMPONENT DESIGN – CASTING CONSIDERATION**

Form design of grey iron, steel, malleable iron and aluminium castings.Redesign of castings based on parting line considerations - Minimizing core requirements, machined holes, redesign of cast members to obviate cores.

**COMPONENT DESIGN - MACHINING CONSIDERATION**

Design features to facilitate machining - drills - milling cutters - keyways - Doweling procedures, counter sunk screws - Reduction of machined area - simplification by separation - simplification by amalgamation - Design for machinability - Design for economy - Design for clampability - Design for accessibility - Design for assembly. Identification of uneconomical design - Modifying the design - group technology -Computer Applications for DFMA.

**DESIGN FOR ENVIRONMENT**

Introduction – Importance of DFE -Environmental objectives – Global issues – Regional and local issues– Design guidelines for DFE –Lifecycle assessment – EPS system - ATANDT's environmentally responsible product assessment - Weighted sum assessment method – Techniques to reduce environmental impact – Design to minimize material usage –Design for disassembly – Design for recyclability – Design for remanufacture –Design for energy efficiency – Design to regulations and standards.

***References:***


1. *Boothroyd, G, **"Design for Assembly Automation and Product Design",** New York, Marcel Dekker, 1980.*
2. *Bralla, **"Design for Manufacture Handbook**", McGraw hill, 1999.*
3. *Boothroyd, G, Heartz and Nike, **"Product Design for Manufacture**", Marcel Dekker, 1994.*
4. *Dickson, John. R, and Corroda Poly, **"Engineering Design and Design for Manufacture and StructuralApproach"**, Field Stone Publisher, USA, 1995.*
5. *Fixel, J. "**Design for the Environment**", McGraw hill. 1996.*
6. *Graedel T. Allen By. B, "**Design for the Environment**", Angle Wood Cliff, Prentice Hall. Reason Pub.1996.*
7. *Kevien Otto and Kristin Wood, "**Product Design**", Pearson Publication, 2004.*
8. *Dr.ING.Robert Matouslk, **"Engineering Design**".Blackie & son limited, 1962.*
9. *Harry peck, **"Designing for Manufacture"**,Pitman publishing.*

| MFE18R 5103 | Maintenance Management | L | T | P | C |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 3 |

**MAINTENANCE CONCEPT**

Maintenance objectives and functions – Tero technology – Five zero concept – Maintenance costs and budgets – Maintenance organization

**FAILURE DATA ANALYSIS**

MTBF, MTTF, useful life – Survival curves – repair time distribution – exponential, Poisson, normal, Weibull applications – Standby systems - Availability of repairable systems – Maintainability prediction – Design for maintainability.

**MAINTENANCE MODELS**

Maintenance policies – Imperfect maintenance – concept of minimal repair – Statistical aids for PM and break-down maintenance – PM schedules: deviations on both sides of target values – PM schedules for functional characteristics and large scale system – replacement models – DOM, opportunistic maintenance – Inspection and repair - Spare parts management.

**TOTAL PRODUCTIVE MAINTENANCE**

TPM philosophy – Policy and objectives – Pillars - Zero breakdown – loss prevention – Overall Equipment Effectiveness (OEE) – Failure Mode Effect Analysis (FMEA) – Risk Priority Number (RPN).

**ADVANCED TECHNIQUES**

Condition monitoring: WDM, Vibration and corrosion monitoring – Signature analysis – MMIS – Expert systems – Reliability centered maintenance (RCM)

***References:***

1. *Gopalakrishnan, P. Banerji, A.K. "**Maintenance and spare parts management**", Prentice Hall of India, 1991.*
2. *Edward Hartmann, "**Maintenance Management**", Productivity and Quality publishing Pvt.Ltd. Madras, 1995.*
3. *Seichi Nakagima, "**Introduction to Total Productive Maintenance**", Productivity Press (India) Pvt.Ltd.,1993*

| MFE18R 5104 | Quality Control and Reliability Engineering | L | T | P | C |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 3 |

**INTRODUCTION AND PROCESS CONTROL FOR VARIABLES**

Introduction, definition of quality, basic concept of quality, definition of SQC, benefits and limitation of SQC, Quality assurance, Quality cost-Variation in process- factors - process capability - process capability studies and simple problems -Theory of control chart- uses of control chart-Control chart for variables - X chart, R chart and s chart.

**PROCESS CONTROL FOR ATTRIBUTES**

Control chart for attributes -control chart for proportion or fraction defectives - p chart and np chart - control chart for defects - C and U charts, State of control and process out of control identification in charts.

**ACCEPTANCE SAMPLING**

Lot by lot sampling - types - probability of acceptance in single, double, multiple sampling techniques-O.C. curves - producer's Risk and consumer's Risk. AQL, LTPD, AOQL concepts-standard sampling plans for AQL and LTPD- uses of standard sampling plans.

**LIFE TESTING – RELIABILITY**

Life testing - Objective - failure data analysis, Mean failure rate, mean time to failure, mean time between failure, hazard rate, system reliability, series, parallel and mixed configuration - simple problems. Maintainability and availability- simple problems. Acceptance sampling based on reliability test - O.C Curves.

**QUALITY AND RELIABILITY**

Reliability improvements -techniques- use of Pareto analysis - design for reliability - redundancy unit and standby redundancy - Optimization in reliability - Product design - Product analysis - Product development - Product life cycles.

***References:***

1. Grant, Eugene .V, Statistical Quality Control, McGraw-Hill, 1996
2. L.$.Srmah, Reliabi!ity Engineering, Affiliated East west press, 1991
3. R.C.Gupta, Statistical Quality control, Khanna Publishers, 1997
4. Besterfield D.H., Quality Control, Prentice Hall, 1993.
5. Sharma S.C., Inspection Quality Control and Reliability, Khanna Publishers, 1998.
6. Connor, P.D.T.O., Practical Reliability Engineering, John Wiley, 1993.

| MFE18R 6101 | Advanced Manufacturing Process | L | T | P | C |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 3 |

**ADVANCED MACHINING**

Abrasive machining – water jet machining - ultrasonic machining – chemical machining – construction working principle– steps - types – process parameters – derivations – problems, merits, demerits and applications.

**ELECTRICAL MACHINING**

Wire cut EDM - Electro chemical machining – ECG - Electric discharge machining – construction – principle – types – control - circuits – tool design – merits, demerits and applications.

**NEWER MACHINING**

Laser beam machining – Electron beam machining – Plasma arc machining – Ion beam machining – construction working principle types – process parameter – derivations – problems, merits, demerits and applications.

**FABRICATION OF MICRO DEVICES**

Semiconductors – films and film depurification – Oxidation - diffusion – ion implantation – etching – metallization – bonding – surface and bulk machining – LIGA Process – Solid free form fabrication.

**MICROFABRICATION TECHNOLOGY**

Wafer preparation – monolithic processing – moulding – PCB board hybrid and MCM technology – programmable devices and ASIC – electronic material and processing– steriolithography SAW devices, Surface Mount Technology.

***References:***


1. *Serope Kalpekijian, Stevan R.S.Chmid* ***"Manufacturing Process Engg Material",*** *2003*
2. *Julian W.Hardner* ***"Micro sensors Mems & Smart Devices",*** *2002*
3. *Brahem T. Smith "****Advanced Machining",*** *I.F.S. UK 1989.*
4. *Jaeger R.C.,* ***"Introduction to Microelectronic fabrication",*** *Addison Wesley, 1988.*
5. *Nario Taniguchi,* ***"Nano Technology",*** *Oxford University Press 1996.*
6. *Pandey P.C. and Shan HS,* ***"Modern Machining Processes"****, Standard Publishing Co., 1980*
7. *More Madon,* ***"Fundamentals of Microfabrication"****, CRC Press, 1997.*

| MFE18R 6181 | Advanced Machining and Automation Lab | L | T | P | C |
|---|---|---|---|---|---|
| | | 0 | 0 | 4 | 2 |

**Advanced Machining:** Exercise on Electrical Discharge Machining and Abrasive Water Jet Machining – complex contour profile using CNC

**Automation:** Practice in Robot programming and its languages. Robotic simulation using software. Robot path control, preparation of various reports and route sheets, Simulation of manufacturing system using CAM software, controller operating system commands.

| MFE18R 6182 | CAD/CAM Lab | L | T | P | C |
|---|---|---|---|---|---|
| | | 0 | 0 | 4 | 2 |

**CAD:** Creation of working drawing, creating geometry, constraining the profile, extracting a part using tools, creating pattern of holes, translating rotating, mirroring, managing the specification tree. Creating sheets and views, creating text and dimensions, creating an assembly, moving components, assembling existing components, creating bill of materials, creating wire frame and surface geometry using generative shape design and sweep tools. Generation of Ferguson's cubic surface patches, Bezier surface patches. Coons patches. Import and export of drawing from other software.

**CAM:** Features and selection of CNC turning and milling centers. Practice in part programming and operation of CNC turning machines, subroutine techniques and use of cycles. Practice in part programming and operating a machining center, tool Joining and selection of sequences of operations, tool setting on machine, practice in APT based NC programming.

# III – PROGRAM ELECTIVE

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| MFE18R 5105 | Work study and Ergonomics | L | T | P | C |
|---|---|---|---|---|---|
| | | 3 | 0 | 0 | 3 |

**WORK STUDY**

Study of operations – work content – work procedure – breakdown – human factors – safety and method study – methods and movements at the workplace – substitution with latest devices – robotic concepts – applications in hazardous workplaces – productivity, quality and safety (PQS).

**ERGONOMICS**

Definition – applications of ergonomic principles in the shop floor – work benches – seating arrangements – layout of electrical panels- switch gears – principles of motion economy – location of controls – display locations – machine foundations – work platforms, fatigue, physical and mental strain – incidents of accident – physiology of workers.

**PERSONAL PROTECTION**

Concepts of personal protective equipment – types – selection of PPE – invisible protective barriers – procurement, storage, inspection and testing – quality – standards – ergonomic considerations in personal protective equipment design.

**PROCESS AND EQUIPMENT DESIGN**

Process design – equipment – instrument – selection – concept modules – various machine tools - in-built safety – machine layout-machine guarding-safety devices and methods – selection, inspection, maintenance and safe usage – statutory provisions, operator training and supervision – hazards and prevention.

**MAN MACHINE SYSTEMS**

Job and personal risk factors – standards-selection and training-body size and posture-body dimension (static/dynamic) – adjustment range – penalties – guide lines for safe design and postures – evaluation and methods of reducing posture strain.

Man-machine interface-controls -types of control-identification and selection-types of displays-compatibility and stereotypes of important operations-fatigue and vigilance-measurement characteristics and strategies for enhanced performance.

**References**

1. Curri and Faraday, Work Study, ELBS, 4th edition, 1978.
2. Benjamin W.Niebel, Motion and Time Study, Richard, D. Irwin Inc., Seventh Edition, 1982.
3. Barnes, R.M., Motion and Time Study, John Wiley, 1980.
4. Stephen Konz., Work Design, Publishing Horizon Inc., Second Edition, 1979.
5. Bridger, R.S., Introduction to Ergonomics, McGraw-Hill, 1995.

| MFE18R 5106 | SUSTAINABLE MANUFACTURING | L | T | P | C |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| | | **3** | **0** | **0** | **3** |

**Introduction**

Sustainability performance evaluators: definitions, indicators, indicator selection and analysis assessing information against performance criteria. Concepts of sustainability and sustainable development - Components of sustainability (Social, Economic, Environmental) - Linkages between technology and sustainability

**Sustainable Product Development**

Sustainable Product Development – Various Phases - Tools and Techniques – Environmental Conscious Quality Function Deployment, Life cycle assessment

**Design for Environment**

Methods to infuse sustainability in early product design phases, Design for Environment, R3 and R6 cycles, Design for Disassembly - EIA Methods –CML, EI 95 and 99, ISO 14001 EMS and PAS 2050 standards, Environmental Impact parameters – Renewable Energy – Remanufacturing, EoL Strategies, Design for recycling – Eco friendly product design methods.

**Sustainable Manufacturing**

Green manufacturing concepts, sustainable material selection, sustainable resource consumption and utilization, Embodied product energy, Energy consumption and conservation

**Decision making in sustainable manufacturing**

Multi-Criteria Decision Making in Sustainability - Frameworks for measuring sustainability- Indicators of sustainability - Product Sustainability and Risk/Benefit assessment– Corporate Social Responsibility, Costing in sustainability - Environmental accounting for business.

***References***

*1. D. Rodick, Industrial Development for the 21st Century: Sustainable Development Perspectives, UN New York, 2007.*

*2. Rogers, P.P., Jalal, K.F. and Boyd, J.A., An Introduction to Sustainable Development, Earthscan, London, 2007.*

*3. Thompson, R., and Thompson, M., Sustainable Materials, Processes and Production (The Manufacturing Guides) Thames & Hudson, Limited, 2013.*

*4. Seliger. G., Jawahir, I.S., Marwan M.K., Khraisheh, Advances In Sustainable Manufacturing Springer, 2008.*

| **MFE18R** | **Rapid prototyping and tooling** | **L** | **T** | **P** | **C** |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| **5107** | | **3** | **0** | **0** | **3** |

**INTRODUCTION**
Rapid Product Development (RPD) –Product Development Cycle – Detail design– Prototype and tooling.

**RAPID PROTOTYPING (RP)**
Principle of RP technologies and their classification of RP systems–Stereo lithography systems – Selection of RP process; Issues in RP ; Emerging trends–Direct Metal Laser Sintering (DMLS) system – Principle – process parameters – process details – Applications.

**ENGINEERING PROCESS**
Fusion Deposition Modeling –Laminated Object Manufacturing –Selective Laser Sintering- Three dimensional Printing-Reverse Engineering -Engineering applications– Medical applications.

**PROCESSING POLYHEDRAL DATA**
Polyhedral BRep modeling–STL format– Defects and repair of STL files– Processing STL files; Overview of the algorithms required for RPANDT- slicing, support generation, feature recognition

**RAPID TOOLING**
Introduction to RT–Indirect RT processes – Silicon rubber molding, Epoxy tooling, Spray metal tooling and Investment Casting; Direct RT processes – Laminated Tooling, Powder Metallurgy based technologies, Welding based technologies, Direct pattern making (Quick Cast, Full Mold Casting); Emerging Trends in RT

***References:***

1. *Terry wohlers, Wohlers Report 2000, Wohlers Associates, USA, 2000.*
2. *Chua Chee Kai and Leong Kah Fai, 1997,* ***"Rapid Protoyping: Principles and Applications in Manufacturing"****, John Wiley AND Sons*
3. *Paul F. Jacobs, 1996,* ***"Stereo-lithography and other RP & M Technologies"****: from Rapid Prototyping to Rapid Tooling, SME/ASME*
4. *D. Faux and M. J. Pratt, 1979, "****Computational Geometry for Design and Manufacture"****, John Wiley and Sons*
5. *Pham, D.T. & Dimov.S.S.,* ***"Rapid manufacturing"****, Springer-Verlag, London, 2001.*

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| **MFE18R** | **Diagnostic techniques** | **L** | **T** | **P** | **C** |

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**DEFECTS AND FAILURE ANALYSIS**

Defect generation-types of failures-Defects reporting and recording-Defect analysis-Failure analysis-Equipment down time analysis-Breakdown analysis-TA,FMEA, FMECA.

**MAINTENANCE SYSTEMS**

Planned and unplanned maintenance-Breakdown maintenance-Corrective maintenance-Opportunistic maintenance-Rou-tine maintenance-Preventive maintenance, Predictive maintenance-Condition based maintenance system-Design out main-tenance-selection of maintenance system.

**SYSTEMATIC MAINTENANCE**

Codification and Cataloguing-Instruction manual and operating manual-Maintenance manual and Departmental manual-Maintenance time standard-Maintenance work order and work permit -job monitoring-Feedback and control-Mainte-nance records and documentation.

**COMPUTER MANAGED MAINTENANCE SYSTEM**

Selection and scope of computerization-Equipment classification-Codification of breakdown, material and facilities-Job sequencing-Material management module-Captive Engineering module.

**CONDITION MONITORING**

Condition monitoring techniques-Visual monitoring-Temperature monitoring-vibration monitoring-Lubricant monitoring-Cracks monitoring-Thickness monitoring-Noise and sound monitoring-condition monitoring of hydraulic system. Machine diagnostics-Objectives-Monitoring strategies-Examples of monitoring and Diagnosis - Control structures for machine diagnosis.

***References:***

1. *Sushil Kumar Srivastava, **"Industrial Maintenance Management**", S.Chand and company Ltd., New Delhi, 2011.*
2. *Manfred Weck, H.Bibring, **"Handbook of Machine Tools,Vol 3."**, John Wiley and Sons.*
3. *Garg H.P, **"Industrial Maintenance"**, S.Chand & company Ltd., NewDelhi, 2009.*

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| **MFE18R 5109** | **Advanced finite element methods** | **L** | **T** | **P** | **C** |

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**INTRODUCTION**

Modeling and Discretization – Interpolation, Elements, Nodes and degrees-of-freedom. Computational Procedures– Stiffness Matrices – Boundary Conditions-Solution of Equations- Ritz method, Variational Method, Method of weighted residuals.

**BASIC ELEMENTS**

Interpolation and shape functions - element matrices-linear triangular elements (CST)-quadratic triangular elements – bilinear rectangular elements-quadratic rectangular elements-solid elements-higher order elements-nodal loads-stress calculations-example problems.

**ISOPARAMETRIC ELEMENTS**

Introduction-bilinear quadrilateral elements – quadratic quadrilaterals – hexahedral elements – Determination of Shape Functions - Numerical Integration – quadrature - static condensation – load considerations – stress calculations – examples of 2D and 3D applications.

**FINITE ELEMENT FORMULATION FOR STRUCTURAL APPLICATIONS**

Linear elastic stress analysis-2D, 3D and axis symmetric problems – Analysis of structural vibration – mass and damping matrices – damping – Harmonic response – direct integration techniques – explicit and implicit methods.

**APPLICATIONS**

Nonlinear Problems – Element formulation – Heat Conduction, Fluid flow –Transient Thermal Analysis-Acoustic frequencies and modes- Incompressible and rotational flows – applications in manufacturing

***References:***

1. *Cook, Robert Davis et al **"Concepts and Applications of Finite Element Analysis"**, Wiley, John & Sons, 1981.*
2. *O.C Zienkiewicz, **"The Finite Element Method"**, 3rd Edition, Tata McGraw-Hill, 2005.*
3. *C.S. Desai and J.F. Abel, **"Introduction to Finite Element Method**", Affiliated East-West Press, 1972.*
4. *Chandrupatla, Belagundu, **"Finite Elements in Engineering**", Prentice Hall Private Ltd., 2002.*

| **MFE18R 5110** | **Non Destructive Evaluation** | **L** | **T** | **P** | **C** |
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**BASIC CONCEPTS OF NDT**

Relative merits and limitations of NDT Vs. Conventional testing –Visual inspection, thermal inspection methods. Liquid penetrant Inspection

**LIQUID PENETRANT AND MAGNETIC PARTICLE TESTS**

Characteristics of liquid penetrants - different washable systems - Developers - applications - Methods of production of magnetic fields - Principles of operation of magnetic particle test - Applications - Advantages and limitations.

**RADIOGRAPHY**

Sources of ray-x-ray production - properties of d and x rays - film characteristics - exposure charts - contrasts - operational characteristics of x ray equipment - applications.

**ULTRASONIC AND ACOUSTIC EMISSION TECHNIQUES**

Production of ultrasonic waves - different types of waves - general characteristics of waves - pulse echo method - A, B, C scans - Principles of acoustic emission techniques - Advantages and limitations - Instrumentation - applications.

**THERMOGRAPHY**

Thermography - Principles, types, applications, advantages and limitations. Optical and Acoustical holography- Principles, types, applications, advantages and limitations. Casestudies: weld, cast and formed components.

***References:***

1. *Barry Hull and Vernon John, **"Non Destructive Testing"**, MacMillan, 1988.*
2. *American Society for Metals, "**Metals Hand Book"**, Vol.II, 1971.*
3. *Hull. **"Non Destructive Testing"**. ELBS Edition. 1991.*
4. *Baldevraj., Jayakumar.T., Thavasimuthu. M., **"Practical Non-destructive Testing"**, Narosa Publishers, 1997.*
5. *McGonnagle. W.T. **"Non-Destructive Testing"**, McGraw Hill. 1961.*
6. *ASM Metals Hand Book. Vol. 9. **"Non-destructive Testing and Inspection"**, 1988.*

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| **MFE18R** | **Lean manufacturing systems and** | **L** | **T** | **P** | **C** |

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**LEAN MANUFACTURING**

Evolution of Lean, Traditional versus Lean Manufacturing, Business of Survival and Growth, Business Model Transformation, Ford Production System, Job Shop Concepts Concept of Lean, Toyota's foray in Lean.

**DESIGN - VALUE STREAM MANAGEMENT**

Definition, VSM Types, Product Family Selection, Value Stream Manager; Current State Map, Process Box, Value Stream Icons, 3 Ms - Muda, Mura, Muri - 7 Types of Muda, Future State Map, Value Stream Plan, Process Stability - Loss Reduction 7 Major Losses Reduction. Demand Stage, Market Dynamics, Customer Demand, PQ Analysis, PR Analysis; TAKT Time, Pitch, Finished Goods Stock, Cycle Stock, Buffer Stock, Safety Stock.

**FUNDAMENTAL LEAN TOOLS**

Flow Stage, Continuous Flow, Cell Layout, Line Balancing, Macro and Micro Motion, Analysis, Standardized Work, Concept of Kaizen, Steps involved in Kaizen Deployment, Industrial Engineering - Concepts and Fundamentals, Kanban Concepts, Types of Kanbans and Practical Application, Concept of Pull, Changeover Time Reduction - External AND Internal, Single Minute Exchange of Die, Quick Die Change, Quality-Vendor, In Process and Customer, Line.

**LEAN IMPLEMENTATION**

Concept of PPM, Pokayoke, Prevention and Detection Types, Maintenance - Preventive, Time Based and Condition Based; Human Development for Lean (Training and Involvement through Autonomous Maintenance) Leveling Stage of Lean Implementation, Production Leveling , Leveling Box, Concept of Water Spider.

**LEAN METRICS AND LEAN SUSTENANCE**

Identify Lean Metrics, Steps involved in Goal Setting; Corporate Goals, Kaizen Cloud, identification in VSM, Lean Assessment, Cultural Change, Reviews, Recognition, Improving Targets and Benchmarks.

***References:***


1. *Askin R G and Goldberg J B,* ***"Design and Analysis of Lean Production Systems"****, John Wiley & Sons, New York, 2003.*
2. *Don Tapping, Tom Luyster and Tom Shuker,"****Value Stream Management****" Productivity Press, 2002.*
3. *Tom Luyster and Don Tapping, "****Creating Your Lean Future State: How to Move from Seeing to Doing****", Productivity Press, 2006.*
4. *Mike Rother and Rick Harris, "****Creating Continuous Flow****", Publisher: Lean Enterprise Institute, Inc., 2001.*
5. *Rick Harris, Chris Harris & Earl Wilson,"****Making Materials Flow****", Lean Enterprise Institute, 2003.*


| MFE18R | Fluid power control and automation | L | T | P | C |
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**OIL HYDRAULIC SYSTEMS AND HYDRAULIC ACTUATORS**

Hydraulic Power Generators – Selection and specification of pumps- types of pumps-pump characteristics. Linear and Rotary Actuators – selection, specification and characteristics.

**CONTROL AND REGULATION ELEMENTS**

Pressure - direction and flow control valves - relief valves, non-return and safety valves - actuation systems.

**HYDRAULIC CIRCUITS**

Reciprocation, quick return, sequencing, synchronizing circuits - accumulator circuits – regenerative and High-low circuits - industrial circuits - press circuits - hydraulic milling machine - grinding, planning – hydraulic copying circuit - forklift and other earth mover circuits- design and selection of components.

**PNEUMATIC SYSTEMS AND CIRCUITS**

Pneumatic fundamentals - control elements- position and pressure sensing - logic circuits - switching circuits - sequential circuits - cascade method – step counter method - KV mapping method - compound and combinational circuit designs.

**INSTALLATION, MAINTENANCE AND SPECIAL CIRCUITS**

Pneumatic equipment- selection of components - design calculations – application -fault finding - hydro pneumatic circuits - use of microprocessors and PLC for sequencing - Robotic circuits. Introduction to Software for pneumatic / hydraulic systems simulation.

***References:***

1. *Antony Espossito, "**Fluid Power with Applications**", Prentice Hall, 2000.*
2. *Dudleyt, A. Pease and John J. Pippenger, "**Basic Fluid power**", Prentice Hall, 1987.*
3. *Michael J., Pinches and John G.Ashby, "**Power Hydraulics**", Prentice Hall, 1989.*
4. *Bolton. W., "**Pneumatic and Hydraulic Systems**", Butterworth –Heinemann, 1997.*
5. *Joji P., "**Pneumatic Controls**", Wiley India Pvt. Ltd., New Delhi, 2008.*

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| **MFE18R** | **Industrial Ergonomics** | **L** | **T** | **P** | **C** |

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**INTRODUCTION**

Concepts of human factors engineering and ergonomics – Man – machine system and design philosophy – Physical work– Heat stress – manual lifting – work posture – repetitive motion.

**ANTHROPOMETRY**

Physical dimensions of the human body as a working machine – Motion size relationships – Static and dynamic anthropometry – Anthropometric aids – Design principles – Using anthropometric measures for industrial design – Procedure for anthropometric design.

**DESIGN OF SYSTEMS**

Displays – Controls – Workplace – Seating – Work process – Duration and rest periods– Hand tool design – Design of visual displays – Design for shift work.

**ENVIRONMENTAL FACTORS IN DESIGN**

Temperature – Humidity – Noise – Illumination –Vibration – Measurement of illumination and contrast – use of photometers– Recommended illumination levels. The ageing eye– Use of indirect (reflected) lighting – cost efficiency of illumination – special purpose lighting for inspection and quality control – Measurement of sound – Noise exposure and hearing loss – Hearing protectors – analysis and reduction of noise – Effects of Noise on Performance – annoyance of noise and interference with communication – sources of vibration discomfort.

**WORK PHYSIOLOGY**

Provision of energy for muscular work – Role of oxygen physical exertion – Measurement of energy expenditure Respiration– Pulse rate and blood pressure during physical work – Physical work capacity and its evaluation.

***References:***

1. *Martin Helander, **"A guide to the ergonomics of manufacturing"**, East West press, 1996*
2. *E.J. McCormic, "**Human factors in engineering design"**, McGraw Hill 1971*
3. *R.S. Bridger, "**Introduction to Ergonomics"**, McGraw Hill, 1995.*

| MFE18R 6105 | Computer Integrated Manufacturing | L | T | P | C |
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**PRODUCTION PLANNING AND CONTROL**

Introduction to CIM - Nature of the CIM system - Types of manufacturing systems – Evolution of CIM - Computers in CIM. Process definition and manufacturing planning - Structures of a process plan - CAD based process planning - coding systems - Methods of CAPP – Process planning systems. Background - Role of MRP - II in CIM systems - Major modules of MRP – II software - Manufacturing, Engineering, financial, marketing and misc. applications.

**CNC SYSTEMS**

CNC Machine tools - Principle of Numerical Control - Types of CNC machine tools – Features and programming of CNC machine tools - CNC programming based on CAD - Applications and economics of usage of CNC machine - Capabilities of a typical NC - CAM software – Integration of computers in CIM environment

**NETWORKING**

Computer communications - Principles of networking, Techniques, components of networking and wiring methods - Network interface cards - Network standards, examples - Operating system - Security - Managing remote systems - design activity in a networked environment – networking in an manufacturing company

**FLEXIBLE MANUFACTURING SYSTEMS**

Flexible manufacturing - Introduction, types, major elements and optimization of FMS - Operational elements in a typical FMC - Typical FMS layout - Lean manufacturing – Agile manufacturing database and DBMS requirements - Features and architecture of a DBMS – query language - SQL - SQL as a knowledge base query language. Integration and Implementation issues in CAD/CAM/CIM.

**ROBOTICS AND ARTIFICIAL INTELLIGENCE**

Artificial Intelligence - Robots -Elements, types and specifications of robots, robot programming methods, robot operation, applications of industrial robots, integration of robots in CIM systems -Expert system - AI in vision system and scheduling - DSS in CIM environment.

***References:***


1. *Mikell P Groover, "**Automation, Production Systems, & Computer Integrated Manufacturing**", Pearson education (Singapore) Pvt. Ltd., New Delhi, 2003.*
2. *Chris McMahon, and Jimmie Browne, "**CAD/CAM Principles, Practice and**", Addison Wesley Longman Limited, England, 1998.*
3. *Narahari Y, Viswanadham N., "**Performance Modeling and Analysis of Automated Manufacturing Systems**", Prentice hall of India, New Delhi, 1998.*
4. *Mikell P Groover, Mitchell Weis, Roger N Nagel, Nicholas G Odrey, **"Industrial Robotics Technology,Programming and Applications"**, McGraw Hill, 1986.*

| MFE18R 6106 | GREEN SUPPLY CHAIN MANAGEMENT | L | T | P | C |
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**Overview of Green Supply Chain Management**

Recent trends in green supply chain management; environmental impacts of supply chains, the green supply chain as a competitive advantage in today's business environment.

**Evolution of Green Legislation**

Drivers of green supply chains; recent trends in green legislation; RoHS, WEEE, and REACH; need for and importance of green legislation related to supply chain management.

**Life-Cycle Approach to Green Supply Chains**

Life-cycle assessment as a tool; greening of supply chains; green supply chain design.

**GreenSCOR model**

Supply chain operations reference (SCOR) model; Supply Chain Council; cross-industry standard and diagnostic tool for supply-chain management; GreenSCOR as a focused model; applications of the GreenSCOR model to a green supply chain.

**Greening Supply Chains by Reverse Logistics**

Reverse logistics; comparison with traditional forward logistics flow; effective means to reduce operational costs; waste generated in supply chain processes; reverse logistics case studies.

***Text books***

1. Sarkis, J., Greener Manufacturing and Operations, Greenleaf Publishing Limited
2. Taylor, D. and Brunt, D. Manufacturing Operations and Supply Chain Management: The LEAN Approach, Thomson Learning

***References***

1. Plenert, G., How to Create an Integrated World-Class Lean SCM Environment, In Reinventing Lean, Chapter 10, pp. 290-294, Butterworth-Heinemann, latest edition
2. Van Hoek, R. I. 2001, Case Studies of Greening the Automotive Supply Chain Through Technology and Operations, International Journal of Environmental Technology and Management, 1(1-2), 140-163
3. Sarkis, J. 2003, A Strategic Decision Framework for Green Supply Chain Management, Journal of Cleaner Production, 11(4), 397-409

| MFE18R 6107 | Artificial intelligence and expert systems | L | T | P | C |
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**KNOWLEDGE REPRESENTATION FOR SMART SYSTEMS**

Concepts of fifth generation computing -. Forward chaining, backward chaining, use of probability and fuzzy logic. Semantic nets, structure and objects, ruled systems for semantic nets; certainty factors, automated learning.

**LANGUAGES USED IN AI**

Programming in AI environment - developing artificial intelligence system, natural language processing, neural networks Using PROLOG to design expert systems, converting rules to PROLOG, conceptual example, introduction to LISP, function evaluation, lists, predicates, rule creation.

**EXPERT SYSTEM DEVELOPMENT**

Definition, choice of domain, collection of knowledge base, selection of inference mechanism, case studies of expert system development in design and manufacturing - Expert systems, controlling reasoning, rule based system, canonical systems, rules and meta rules, associative nets and frame systems, graphs trees and networks, representing uncertainity, probability in expert systems-learning, forms of learning, inductive learning.

**EXPERT SYSTEM TOOLS**

Decision trees, knowledge in learning, heuristic classification, heuristic matching, case studies in expert systems, MYCIN, Meta- Dendral, general structure of an expert system shell, examples of creation of an expert system using an expert system tool, fundamentals of object oriented programming, creating structure and object, object operations, invoking procedures, programming applications, object oriented expert system.

**INDUSTRIAL APPLICATION OF AI AND EXPERT SYSTEMS**

Robotic vision systems, image processing techniques, application to object recognition and inspection, automatic speech recognition – applications in automotive industries and nuclear power projects.

***References:***


1. *Robert Levine et al, "**A Comprehensive Guide to AI and Expert Systems"**, McGraw Hill Inc, 1988.*
2. *Henry C Mishkoff, **"Understanding AI"**, BPB Publication, New Delhi, 1986.*
3. *Peter Jackson, "**Introduction to Expert Systems"**, First Indian Reprint, 2000, Addison, Wesley.*
4. *Stuart Russell and Peter Norvig, "**Artificial Intelligence: A Modern Approach"**, Prentice Hall, 1995.*
5. *Elaine Rich et al., **"Artificial Intelligence"**, McGraw Hill, 1995.*
6. *Winston P H, **"Artificial Intelligence"**, Addison Wesley, Reading, Massachusetts, Third Edition, 1992*

| MFE18R 6108 | Reliability and quality engineering | L | T | P | C |
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**QUALITY CONCEPTS**

Quality objectives - Quality control - Quality Assurance - Quality systems, economics, Statistical tolerancing - Quality loss function.

**STATISTICAL PROCESS CONTROL**

Process variability - Control charts for variables and attributes, Moving average control charts, multivarichart- Cumulative chart - demerit control chart - process capability studies.

**DESIGN OF EXPERIMENTS**

Factorial experiments - fractional replication - Taguchi methods - Use of orthogonal arrays –Response surface methodol-ogy- Cases.

**RELIABILITY AND QUALITY MANAGEMENT**

Reliability function – failure rate – mean time between failures (MTBF) – mean time to failure (MTTF) – A priori and a posteriori concept - mortality curve – useful life – availability – maintainability – system effectiveness Reliability predic-tion and testing - Quality circles - Zero defects program - ISO 9000 and TQM - Total quality organisation.

**RELIABILITY MANAGEMENT AND RISK ASSESSMENT**

Reliability testing – Reliability growth monitoring – Non-parametric methods – Reliability and life cycle costs – Reliability allocation – Replacement model-Definition and measurement of risk – risk analysis techniques – risk reduction resources– industrial safety and risk assessment.

***References:***


1. *Logothetis.N, **"Managing for total quality from Deming to Taguchi and SPC**", PHI, 1997.*
2. *Fiegenbarum.A.V**, "Total Quality Control"**, McGraw Hill Inc., 1991.*
3. *Douglas, C.Montgomery, **"Introduction to Statistical quality control"**, Second Edition John Wiley AND Sons, 1991.*
4. *Srinath L.S, **"Reliability Engineering"**, Affiliated East-West Press Pvt Ltd, New Delhi, 1998.*
5. *Modarres, **"Reliability and Risk analysis**", Maral Dekker Inc.1993.*
6. *Dale H.Besterfield, **"Quality Improvement",** PHI, 2010.*

| MFE18R 7101 | Manufacturing Strategy | L | T | P | C |
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**STRATEGY PLANNING**

Nature of production-inventory management systems. Strategic, Tactical and Operational decisions. general discrete location-allocation problems - features and formulations. Facility location models median model - distribution model - brown and gibson model

**TACTICAL PLANNING**

Aggregate production planning - ways to absorb demand fluctuations - costs relevant to aggregate production planning - aggregate production planning models - Inventory management - EOQ decision rules - costs in an inventory system - simple lot size model

**SCHEDULING**

Operations scheduling - Flow shop - n jobs – 2 machine Johnson's rule, 2 Jobs –M machine, N-Jobs M machine Sequencing Job on parallel machine - Assembly Line Balancing- Project Scheduling-crashing of project network with cost trade off

**MRP & MRP-II**

Material Requirement Planning (MRP) - working of MRP - Use of MRP system - evolution from MRP to MRP II - master production scheduling - rough cut capacity planning - capacity requirement planning - Lot sizing in MRP II system.

**SCM & QUALITY MANAGEMENT**

Concept of supply management and SCM, Flow in supply chains, Key issues in supply chain management, Decision phases in supply chain, concept of quality management - standards for quality management - statistical process control - Taguchi method of quality control.

**REFERENCES**

1. H.G. Menon,, “TQM in New Product Manufacturing”, Mc Graw Hill, 1992.
2. Hax and Candea., “Production and Inventory Management”, Prentice Hall, 1984.

Buffa., “Modern Production Management”, John Welley, 1983.

| MFE18R 7102 | Advanced tool design | L | T | P | C |
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**TOOL-DESIGN METHODS**

Introduction – The Design Procedure – Statement of the problem – The Needs Analysis – Research and Ideation – Tentative Design Solutions – The Finished Design – Drafting and Design Techniques in Tooling drawings – Screws and Dowels – Hole location – Jig-boring practice – Installation of Drill Bushings – Punch and Die Manufacture – Electro-discharge machining – Electro-discharge machining for cavity.

**TOOLING MATERIALS AND HEAT TREATMENT**

Introduction – Properties of Materials – Ferrous Tooling Materials – Tool steels – Cast Iron – Mild, or low-carbon Steel– Nonmetallic Tooling Materials – Nonferrous Tooling Materials – Metal cutting Tools – Single-point cutting tools – Milling cutters – Drills and Drilling – Reamer classification – Taps – Tap classification- the selection of carbide cutting tools – Determining the insert thickness for carbide tools.

**DESIGN OF DRILL JIGS**

Introduction – Fixed Gages – Gage Tolerances – The selection of material for Gages – Indicating Gages – Automatic gages – Principles of location – Locating methods and devices – Principles of clamping – Drill jigs – Chip formation in drilling – General considerations in the design of drill jigs – Drill bushings – Methods of construction – Drill jigs and modern manufacturing.

**DESIGN OF FIXTURES AND DIES**

Introduction – Fixtures and economics – Types of Fixtures – Vise Fixtures – Milling Fixtures – Boring Fixtures – Broaching Fixtures – Lathe Fixtures – Grinding Fixtures – Types of Die construction – Die-design fundamentals – Blanking and Piercing die construction – Pilots – Strippers and pressure pads- Presswork materials – Strip layout – Short-run tooling for Piercing – Bending dies – Forming dies – Drawing operations.

**TOOL DESIGN FOR NUMERICALLY CONTROLLED MACHINE TOOLS**

Introduction – The need for numerical control – A basic explanation of numeric control – Numerical control systems in use today – Fixture design for numerically controlled machine tools – Cutting tools for numerical control – Tool holding methods for numerical control – Automatic tool changers and tool positioners – Tool presetting – Introduction – General explanation of the Brown and sharp machine – tooling for Automatic screw machines

***References:***

1. *Cyrll Donaldson, George H.LeCain, V.C. Goold, "**Tool Design**", Tata McGraw Hill Publishing Company Ltd., 2000.*
2. *Prakash Hiralal Joshi, **"Tooling data"**, Wheeler Publishing, 2000*

| MFE18R 7103 | Composite Materials | L | T | P | C |
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**INTRODUCTION**

Fundamentals of composites- need for composites- classifications of composites- Matrix-Polymer matrix composite (PMC),Metal matrix composites(MMC),Ceramic matrix composites(CMC), Graphite matrix composites- Reinforcement-Particle reinforced composites, Fibre reinforced composites. Types of fibre and resin materials and their properties-Advantages and applications of various types of composites.

**BASIC CONCEPTS**

Hooke's law for orthotropic and anisotropic materials-Governing equations for orthotropic and anisotropic plates-Micromechanics and Macro mechanics-Lamina-Laminates- Angle ply and cross ply Laminates - Lamina stress-strain relations.

**ANALYSIS OF LAMINATED COMPOSITES**

Static, dynamic and stability analysis for simpler cases of laminated composite plates-inter laminar stresses.

**ANALYSIS AND FAILURE THEORY**

Netting analysis- Failure criteria- Sandwich construction.

**PROCESSING OF METAL MATRIX COMPOSITES AND CERAMIC MATRIX COMPOSITES**

Solid state fabrication techniques – diffusion bonding – powder metallurgy techniques plasma spray, chemical and physical vapour deposition of matrix on fibres Chemical vapour infiltration – liquid state fabrication methods – infiltration – squeeze and stir casting – rheo casting – compo casting - Interfaces properties– application of MMC and ceramic matrix composites.

***References:***


1. *R.M. Jones, "**Mechanics of Composite Materials**", 2nd Edition, Taylor & Francis, 1999*
2. *L.R. Calcote, "**Analysis of laminated structures**", Van Nostrand Reinhold Co., 1989*
3. *G.Lubin, "**Hand Book on Fiber Glass and Advanced Plastic Composites**", Van Nostrand Co., 1989.*
4. *B.D. Agarwal and L.J. Broutman, "**Analysis and Performance of Fiber Composites**", John-Wiley and Sons, 1990.*
5. *Autar K. Kaw, "**Mechanics of Composite Materials"**, CRC Press LLC, 1997*

| MFE18R 7104 | Corrosion and surface engineering | L | T | P | C |
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**MFEHANISMS AND TYPES OF CORROSION**

Principles of direct and Electro chemical Corrosion, Hydrogen evolution and Oxygen absorption mechanisms – Galvanic corrosion, Galvanic series-specific types of corrosion such as uniform, Pitting, Intergranular, Cavitations, Crevice Fretting, Erosion and Stress Corrosion –Factors influencing corrosion

**TESTING AND PREVENTION OF CORROSION**

Corrosion testing techniques and procedures- Prevention of Corrosion-Design against corrosion Modifications of corrosive environment –Inhibitors – Cathodic Protection – Protective surface coatings.

**CORROSION BEHAVIOR OF MATERIALS**

Corrosion of steels, stainless steel, Aluminum alloys, copper alloys, Nickel and Titanium alloys- corrosion of Polymers, Ceramics and Composite materials.

**SURFACE ENGINEERING FOR WEAR AND CORROSION RESISTANCE**

Diffusion coatings –Electro and Electroless Plating –Hot dip coating –Hard facing-Metal spraying, Flame and Arc processes-Conversion coating –Selection of coating for wear and Corrosion resistance.

**THIN LAYER ENGINEERING PROCESSES**

Laser and Electron Beam hardening –Effect of process variables such as power and scan speed - Physical vapor deposition, Thermal evaporation, Arc vaporization, Sputtering, Ion plating - Chemical vapor deposition – Coating of tools, TiC, TiN, $Al_2O_3$ and Diamond coating – Properties and applications of thin coatings.

***References:***


1. *Fontana. G., **"Corrosion Engineering"**, McGraw Hill, 1985.*
2. *Serope Kalpakjian, **"Manufacturing Engineering and Technology"** Addison Wesley Publishing Co; New York 1995.*
3. *Schweitzer. P.A., **"Corrosion Engineering Hand Book"**, 3rd Edition, Marcel Decker, 1996.*
4. *Winston Revie.R. Uhlig, **Corrosion, Hand Book 2nd Edition**. John Wiley, 2000.*
5. *Kenneth G.Budinski, **"Surface Engineering for Wear Resistance"**, Prentice hall, 1988.*
6. *ASM Metals Hand Book –Vol. 5, "**Surface Engineering"**, 1996.*

| MFE18R 7105 | Advances in casting and welding processes | L | T | P | C |
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**CASTING METALLURGY AND DESIGN**

Heat transfer between metal and mould – Solidification of pure metal and alloys – Shrinkage in cast metals – progressive and directional solidification – Principles of grating and restring – Degasification of the melt – Design considerations in casting – Designing for directional solidification and minimum stresses – casting defects

**SPECIAL CASTING PROCESSES**

Shell moulding – Precision investment casting – $CO_2$ – moulding – centrifugal casting – Die casting – Continuous casting.

**WELDING METALLURGY AND DESIGN**

Heat affected Zone and its characteristics – Weldability of steels, cast iron, Stainless steel,aluminum and Titanium alloys– Hydrogen embrittlement – Lamellar tearing – Residual stress – Heat transfer and Solidification – Analysis of stresses in welded structures – pre and post welding heat treatments – Weld joint design – Welding defects – testing of weldment by FEA technique

**UNCONVENTIONAL AND SPECIAL WELDING PROCESSES**

Friction welding – Explosive welding – Diffusion bonding – High frequency Induction welding – Ultrasonic welding – Electron beam welding – Laser beam welding

**RECENT ADVANCES IN CASTING AND WELDING**

Layout of mechanised foundry – sand reclamation – Material handling in foundry – pollution control in Foundry – Recent trends in casting – Computer Aided design of Castings, Low pressure die casting, Squeeze casting and full mould casting process – Automation in welding – Welding robots – Overview of automation of welding in aerospace, nuclear, surface transport vehicles and under water welding.

***References:***


1. *R. W. Ruddle, "**Solidification of Castings, Institute of Metals"**, London, 1957.*
2. *J. Campbell, "**Casting"**, Butterworkth Heineman, Oxford, 1993.*
3. *Schwartz, M.M., "**Metal Joining Manual**", McGraw Hill, NY, 1979.*
4. *Titoun.D. and Stepanov .YU.A., **"Foundry Practice"**, MIR Publishers, 1981.*
5. *Iotrowski, **"Robotic welding – A guide to selection and application"**, Society of Mechanical Engineers, 1987.*
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7. *Serope Kalpakjian**, "Manufacturing Engineering and Technology"** Third Edition, Addison Wesley Publishing Co.1995*
8. *P.N.Rao, **"Manufacturing Technology (Foundry, Forming and Welding)",** Second*

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## IV – INTERDISCIPLINARY ELECTIVE

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| MFE18R 6109 | Industrial safety management | L | T | P | C |
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**SAFETY MANAGEMENT**

Evaluation of modern safety concepts - Safety management functions - safety organization, safety department - safety committee, safety audit - performance measurements and motivation - employee participation in safety - safety and productivity.

**OPERATIONAL SAFETY**

Hot metal Operation - Boiler, pressure vessels - heat treatment shop - gas furnace operation - electroplating-hot bending pipes - Safety in welding and cutting. Cold-metal Operation - Safety in Machine shop - Cold bending and chamfering of pipes - metal cutting - shot blasting, grinding, painting - power press and other machines.

**SAFETY MEASURES**

Layout design and material handling - Use of electricity - Management of toxic gases and chemicals - Industrial fires and prevention - Road safety - highway and urban safety - Safety of sewage disposal and cleaning - Control of environmental pollution - Managing emergencies in Industries - planning, security and risk assessments, on- site and off site. Control of major industrial hazards.

**ACCIDENT PREVENTION**

Human side of safety - personal protective equipment - Causes and cost of accidents. Accident prevention programmes - Specific hazard control strategies - HAZOP - Training and development of employees - First Aid- Fire fighting devices - Accident reporting, investigation.

**SAFETY, HEALTH, WELFARE AND LAWS**

Safety and health standards – OHAS Industrial hygiene - occupational diseases prevention - Welfare facilities - History of legislations related to Safety-pressure vessel act-Indian boiler act - The environmental protection act - Electricity act - Explosive act.

***References:***


1. *John V. Grimaldi and Rollin H. Simonds, "**Safety Management**", All India Travellers bookseller, New Delhi-1989.*
2. *Krishnan N.V., "**Safety in Industry**", Jaico Publisher House, 1996.*
3. ***Occupational Safety Manual** BHEL.*
4. ***"Industrial safety and the law"** by P.M.C. Nair Publisher's, Trivandrum.*
5. ***"Managing emergencies in industries"**, Loss Prevention of India Ltd., Proceedings, 1999.*
6. ***"Safety security and risk management"** by U.K. Singh & J.M. Dewan, A.P. Publishing company, New Delhi,1996.*
7. *Singh,U.K and Dewan.J.M, "**Safety, Security and Risk management**", APH PublishingCompany, New Delhi, 1996*

| MFE18R 6110 | MEMS and nano technology | L | T | P | C |
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**OVERVIEW OF MEMS AND MICROSYSTEMS**

Definition – historical development – fundamentals – properties, micro fluidics, design and fabrication micro-system, microelectronics, working principle and applications of micro system, MEMS Simulation and Design tools-Behavioral model ling simulation tools and Finite element simulation tools.

**MATERIALS, FABRICATION PROCESSES AND MICRO SYSTEM PACKAGING**

Substrates and wafers, silicon as substrate material, mechanical properties of Si, Silicon Compounds silicon piezo resistors, Galium arsenide, quartz, polymers for MEMS, conductive polymers. Photolithography, photo resist applications, light sources, in implantation, diffusion process exudation – thermal oxidation, silicon diode, chemical vapour deposition, sputtering - deposition by epitoxy – etching – bulk and surface machining – LIGA process Micro system packaging – considerations packaging – levels of micro system packaging die level, device level and system level.

**MICRO DEVICES AND MATERIALS**

Sensors – classification – signal conversion ideal characterization of sensors micro actuators, mechanical sensors – displacement sensors, pressure and flow sensors, micro actuators – smart materials – applications.

**SCIENCE OF NANO MATERIALS**

Classification of nano structures – effect of the nanometer length scale effects of nanoscale dimensions on various properties – structural, thermal, chemical, mechanical, magnetic, optical and electronic properties – effect of nanoscale dimensions on biological systems. Fabrication methods – Top down processes – bottom up process.

**CHARACTERIZATION OF NANO MATERIALS**

Nano-processing systems – Nano measuring systems – characterization – analytical imaging techniques – microscopy techniques, electron microscopy scanning electron microscopy, transmission electron microscopy, transmission electron microscopy, scanning tunneling microscopy, atomic force microscopy, diffraction techniques – spectroscopy techniques – Raman spectroscopy, 3D surface analysis – Mechanical, Magnetic and thermal properties – Nano positioning systems.

***References:***

1. *Tai – Ran Hsu, **"MEMS and Microsystems Design and Manufacture"**, Tata-McGraw Hill, New Delhi, 2002.*
2. *Mark Mado, **"Fundamentals of Microfabrication"**, CRC Press, New York, 1997.*
3. *Norio Taniguchi, **"Nano Technology"**, Oxford University Press, New York, 2003*
4. *Mohamed Gad-el-Hak, **"The MEMS Hand book"**, CRC Press, New York, London.*

5. *Charles P Poole, Frank J Owens, **"Introduction to Nano technology**", John Wiley and Sons, 2003*
6. *Julian W. Hardner , **"Micro Sensors, Principles and Applications**", CRC Press 1993.*

| MFE18R 6111 | Testing, inspection and quality control of weldments | L | T | P | C |
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**DESTRUCTIVE TESTING OF WELDMENTS**

Tensile tests, impact tests, all-weld – metal tests, COD test, transverse test, Nick-break test, bend tests, hardness tests, hot cracking tests, cold cracking tests, transition temperature test – Experimental stress analysis –HAZ and white layer thickness analysis

**BASIC CONCEPTS OF NDT**

Relative merits and limitations of NDT Vs. Conventional testing – Visual inspection, thermal inspection methods. Liquid penetrant Inspection: Principles, applications advantages and limitations, Dyes, developers and cleaners, fluorescent penetrant test application of liquid penetrant testing to weldments.Magnetic Particle Inspection: Principle, application, magnetization methods – magnetic particles, dry and wet technique, demagnetization. Principles, application and Instrumentation of Eddy current testing.

**X-RAY RADIOGRAPHY**

Types of radiation, properties of X- rays relevant to NDE, absorption of X-rays, scattering, types and use of filters and screens, geometric factors, inverse square law, film types and processing, characteristics of films – grain fineness, density, speed contrast characteristics curves, penetrameters, Exposure charts, radiographic equivalence.Gamma ray Radiography:Gamma ray sources, comparison with X ray radiography radioactive decay, artificial radioactivity, characteristics of Gamma ray sources, Gamma exposure chart. Measurement of radioactivity, radiation hazards, units of radiation dose measurement, permissible radiation dose, radiation detection and measurement instruments, protection against radiation. Brief description of fluoroscopy, gamma radiography. Standard radiographys, Interpretation of radiographs, application of radiographic testing to weldments.

**ULTRASONICS**

Types of ultrasonics waves, principles of wave propagation characteristics of ultrasonic waves, attenuation, production of ultrasonic waves, couplants. Inspection methods – pulse echo, transmission and resonance, thickness measurement. Types of scanning, test blocks IIW reference block. Calibration of Ultrasonic equipment, application of ultrasonic testing to weldments. Holography, acoustic emission techniques – Miscellaneous techniques like leak testing, pressure testing, chemical spot testing, spark testing.

**INSPECTION AND QUALITY CONTROL**

Principles of inspection, inspection organization, qualification of inspectors, authority and responsibility, quantum of inspection, types of inspection, statistical quality control. Welding procedure specification, procedure qualification records, performance

qualification, variables.

***References:***


1. *Hull, "**Non Destructive Testing**", ELBS Edition, 1991.*
2. *Baldevraj, Jayakumar.T, Thavasimuthu.M, **"Practical Non-destructive Testing**", Narosa Publishers, 1997.*
3. *McGonnagle.W.T, "**Non-Destructive Testing**", McGraw Hill, 1961.*
4. *Nadkarni.S.V, "Modern **Arc Welding Technology**", Oxford IBH, 1996.*
5. *Montgomery.C.Douglus, "**Introduction to Statistical Quality Control**", 2nd Edition, John Wiley and Sons, 1991.*
6. *Mohamed Zairi, "**Total Quality Management for Engineers**", Woodhead Publishing*

| MFE18R 6112 | Vibration control and condition monitoring | L | T | P | C |
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**INTRODUCTION**

Review of Fundamentals of single Degree Freedom systems-Two Degree Freedom systems, Multi Degree Freedom systems, Continuous systems, Determination of Natural frequencies and mode shapes, Numerical methods in Vibration Analysis.

**VIBRATION CONTROL**

Introduction-Reduction of Vibration at the source-Control of vibration-by structural design-Material selection- Localized additions-Artificial Damping-Resilient isolation, Vibration isolation and absorbers.

**ACTIVE VIBRATION CONTROL**

Introductions - Concepts and Applications, Review of smart materials-Types and characteristic review of smart structures - Characteristic Active vibration control in smart structures.

**CONDITION BASED MAINTENANCE PRINCIPLES AND APPLICATIONS**

Introduction-condition monitoring methods- Design of Information system, Selecting methods of monitoring, Machine condition monitoring and diagnosis-Vibration severity criteria-Machine Maintenance Techniques-Machine condition monitoring techniques-Vibration monitoring techniques-Instrumentation systems-choice of monitoring parameter.

**DYNAMIC BALANCING AND ALIGNMENT OF MACHINERY**

Introduction, Dynamic balancing of Rotors, Field Balancing in one plane, Two planes and in several planes, Machinery alignment, Rough Alignment methods, The Face Peripheral Dial Indicator Method, Reverse indicator Method, Shaft-to-coupling spool method

***References:***

1. *Singiresu S.Rao, "**Mechanical vibrations**", Addison - Wesley Publishing Co., 1995.*
2. *J.O.Den Hartog, "**Mechanical Vibrations**"-McGraw Hill, NMewYork, 1985.*
3. *Rao J S, "**Vibratory Condition Monitoring of Machines**", Narosa Pubulishing House, 2000.*

| MFE18R 6113 | Financial management and cost accounting | L | T | P | C |
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**TECHNIQUES OF INVESTMENT ANALYSIS**

Payback period method, Accounting Rate of Return, Introduction to Discounting and cash flows estimation, DCF methods, IRR, NPV, PI, Discounted payback methods, DCF method compared- conflicts resolution-Leasing and Lease evaluation.

**FINANCING DECISION**

Cost of capital, cost of equity, Debt, convertible Debentures, preference share capital, Minimum rate of return, capital structure, Optimum capital structure, Traditional theory, MM theory, corporate debt capacity, Indifference point.

**DIVIDEND DECISION**

Dividend policy, Gordon's dividend Growth model, Walter's model, MM dividend Irrelevance Model, Practice in Industry.

**WORKING CAPITAL MANAGEMENT**

Current asset and liability decisions, estimation of working capital requirements, cash and marketable securities, Management of accounts receivables, financial aspects of investment, spontaneous financing, short term borrowings

**COST ACCOUNTING**

Meaning and objectives, Classification, Elements of cost Accounting, Elements of costs, Preparation of cost sheet, Allocation and absorption of overheads, Budgetary Control - Types of budgets - Cash Budget, Functional Budgets, Flexible Budgets - Preparation and Interpretation

***References:***

1. *Pandey, I.M, "**Financial Management**", Vikas Publishing House Pvt. Ltd., 8th Edition, 1999.*
2. *Prasanna Chandra, "**Financial Management**", Theory and Practice, Tata McGraw-Hill Publishing Company Ltd, 5th Edition, 2001.*
3. *James C Vanhorne, "**Financial Management and Policy",** Pearson Education Asia, 2002.*
4. *Khan and Jain, "**Basic Financial Management and Practice**", Tata McGraw Hill – 2001.*
5. *S.K Bhattacharyya., John Dearden., "**Costing for Management**", Vikas Publishing*

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| MFE18R 6114 | Logistics and Supply Chain Management | L | T | P | C |
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**INTRODUCTION**

Evolution, Importance, Components, Scope and Objectives, Significance – Interface with other functions. Concept of Logistics and Supply Chain Management and evolution to 4PL, Trade off Customer Service & Cost

**INVENTORY**

Need of Inventory – Costs associated with Inventory – Types of Inventory – Basic EOQ Model – EOQ with discounts – Classification of material – ABC Analysis – VED, HML, FSN, GOLF, SOS

**MATERIAL REQUIREMENT PLANNING**

Advantages over conventional planning (Order Point Method) – Input and output of MRP system – Forecasting – Overview of quantitative and qualitative methods of forecasting – Master Production Schedule – Bill of Materials – BOM Explosion – Material flow in MRP. MRP II.

**PURCHASING MANAGEMENT AND STORES**

Responsibilities of Purchase Department – Purchase Cycle – Negotiation & Bargaining – Vendor relations – Purchasing Methods – Global sourcing, Stores-Functions, Importance, Organization of stores & Stores layout. Stores procedure – documentation.

**INVENTORY CONTROL & COST REDUCTION TECHNIQUES**

Inventory turns ratios – Standardization – need and importance. Codification – concept, benefits. Value Engineering and Value Analysis – concept and process.

**References**

1. L C Jhamb, "Materials and logisticsManagement", Everest Publishing House.
2. Gopalkrishnan, P, "Handbook Of Materials Management", PHI.
3. Saroj Kumar & Priyanka Singh, "Materials and Logistics Management", Thakur Publishers.