# Scheme of Teaching and Examination for M.Tech.-Manufacturing Science & Engineering (MSE)

## I Semester

<table>
<thead>
<tr>
<th>Subject Code</th>
<th>Name of the Subject</th>
<th>Teaching hours/week</th>
<th>Marks for Total</th>
<th>CREDITS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lecture</td>
<td>I.A.</td>
<td>Exam</td>
</tr>
<tr>
<td>14 MSE 11</td>
<td>Quality &amp; Reliability Engineering</td>
<td>4</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>14 MSE 12</td>
<td>Advanced Foundry Technology</td>
<td>4</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>14 MSE 13</td>
<td>Theory of Metal Forming</td>
<td>4</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>14 MSE 14</td>
<td>Advanced Materials &amp; Processing</td>
<td>4</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>14 MSE 15x</td>
<td>Elective - I</td>
<td>4</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>14MSE16</td>
<td>Lab Component</td>
<td>--</td>
<td>25</td>
<td>50</td>
</tr>
<tr>
<td>14MSE17</td>
<td>Seminar</td>
<td>--</td>
<td>25</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>20</strong></td>
<td><strong>300</strong></td>
<td><strong>550</strong></td>
</tr>
</tbody>
</table>

### Elective – I

<table>
<thead>
<tr>
<th>Sub. Code</th>
<th>Name of the Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 MSE 151</td>
<td>Applied Probability and Statistics</td>
</tr>
<tr>
<td>14 MSE 152</td>
<td>Composite Materials</td>
</tr>
<tr>
<td>14 MSE 153</td>
<td>Theory of Metal Cutting</td>
</tr>
<tr>
<td>14 MSE 154</td>
<td>Computer Integrated Manufacturing &amp; Automation</td>
</tr>
<tr>
<td>14MSE 155</td>
<td>Quantitative Techniques in Decision Making</td>
</tr>
<tr>
<td>14MSE156</td>
<td>Operations Management</td>
</tr>
</tbody>
</table>
## II Semester

<table>
<thead>
<tr>
<th>Subject Code</th>
<th>Name of the Subject</th>
<th>Teaching hours/week</th>
<th>Duration of Exam in Hours</th>
<th>Marks for Total Marks</th>
<th>CREDITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 MSE 21</td>
<td>Industrial Robotics</td>
<td>Lecture: 4, Practical / Field Work / Assignment / Tutorials: 2</td>
<td>3</td>
<td>50 100 150</td>
<td>4</td>
</tr>
<tr>
<td>14 MSE 22</td>
<td>Non-Traditional Machining Processes</td>
<td>Lecture: 4, Practical / Field Work / Assignment / Tutorials: 2</td>
<td>3</td>
<td>50 100 150</td>
<td>4</td>
</tr>
<tr>
<td>14 MSE 23</td>
<td>Non-Destructive Testing</td>
<td>Lecture: 4, Practical / Field Work / Assignment / Tutorials: 2</td>
<td>3</td>
<td>50 100 150</td>
<td>4</td>
</tr>
<tr>
<td>14 MSE 24</td>
<td>Surface Treatment &amp; Finishing</td>
<td>Lecture: 4, Practical / Field Work / Assignment / Tutorials: 2</td>
<td>3</td>
<td>50 100 150</td>
<td>4</td>
</tr>
<tr>
<td>14 MSE 25x</td>
<td>Elective-II</td>
<td>Lecture: 4, Practical / Field Work / Assignment / Tutorials: 2</td>
<td>3</td>
<td>50 100 150</td>
<td>4</td>
</tr>
<tr>
<td>14MSE26</td>
<td>Lab Component</td>
<td>Lecture: 3, Practical / Field Work / Assignment / Tutorials: 3</td>
<td>3</td>
<td>25 50 75</td>
<td>2</td>
</tr>
<tr>
<td>14MSE27</td>
<td>Seminar</td>
<td>Lecture: --, Practical / Field Work / Assignment / Tutorials: 3</td>
<td>--</td>
<td>25 -- 25</td>
<td>1</td>
</tr>
</tbody>
</table>

**Project Phase-I (6 week Duration)**

**Total**

<table>
<thead>
<tr>
<th>Lecture</th>
<th>Practical / Field Work / Assignment / Tutorials</th>
<th>I.A.</th>
<th>Exam</th>
<th>Total Marks</th>
<th>CREDITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>13</td>
<td>15</td>
<td>300</td>
<td>550</td>
<td>850</td>
</tr>
</tbody>
</table>

---

**Elective – II**

<table>
<thead>
<tr>
<th>Sub. Code</th>
<th>Name of the Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 MSE 251</td>
<td>Simulation &amp; Modeling of Manufacturing Systems</td>
</tr>
<tr>
<td>14 MSE 252</td>
<td>Finite Element Methods</td>
</tr>
<tr>
<td>14 MSE 253</td>
<td>Agile manufacturing</td>
</tr>
<tr>
<td>14 MSE 254</td>
<td>Advanced Joining Processes</td>
</tr>
<tr>
<td>14 MSE 255</td>
<td>Agile manufacturing</td>
</tr>
</tbody>
</table>

**Between the II Semester and III Semester, after availing a vocation of 2 weeks.**
### VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELGAUM

**SCHEME OF TEACHING AND EXAMINATION FOR**

**M.TECH.-MANUFACTURING SCIENCE & ENGINEERING (MSE)**

### III Semester: INTERNSHIP

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Subject</th>
<th>No. of Hrs./Week</th>
<th>Duration of the Exam in Hours</th>
<th>Marks for Total Marks</th>
<th>CREDITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>14MSE31</td>
<td>Seminar / Presentation on Internship (After 8 weeks from the date of commencement)</td>
<td>-</td>
<td>-</td>
<td>25 -</td>
<td>25</td>
</tr>
<tr>
<td>14MSE32</td>
<td>Report on Internship</td>
<td>-</td>
<td>-</td>
<td>75 75</td>
<td>15</td>
</tr>
<tr>
<td>14MSE33</td>
<td>Evaluation and Viva-voce</td>
<td>-</td>
<td>-</td>
<td>50 50</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>-</td>
<td>-</td>
<td>25 125</td>
<td>20</td>
</tr>
</tbody>
</table>

**CREDIT BASED**

**Total Credits: 20**
# Scheme of Teaching and Examination for M.Tech.-Manufacturing Science & Engineering (MSE)

## IV Semester

<table>
<thead>
<tr>
<th>Subject Code</th>
<th>Subject</th>
<th>No. of Hrs./Week</th>
<th>Duration of Exam in Hours</th>
<th>Marks for Total Marks</th>
<th>CREDITS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lecture</td>
<td>Field Work / Assignment / Tutorials</td>
<td>I.A.</td>
<td>Exam</td>
</tr>
<tr>
<td>14MSE41</td>
<td>Tool Design</td>
<td>4</td>
<td>--</td>
<td>3</td>
<td>50</td>
</tr>
<tr>
<td>14MSE42</td>
<td>X Elective-III</td>
<td>4</td>
<td>-</td>
<td>3</td>
<td>50</td>
</tr>
<tr>
<td>14MSE43</td>
<td>Evaluation of Project Phase-II</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>25</td>
</tr>
<tr>
<td>14MSE44</td>
<td>Evaluation of Project Phase-III</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>25</td>
</tr>
<tr>
<td>14MSE45</td>
<td>Evaluation of Project Work and Viva-voce</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>12</td>
<td>07</td>
<td>09</td>
<td>150</td>
</tr>
</tbody>
</table>

**Grand Total (I to IV Sem.) : 2400 Marks; 94 Credits**

## Elective – III

<table>
<thead>
<tr>
<th>Sub. Code</th>
<th>Name of the Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 MSE 421</td>
<td>Industrial Design &amp; Ergonomics</td>
</tr>
<tr>
<td>14 MSE 422</td>
<td>Advanced Manufacturing Practices</td>
</tr>
<tr>
<td>14 MSE 423</td>
<td>Advanced Fluid Power Systems</td>
</tr>
<tr>
<td>14 MSE 424</td>
<td>Project Management</td>
</tr>
<tr>
<td>14 MSE 425</td>
<td>Nano Technology</td>
</tr>
</tbody>
</table>
Note:

1) Project Phase – I: 6 weeks duration shall be carried out between II and III Semesters. Candidates in consultation with the guides shall carryout literature survey / visit to Industries to finalise the topic of dissertation.

2) Project Phase – II: 16 weeks duration. 3 days for project work in a week during III Semester. Evaluation shall be taken during the first two weeks of the IV Semester. Total Marks shall be 25.


Marks of Evaluation of Project:

• The I.A. Marks of Project Phase – II & III shall be sent to the University along with Project Work report at the end of the Semester.

4) During the final viva, students have to submit all the reports.

5) The Project Valuation and Viva-Voce will be conducted by a committee consisting of the following:

   a) Head of the Department (Chairman)
   b) Guide
   c) Two Examiners appointed by the university. (out of two external examiners at least one should be present).
QUALITY AND RELIABILITY ENGINEERING

Subject Code : 14 MSE 11  IA Marks : 50
No. of Lecture Hours/Week : 04  Exam Hours : 03
Total No. of Lecture Hours : 52  Exam Marks : 100

Basic Concepts: Definitions of quality and Reliability, Parameters and Characteristics, Quality control, statistical Quality Control, Reliability concepts.


Introduction to Probability Distributions : Normal, Poisson and Binomial distribution.

Control Charts : Variable Chart – X Bar chart, R-chart and Sigma chart. Attribute Chart : P – Chart, nP Chart, C-Chart and U – Chart.

Acceptance Sampling: Fundamentals of acceptance sampling, types of acceptance sampling, O.C Curve, AQL, LTPD, AOQL.

Failure Data Analysis : Introduction, Failure Data, Quantitative measures, MTTF, MTBF, Bathtub Curve, Mean Life, Life Testing, Problems, Introduction to Failure Mode and Effect Analysis.

System Reliability: Series, parallel and mixed configuration, Block diagram concept, r- out-of-n structure solving problems using mathematical models.

Reliability Improvement and Allocation : Difficulty in achieving reliability, Methods for improving reliability during design, Different techniques available to improve reliability, Optimization, Reliability-Cost trade off, Prediction and Analysis, Problems.

Maintainability and Availability: Introduction, Formulas, Techniques available to improve maintainability and availability trade-off among reliability, maintainability and availability, Simple problems

REFERENCE BOOKS:


ADVANCED FOUNDRY TECHNOLOGY

Subject Code: 14 MSE 12  
IA Marks: 50

No. of Lecture Hours/Week: 04  
Exam Hours: 03

Total No. of Lecture Hours: 52  
Exam Marks: 100


Design of Casting: Factors to be considered in casting design. Design consideration in pattern making, moulding techniques and core making and assembly. Cooling stresses and hot spots in casting and modification in casting geometry to overcome them.

Casting Quality Control: Casting defects and factors responsible for them. Different inspection and testing methods to evaluate the casting. Quality control activities in a foundry. Salvaging methods of defective casting.


Malleable Cast Iron: Chemical composition and structure of White-heart and black-heart malleable cast iron. Melting malleabilisation heat treatment and application of malleable cast iron.


Steel Casting Practice: Common steel casting, their composition,structure and properties. Melting and refining of steel. Gating and risering of steel castings cleaning of steel castings.

Aluminium Foundry Practice: Composition, properties and application of common aluminum alloy casting. Melting and casting of Al-alloys. Gating and risering of Al-alloy casting.

Copper alloy Foundry Practice: General characteristics of common cast copper alloys. Melting and casting of copper alloys. Gating and risering of cu-alloy castings.


REFERENCE BOOKS:

3. Foundry Technology - Beeley, P.R. – Butterworth.
THEORY OF METAL FORMING

Subject Code : 14 MSE 13  
IA Marks : 50  
No. of Lecture Hours/Week : 04  
Exam Hours : 03  
Total No. of Lecture Hours : 52  
Exam Marks : 100


Forging: Classification, various stages during forging.Forging equipment, brief description, deformation in compression, forging defects. Residual stresses in forging.

Rolling of Metals: Classification, forces and geometrical relationships in rolling.

Variables in Rolling: Deformation in rolling, Defects in rolled products, Residual stresses in rolled products. Torque and Horsepower.

Extrusion: Classification, Extrusion equipment, variables in extrusion, Deformation in extrusion, Extrusion defects, Work done in extrusion.

Drawing: Principles of Rod and wire drawing, variables in wire drawing, Residual stresses in rod, wire and tube drawing, Defects in Rod and wire drawing.

Sheet Metal Forming: Introduction, Forming methods, shearing andBlanking, Bending, stretch forming, Deep drawing, redrawing operations, Defects in formed products.

REFERENCE BOOKS:

Classification and characteristics: Metals, Ceramics, Polymers and composites.

General properties and structure: Atoms, molecules bonds in solids, Crystalline - Defects in Metallic structure, Dislocations and plastic deformation - Strengthening mechanism - grain size, dislocation - Cold work, precipitation hardening, dispersion hardening - phase reactions, fatigue and Creep behavior.


Non Ferrous alloys: Alloys of copper, Aluminum, nickel, magnesium, titanium, lead, tin, Zinc - composition, heat treatment, structure, properties and application.

Polymers and polymerizations: Structure and properties of thermoplastics and thermo sets – Engineering Applications - property modifications - Mechanical and thermal behavior – processing methods.


Composites: Definition - classification and characteristics of composite materials - Volume fraction - laminated composites particulate composites, fibrous composites - Types of reinforcements, their shape and size - production and properties of fiber reinforced plastics, Metal Matrix composites and ceramic matrix composites - Applications.

Processing of Polymers: composites, ceramics - thermal spraying - Ion beam machining diamond coating techniques-tribological Applications.

REFERENCE BOOKS:

1. Engineering Metallurgy - Raymond and Higgens - ELBS/EA
Elective – I

APPLIED PROBABILITY AND STATISTICS

<table>
<thead>
<tr>
<th>Subject Code</th>
<th>IA Marks</th>
<th>No. of Lecture Hours/Week</th>
<th>Exam Hours</th>
<th>Total No. of Lecture Hours</th>
<th>Exam Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 MSE 151</td>
<td>50</td>
<td>04</td>
<td>03</td>
<td>52</td>
<td>100</td>
</tr>
</tbody>
</table>

Introduction to statistics: Statistical Thinking, Collecting data, Statistical Modeling Framework, measure of central tendency and variance, Importance of Data summary and Display, Tabular and Graphical display.


Continuous Random Variables and Probability Distributions: Continuous random variables, Probability distributions and probability density functions, cumulative distribution functions, Mean and Variance of a continuous random variable, uniform distribution, Normal distribution, Normal approximation to Binominal and Poisson distribution, Exponential distribution.

Testing of Hypothesis: Estimation theory, Hypothesis testing, Inference on the mean of a population (variance known and unknown), Inference on the variance of a normal population, Inference on a population proportion, Testing for Goodness of Fit, Inference for a difference in Means, Variances known, Inference for a difference in means of two normal distributions, Variances unknown, Inference on the Variances of two normal populations, Inference on two population proportions.

Simple Linear Regressions and Correlation: Simple Linear Regression, Properties of Least square Estimators and Estimation of variances, Transformations to a straight line, Correlation.

Multiple linear regressions: Multiple linear regressions model, least square estimation of parameters, Matrix approach to multiple linear regression, properties of least square estimators and estimation of variance.

TEXT BOOKS:

REFERENCES:
**COMPOSITE MATERIALS**

<table>
<thead>
<tr>
<th>Subject Code</th>
<th>14 MSE 152</th>
<th>IA Marks</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Lecture Hours/Week</td>
<td>04</td>
<td>Exam Hours</td>
<td>03</td>
</tr>
<tr>
<td>Total No. of Lecture Hours</td>
<td>52</td>
<td>Exam Marks</td>
<td>100</td>
</tr>
</tbody>
</table>

**Introduction to Composite Materials:** Definition, Classification, Types of matrices & reinforcements, characteristics & selection, Fiber composites, laminated composites, particulate composites, prepegs, sandwich construction.

**Micro Mechanical Analysis of a Lamina:** Introduction, Evaluation of the four elastic moduli – Rule of mixture, Macro mechanics of a lamina: Hooke’s law for different types of materials, number of elastic constants, Laminate code, Failure criterion.

**Manufacturing: Lay Up and Curing** – open and closed mould processing – Hand lay up techniques Bag moulding and filament winding. Pultrusion, Pulforming, Thermoforming, Injection moulding, Cutting, Machining and joining, tooling, Quality assurance Introduction, material qualification, types of defects, NDT methods.

**Fabrication of Composites:** Cutting, machining, drilling, mechanical fasteners & adhesive bonding joining computer aided design manufacturing tooling fabrication equipment

**Design of Fibre Reinforced Composite Structures:**
Introduction, Composite structural design, Design criteria, Laminate design, Mathematical analysis of the laminate, Design of composite stiffeners.

**Application Developments** – Aircrafts, missiles, space hardware, automobile, electrical and electronics, marine, recreational and sports equipment-future potential of composites.

**Metal Matrix Composites:** Re-inforcement materials, types, Characteristics & Selection, base metals-selection, applications. Powder metallurgy technique, liquid metallurgy technique

**TEXT BOOKS:**

THEORY OF METAL CUTTING

<table>
<thead>
<tr>
<th>Subject Code</th>
<th>14 MSE 153</th>
</tr>
</thead>
<tbody>
<tr>
<td>IA Marks</td>
<td>50</td>
</tr>
<tr>
<td>No. of Lecture Hours/Week</td>
<td>04</td>
</tr>
<tr>
<td>Exam Hours</td>
<td>03</td>
</tr>
<tr>
<td>Total No. of Lecture Hours</td>
<td>52</td>
</tr>
<tr>
<td>Exam Marks</td>
<td>100</td>
</tr>
</tbody>
</table>

**Mechanics of Metal Cutting:** Mechanism of chip formation, Orthogonal & Oblique cutting, types of chips, built-up edge, Determination of shear plane angle, forces on the chips, forces in orthogonal cutting, Merchant circle diagram and analysis, Theory of Lee & Shaffer, co-efficient of friction, power & energy relationship, velocity relationship, shear-strain, factors affecting forces and power, problems.

**Geometry of Cutting Tools:** Single point and multi point cutting tools, tools nomenclature, tool point reference systems, tool angle specifications –ISO and ASA systems, conversion from one system to another. Recommended tool angles, Effect of cutting parameters on tool geometry.

**Tool Materials and Their Properties:** Characteristics of tool materials, types of tool materials – carbon tool steels, high speed steels, cast alloys, cemented carbides, ceramics, diamonds, SIALON, CBN, UCON, recommended cutting speeds for the above tools, discussion on steels, air, water, oil hardening of tools and their applications.

**Measurement of Cutting Forces:** Reasons for measuring cutting forces, Classification of cutting force dynamometers – mechanical, hydraulic, pneumatic, optical, inductance, piezoelectric, and strain gage type dynamometers, Dynamometers for lathe, drilling, and milling, Calibration of dynamometers.

**Tool Wear, Tool Life:** Mechanisms of tool wear, Sudden & gradual wear, crater wear, flank wear, tool failure criteria, tool life equations, effect of process parameters on tool life, tool life tests, conventional & accelerated tool wear measurement, machinability index

**Thermal Aspects in Metal Cutting:** Heat sources in metal cutting, temperature in chip formation, temperature distribution, experimental determination of tool temperatures.

**Cutting fluids:** Basic actions of cutting fluids, properties of cutting fluids, selection of cutting fluids, application of cutting fluids, filtration of fluids, recommended cutting fluids.

**Economics of Machining:** Introduction, elements of total production cost, optimum cutting speed and tool life for minimum cost, optimum cutting speed and tool life for maximum production, problems.

**Reference Books**


**Metal Cutting** - Dr. B.J.Ranganath - Vikas Publications

Computer Process Monitoring: Process control methods, direct digital control, supervisory computer control, steady state optimal control, on line search strategies, adaptive control.

Computer Aided Quality Control: The computer in Q.C, automated inspection principles and methods, Contact inspection methods, non-contact inspection methods, machine vision system, optical inspection method, sensors, coordinate, measuring machine, Computer-Aided testing, Integration of CAQL with CAD/CAM.


Detroit type of Automation: Flow lines, Transfer Mechanisms, work pattern transfer, Different methods, & Problems.

Analysis of Automated flow lines: Analysis of transfer lines without storage with storage buffer single stage, Double stage, Multistage with problems, Automated assembly systems, Design for automated assembly, parts feeding devices, analysis of Multi station assembly machine, Analysis of Single stage assembly machine,

Automated Material Handling Storage: Material functions, types of material handling equipment, analysis of material handling systems, design of system, conveyor system, automated guided vehicle systems, automated storage/retrieval systems, caroused storage systems work in process storage, interfacing handling & storage with manufacturing.

REFERENCE BOOKS:

1. CAD/CAM - Zimmers & Grover – PHI.
Introduction: Applications of statistics in managerial decision making, The basic vocabulary of statistics, Types of variables, Data collection – primary and secondary data, the methods of collecting data, Measures of central tendency, Measure of dispersion, Skewness and Kurtosis, Measures of a population, Probability - basic concepts, types, rules of probability, Baye’s theorem; Random variables, Probability distributions - Binomial, Poisson, and Normal.


Transportation and Assignment Problems: Structure of transportation problem and various methods to find I.B.F.S., Optimality test of transportation problems by MODI method, Solution of unbalanced transportation problems and maximization problems, degeneracy in the solution of transportation problems; Assignment problems and solution by Hungarian method, Traveling Salesman problem.

Decision Making under Uncertainty: Alternative criteria for decision under uncertainty, Bayesian approach.

Theory of Games: Terminology involved, Types of games, Solution of mixed strategy games by dominance rule, algebraic method, graphical method, and by linear programming approach.

Network Analysis: Network construction, Analysis techniques – PERT and CPM, Determination of critical path, Computation of ES, EF, LS, LF, TF and FF, Crashing of a project, Resource scheduling and leveling in a project.

Waiting Line: Basic structure of queuing systems and characteristics, Expressions for M/M/l and M/M/c queuing models.

Simulation of Management Systems: Steps in building a simulation model, Advantages and disadvantages of simulation, the applications of simulation to managerial decision making, Monte Carlo Simulation, Waiting line and Inventory simulation models.

REFERENCE BOOKS:

OPERATIONS MANAGEMENT

Sub Code : 10 MSE 156  IA Marks : 50
No. of Lecture Hrs/week : 04  Exam Hours : 03
Total Lecture Hrs : 52  Exam Marks : 100


System Design and Capacity: Introduction, Manufacturing and service systems, Design and systems capacity, Capacity planning.

Forecasting Demand: Forecasting objectives and uses, Forecasting variables, Opinion and Judgmental methods, Time series methods, Moving Average methods , Exponential smoothing, Trend adjusted Exponential Smoothing, Regression and correlation methods, Application and control of forecasts-Mean Absolute Deviation, BIAS, Tracking Signal.

Aggregate Planning and Master Scheduling: Introduction- planning and scheduling, Objectives of aggregate planning, Three Pure Strategies, Aggregate planning methods, Master scheduling objectives, Master scheduling methods.

Material and Capacity Requirements Planning: Overview: MRP and CRP, MRP: Underlying concepts, System parameters, MRP logic, System refinements, Capacity management, CRP activities.

Scheduling and Controlling Production Activities: Introduction, PAC, Objectives and Data requirements, Loading –Finite and Infinite Scheduling methodology, priority sequencing, capacity control.

Single Machine Scheduling: Concept, measures of performance, SPT rule, Weighted SPT rule, EDD rule.

Flow –Shop Scheduling: Introduction, Johnson’s rule for ‘n’ jobs on 2 and 3 machines, CDS heuristic.

Job-Shop Scheduling: Types of schedules, Heuristic procedure, scheduling 2 jobs on ‘m’ machines.

Text Books:
2. Productions & operations management by Adam & Ebert.
3. Pannerselvam. R., Production and Operations Management, PHI.

References:
Laboratory Exercises
14 MSE 16

Perform any Eight / Ten experiments:

1. Determination of Chip reduction co-efficient (reciprocal of chip thickness ratio) during single point turning.

2. Forces measurements during orthogonal turning.

3. Estimation of Power required during orthogonal turning.

4. Torque and Thrust measurement during drilling.

5. Determination of cutting forces during milling using Milling tool dynamometer.


7. Study the variation of surface roughness with different speed and feed during plain milling operation on flat surface.

8. Study of capstan lathe and its tooling and prepare a tool layout & job as per given drawing.

9. To prepare metallic samples for metallographic examination and to study the principle & construction of the Metallurgical Microscope.

10. Study of Microstructure and Hardening of steel in different medium and cooling rates.

11. Effect of Carbon percentage on the hardness of Steel.

12. CNC milling- Writing and execution of part program for contour milling.
II SEMESTER
INDUSTRIAL ROBOTICS

Subject Code : 14 MSE 21 IA Marks : 50
No. of Lecture Hours/Week : 04 Exam Hours : 03
Total No. of Lecture Hours : 52 Exam Marks : 100


COMPUTER CONSIDERATIONS FOR ROBOTIC SYSTEMS: Computer architecture for robots, hardware, Computational elements in robotic applications – Robot programming – sample programs path planning – Robot’s computer system.


TEXT BOOKS:

REFERENCE BOOKS:
NON-TRADITIONAL MACHINING PROCESSES

<table>
<thead>
<tr>
<th>Subject Code</th>
<th>No. of Lecture Hours/Week</th>
<th>Total No. of Lecture Hours</th>
<th>IA Marks</th>
<th>Exam Hours</th>
<th>Exam Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 MSE 22</td>
<td>04</td>
<td>52</td>
<td>50</td>
<td>03</td>
<td>100</td>
</tr>
</tbody>
</table>

**Introduction:** Need for non-traditional machining processes. Processes selection classification on – comparative study of different processes.

**Mechanical Process:** Ultrasonic Machining-Definition-Mechanism of metal elements of the process- Tool feed mechanism, theories of mechanics of causing effect of parameter applications.

**Abrasive Jet Machining:** Principles - parameters of the process applications-advantages and advantages.


**Chemical Machining:** Introduction-fundamental principle types of chemical machining Maskants- Etchenes- Advantages and disadvantages-applications.

**Plasma arc Machining:** Introduction-Plasma-Generation of Plasma and equipment Mechanism of metals removal, PAN parameters-process characteristics - type of torches applications.

**Electron Beam Machining (EBM):** Introduction-Equipment for production of Electron beam - Theory of electron beam machining Thermal & Non thermal types characteristics - applications.

**Laser Beam Machining (LBM):** Introduction-principle of generation of lasers Equipment and Machining procedure-Types of Lasers-Process characteristics-advantages and limitations-applications

**Ion Beam Machining:** Introduction-Mechanism of metal removal and associated equipment-process characteristics applications

**High Velocity Forming Process:** introduction - development of specific process selection-comparison of conventional and high velocity forming methods - Types of high velocity forming methods- explosion forming process-elector hydraulics forming magnetic pulse forming.

**REFERENCE BOOKS:**

1. New technology Institution of Engineers - Bhattacharya - India
NON-DESTRUCTIVE TESTING

<table>
<thead>
<tr>
<th>Subject Code</th>
<th>14 MSE 251</th>
<th>IA Marks</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Lecture</td>
<td>04</td>
<td>Exam Hours</td>
<td>03</td>
</tr>
<tr>
<td>Hours/Week</td>
<td></td>
<td>Exam Marks</td>
<td>100</td>
</tr>
<tr>
<td>Total No. of Lecture Hours</td>
<td>52</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Introduction to ND Testing: Selection of ND methods, visual inspection, leak testing, Liquid penetration inspection, its advantages and limitation.

Magnetic Particle Inspection: Methods of generating magnetic field, types of magnetic particles and suspension liquids steps in inspection – application and limitations.

Eddy Current Inspection: principles, operation variables, procedure, inspection coils, and detectable discounts by the method.

Microwave Inspection: Microwave holography, applications and limitations.

Ultrasonic inspection: Basic equipment characteristics of ultrasonic waves, variables inspection, inspection methods pulse echo A,B,C scans transmission, resonance techniques, transducer elements couplets, search units, contact types and immersion types inspection standards-standard reference blocks.

Radiography Inspection: principles, radiation source X-rays and gamma rays, X-ray-tube, radio graphic films, neutron radiography, Thermal inspection principles, equipment inspection methods applications.

Optical Holography: Basics of Holography, recording and reconstruction - Acoustical Holography: systems and techniques applications. Indian standards for NDT.

REFERENCE BOOKS:

SURFACE TREATMENT & FINISHING

<table>
<thead>
<tr>
<th>Subject Code</th>
<th>14 MSE 252</th>
<th>IA Marks</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Lecture</td>
<td>04</td>
<td>Exam Hours</td>
<td>03</td>
</tr>
<tr>
<td>Hours/Week</td>
<td></td>
<td>Total No. of Lecture Hours</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Exam Marks</td>
<td>100</td>
</tr>
</tbody>
</table>


**Vacuum coating**, FVD & CVD metal spraying - Methods, surface preparation, mechanical

**Properties of sprayed metals, plasma coating.**

**Plastic coating of metal** - PVC coating Spherodising process details, phosphate coating - mechanism of formation.

**Testing of surface coating** methods.


**Heat treatment methods for gears, spindles, cutting tools.**

**Advanced coating technologies**: Hard facing, electro deposition technique, nanocoatings, coating characterization

**REFERENCE BOOKS:**

5. **Metals Hand Book** – ASM.
SIMULATION AND MODELING OF MANUFACTURING SYSTEMS.

Subject Code : 14 MSE 253  IA Marks : 50
No. of Lecture Hours/Week : 04  Exam Hours : 03
Total No. of Lecture Hours : 52  Exam Marks : 100


System and Environment: Components of a system -discrete and continuous systems, Models of a system -a variety of modeling approaches.


Statistical Models in Simulation: Discrete distributions, continuous distributions.

*** Ivica Cmkovic, Ulfaskluna and Annita borsen Dohlgvist Publisher Artechhouse.

Random Variable Generation: Inversion transforms technique-exponential distribution, uniform distribution, weibul distribution, continuous distribution, generating approximate normal variates-Erlang distribution.

Empirical Discrete Distribution: Discrete uniform -distribution poisson distribution -geometric distribution -acceptance -rejection technique for Poisson distribution gamma distribution.


Simulation Software: Selection of simulation software, simulation packages.

TEXT BOOKS:

REFERENCE BOOKS:
### FINITE ELEMENT METHODS

<table>
<thead>
<tr>
<th>Subject Code</th>
<th>: 14MSE 254</th>
<th>IA Marks : 50</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Lecture Hours/Week</td>
<td>: 04</td>
<td>Exam Hours : 03</td>
</tr>
<tr>
<td>Total No. of Lecture Hours</td>
<td>: 52</td>
<td>Exam Marks : 100</td>
</tr>
</tbody>
</table>

**Introduction:** Equations of equilibrium, stress-strain relations for 2-D and 3-D, Potential energy and equilibrium, Boundary conditions, Von Misses Stresses

**FEM for 1-D Problems:** General procedure for FEA, Raleigh Ritz method, Galerkin Approach, shape functions, stiffness matrix, load vectors, temperature effects, Applications of boundary conditions using elimination, penalty and multi-constraint approaches, Application problems – 1-D bar element, Trusses and beams

**FEM for 2-D Problems:** Shape functions, stiffness matrix, strain matrix, load vectors for CST Elements and application problems

**FEM for Axisymmetric Problems:** Axisymmetric formulation, triangular elements, PE approach, Body force term, application problems

**FEM for Scalar Field Problems:** 1-D Steady state heat transfer, torsion, potential flow and fluid flow in ducts and application problems

**Dynamic Analysis:** Equations of motion for dynamic problems --consistent and lumped mass matrices --formulation of element mass matrices free vibration and forced vibration problems formulation,

**REFERENCE BOOKS:**

AGILE MANUFACTURING

Subject Code : 14 MSE 253 IA Marks : 50
No. of Lecture Hours/Week : 04 Exam Hours : 03
Total No. of Lecture Hours : 52 Exam Marks : 100

Introduction - What is agile Manufacturing? - Competitive environment of the future the business case for agile manufacturing conceptual frame work for agile manufacturing.

Four Core Concepts: Strategy driven approach - integrating organization, people technology interdisciplinary design methodology.

Agile Manufacturing and Change Management: The change implications. Post failures in advanced manufacturing, changes on the way, traditional management accounting, paradigm, investment appraisal, product costing - performance, measurement and control systems, Traditional organization, control technological and design paradigms traditional problems in workplace- organizational issues - role of technology.

Agile Manufacturing Enterprise Design: Agile manufacturing - enterprise design.. system concepts as the basic manufacturing theory - joint technical & organizational design and a model for the design of agile manufacturing enterprise, enterprise design process insights into design processes, what is interdisciplinary design, Main issues - simple design example.


REFERENCE BOOKS:
ADVANCED JOINING PROCESSES

Subject Code : 14 MSE 254  
IA Marks : 50

No. of Lecture Hours/Week : 04  
Exam Hours : 03

Total No. of Lecture Hours : 52  
Exam Marks : 100

Distortion- methods to avoid distortion. Stresses in Joint Design.

Welding and Cladding of dissimilar materials, overlaying and surfacing.


Advanced soldering and Brazing processes different types.

Welding of plastics.

Inspection of Welds: Destructive techniques like Tensile, Bend, Nick break, Impact & Hardness. Non-Destructive techniques like 'X' rays, Ultrasonic, Magnetic particle, Dye Penetrant, Gamma ray inspection.

Welding Symbols- Need for, Representing the welds, Basic weld symbols, Location of Weld, Supplementary symbols, Dimensions of welds, Examples


Quality Control in Welding - Introduction, Quality assurance v/s Quality control, Weld quality, Discontinuities in welds, their causes and remedies and Quality conflicts.


REFERENCE BOOKS:

4. **Welding Technology** - O.P. Khanna
5. **Welding for Engineers** - Udin, Funk & Wulf
AGILE MANUFACTURING

<table>
<thead>
<tr>
<th>Subject Code</th>
<th>: 14 MSE255</th>
<th>IA Marks : 50</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Lecture Hours/Week</td>
<td>: 04</td>
<td>Exam Hours : 03</td>
</tr>
<tr>
<td>Total No. of Lecture Hours</td>
<td>: 52</td>
<td>Exam Marks : 100</td>
</tr>
</tbody>
</table>

**Introduction** - What is agile Manufacturing? - Competitive environment of the future the business case for agile manufacturing conceptual frame work for agile manufacturing.

**Four Core Concepts:** Strategy driven approach - integrating organization, people technology interdisciplinary design methodology.

**Agile Manufacturing and Change Management:** The change implications. Post failures in advanced manufacturing, changes on the way, traditional management accounting, paradigm, investment appraisal, product costing - performance, measurement and control systems, Traditional organization, control technological and design paradigms traditional problems in workplace- organizational issues - role of technology.

**Agile Manufacturing Enterprise Design:** Agile manufacturing - enterprise design.. system concepts as the basic manufacturing theory - joint technical & organizational design and a model for the design of agile manufacturing enterprise, enterprise design process insights into design processes, what is interdisciplinary design, Main issues - simple design example.

**Skill & Knowledge Enhancing Technologies for Agile Manufacturing:** Skill and Knowledge enhancing Technologies - scheduling - technology design strategic-Design Concepts. Design and Skill of Knowledge enhancing Technologies for machine tool systems - Historical overview, Lessons, problems and Future development.

**REFERENCE BOOKS:**

Laboratory Exercises

14 MSE 26

01. Study of pick and place Robot- basic components, configuration, work volume

02. Experiments with Robot. Kit for minimum four assembly activities and programming

03. Programming of robots by manual, lead through and off line methods

04. Programming languages for stacking of objects in increasing or decreasing size. Palletizing operations, assembly and inspection operation etc.

05. To become acquainted with the operation of a revolute-type 6 DOF robot. To program a robotic system using a teaching pendant and a high level programming language. Emphasis is made on the constraints associated when positioning and orienting an object within a 3-D space. The practical includes point-to-point tasks and continuous robot motion.
IV SEMISTER

TOOL DESIGN

<table>
<thead>
<tr>
<th>Subject Code</th>
<th>IA Marks</th>
<th>No. of Lecture Hours/Week</th>
<th>Exam Hours</th>
<th>Total No. of Lecture Hours</th>
<th>Exam Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>14MSE41</td>
<td>50</td>
<td>04</td>
<td>03</td>
<td>52</td>
<td>100</td>
</tr>
</tbody>
</table>

Tool-design Methods: Introduction, the design procedure, drafting and design techniques in tooling drawing

Tool-making Practices: Introduction, tools of the tool maker, hand finishing and polishing, screws and dowels, hole location, jig-boring practice, installation of drilling bushings, punch and die bushings, punch and die manufacture, EDM, EDM for cavity applications, tracer and duplicating mills for cavity applications, low-melting tool materials.


Design of Cutting Tools: Introduction, the metal cutting process, revision of metal cutting tools-single point cutting tools, milling cutters, drills and drilling, reamers, taps. Selection of carbide tools, determining the insert thickness for carbide tools.

Design of Tools for Inspection and Gauging: Introduction, work piece quality criteria, principles of gauging, types of gages and their applications, amplification and magnification of error, gage tolerances, selection of material for gages, indicating gages, automatic gages, gauging positionally tolerance parts, problems.

Locating and Clamping Methods: Introduction, basic principle of location, locating methods and devices, basic principle of clamping.


Design of Fixtures: Introduction, types of fixtures, fixtures and economics.

Design of Press-working Tools: Power presses, cutting operations, types of die-cutting operations - and their design, evolution of blanking and progressive blanking.


Tool Design for NC Machine Tools: Revision of NC control, fixture design for NC machine tools, cutting tools and tool-holding methods, automatic tool chargers and tool positioners.

Plastics as Tooling Materials: Introduction, plastics commonly used as tooling materials, application of epoxy plastic tools, construction methods, metal forming operations with Urethane dies, calculating forces for Urethane
pressure pads, problems.

TEXT BOOKS:


REFERENCE BOOKS:

ELECTIVE -III

INDUSTRIAL DESIGN & ERGONOMICS

Subject Code : 14MSE421  IA Marks : 50
No. of Lecture Hours/Wk : 04  Exam Hours : 03
Total No. of Lecture Hours : 52  Exam Marks : 100

Introduction: An approach to industrial design - elements of design structure for industrial design in engineering application in modern manufacturing systems.

Ergonomics and Industrial Design: Introduction - general approach to the man-machine relationship-workstation design-working position.

Control and Displays: shapes and sizes of various controls and displays - multiple displays and control situations - design of major controls in automobiles, machine tools etc., - design of furniture design of instruments.

Ergonomics and Production: Ergonomics and product design ergonomic in automated systems-expert systems for ergonomic design, Anthropomorphic data and its applications in ergonomic design limitations of anthropomorphic data - use of computerized database.

Visual Effects of Line and Form: The mechanics of seeing psychology of seeing, general influences of lined and form.

Colour: colour and light - colour and objects - colour and the eye colour consistency - colour terms - reactions to colour and colour continuation - colour on engineering equipments.

Aesthetic Concepts: Concept of unity - concept of order with variety - concept of purpose style and environment - Aesthetic expressions. Style-components of style - house style, observations style in capital goods.

Industrial Design in Practice: General design - specifying design equipments - rating the importance of industrial design – industrial design in the design process.

TEXT BOOKS:

ADVANCED MANUFACTURING PRACTICES

Subject Code : 14 MSE 422 IA Marks : 50
No. of Lecture Hours/Week : 04 Exam Hours : 03
Total No. of Lecture Hours : 52 Exam Marks : 100

Need of CPC for a company, what CPC can do, CPC-getting the right tool.

JIT – Introduction – The spread of JIT Movement, some definitions of JIT, core Japanese practices of JIT, Creating continuous Flow Manufacture, Enabling JIT to occur, Basic elements of JIT, Benefits of JIT.

Just in Time Production – Primary purpose, profit through cost reduction, Elimination of over production, Quality control, Quality Assurance, Respect for Humanity, Flexible work Force, JIT Production Adapting to changing production Quantities, process layout for shortened lead Times, Standardization of operation, Automation.

Sequence and Scheduling Used by Suppliers: Monthly and daily Information. Sequenced withdrawal system by sequenced schedule table, problems and counter measures in applying the Kanban system to sub contractors.

Toyota Production System–The philosophy of TPS, Basic Frame work of TPS, Kanbans. Determining the Number of Kanbans in Toyota Production System.
   a) Kanban Number under Constant Quantity Withdrawal System.
   b) Constant Cycle, Non-constant Quantity Withdrawal System.

Supplier Kanban and the Sequence Schedule for Use by Suppliers.
   a) Later Replenishment System by Kanban.
   b) Sequenced Withdrawal System.
   c) Circulation of the Supplier Kanban within Toyota.

Production Smoothing in TPS
Production Planning
Production Smoothing
Adaptability to Demand Fluctuations
Sequencing Method for the Mixed Model Assembly Line to Realize Smoothed Production of Goal.

Just-in-Time Production with Total Quality Control just in time concept, cutting lot sizes, cutting set-up times, cutting purchase order costs, the JIT cause-Effect chain, Scrap/Quality Improvements, Motivational effects, Responsibility effects, small Group improvement Activities, withdrawal of Buffer Inventory, the total Quality Control Concept.

Total Quality Control-Introduction–Total Quality Control concepts, responsibility, learning from the west, TQC concepts categorized, Goals, Habit of improvement, perfection, Basics, process control, Easy to see Quality control as facilitator, small lot sizes, Housekeeping, Less than full capacity scheduling, Daily machine checking, Techniques and Aids, Exposure of problems, Fool proof Devices, Tools of Analysis, QC Circles, TQC in Japanese-owned US Electronics plant, TQC in Japanese-owned Automotive plants.

Plant Configurations: Introduction–ultimate lant configuration, job shop Fabrication, Frame Welding, Forming Frame parts from Tubing, Dedicated production lines, overlapped production, the daily schedule, Forward Linkage by means of Kanban, physical merger of processes, Adjacency, mixed Models, Automated production Lines, Pseudo Robots, Robots, CAD and Manufacturing, Conveyors and stacker Cranes, Automatic Quality Monitoring
TEXT BOOKS:
2. **Just In Time Manufacturing** – Kargoanker (manual).

REFERENCE BOOKS:
1. **An Integrated Approach To Just In Time** - Yasuhiro Monden - Toyota Production system.
**ADVANCED FLUID POWER SYSTEMS**

<table>
<thead>
<tr>
<th>Subject Code</th>
<th>IA Marks</th>
<th>No. of Lecture Hours/Week</th>
<th>Exam Hours</th>
<th>Total No. of Lecture Hours</th>
<th>Exam Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>14MSE423</td>
<td>50</td>
<td>04</td>
<td>03</td>
<td>52</td>
<td>100</td>
</tr>
</tbody>
</table>

**Introduction:** Pascal Law, Advantages of Fluid Power, Applications of Fluid Power, Components of a Fluid Power.

**Hydraulic Power Unit:** Introduction, Pumping Theory, Pump Classification, Gear Pumps, (Vane Pumps- simple, balanced & pressure compensated vane pump, Vane design) Piston Pumps- Radial, Axial (Bent axis & Swash plate), Pump Performance, Pump Noise, Ripple in pumps.

**Hydraulic Actuators:** Linear actuator- cylinders, Mechanics of Hydraulic cylinder loading, limited rotation hydraulic actuator, cylinder cushioning, Gear, Vane & Piston motor, Motor performance, Hydrostatic transmission

**Power Controlling Elements – Valves:**

i) Directional Control Valves – Classification, 2/2, 3/2,4/2 & 4/3 ways Dcv’s, Different Centre configurations in 4/3 way valves, actuation of DCV’s, Indirect actuation, Valve Lap – Lap during Stationary and during switching.

ii) Pressure Control Valves: Classification, opening & Closing Pressure difference, Cracking Pressure, Pressure Relief Valve – Simple & Compound type, Pressure reducing valve, sequence, unloading & Counter balance valve, Pressure switches.


iv) Check valve, Pilot operated check valve.

**Hydraulic Circuit Design & Analysis:** Control of Single & double acting cylinder, Regeneration circuit, cylinder sequencing & Synchronizing circuit. Speed control of cylinder & Motors, Analysis of Hydraulic system with frictional losses, Accumulators &accumulator circuits.

**Pneumatic System:** Introduction, – Generation of compressed air, air receiver, servicing FRL unit, Air filter, pressure regulation, lubricator, Pneumatic cylinder & air motor – different types of cylinder, cushion assembly. Cylinder performance.

**Pneumatic Valve:** Directional control valves, impulse valve, Quick exhaust valve, shuttle valve, Twin pressure valve, Time delay valve,

**Pneumatic Circuit & Logic Circuits:** Control of single and double acting cylinder, impulse operation, speed control, sequencing, Pneumatic Vacuum system AND,OR, NOT, NAND, NOR, YES Function, Logic circuits design using shuttle valve & twin pressure valve, Binary Arithmetic, logic & Boolean Algebra, use of kannaugh veitch map for pneumatic circuit design.

**Electrical Control in Fluid Power:** Contactors, & Switches, Relays, Limit switch, Electro hydraulic & Electro Pneumatic Circuits, Simple Cylinder reciprocation, interlocking using relays, Proximity switches, application of proximity switches, Time dependent will dependent and travel dependent circuits.

**REFERENCE BOOKS:**

2. Oil hydraulics -Principles & maintenance - S.R. Majumdar - Tata M C Graw Hill
3. Components & Application - Bosch Rexroth didactic - Hydraulics Trainer - vol 1. Publication
5. Pneumatics: Theory and Applications - Bosch Rexroth didactic - Publication

MEANS OF FINANCING: Profitability and Breakeven Analysis—Cash Flows of Projects—Tax factor in investment Analysis—Interest—Compounding and Discounting.


NETWORKS TECHNIQUE IN PROJECT MANAGEMENT: PERT/CPM Analysis—Administrative aspects of Capital Investment.

REFERENCE BOOKS:

3. Project Management—Dennis lock.
NANO TECHNOLOGY

Sub Code : 14 MSE 425
IA Marks : 50
No. of Lecture Hrs/week : 04
Exam Hours : 03
Total Lecture Hrs : 52
Exam Marks : 100

Metal based nanocomposites - Metal-Oxide or Metal-Ceramic composites, Different aspects of their preparation techniques and their final properties and functionality. Metal-metal nanocomposites, some simple preparation techniques and their new electrical and magnetic properties.

Design of Super hard materials - Super hard nanocomposites, its designing and improvements of mechanical properties.

Nanofiller synthesis, applications, Polymer nanocomposites, particulate and fibre modified nanocomposites, matrices and fibres, polymer-filler interphase, pull-out strength, effect of various treatments.


Polymer-carbon nanotubes based composites, processing methods and characterization using SEM, XRD, TEM

Characterization of Polymer nanotubes based composites for Mechanical, Electrical and Thermal Properties and their applications - Polymer / nanofillers (metallic nanopowders) systems, Rheological measurements, processing characteristics

Testing of nanocomposites, Thermal analysis such as TGA, TMA, DSC, DMTA

REFERENCE BOOKS:
