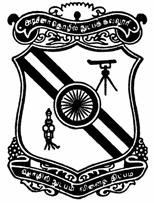
MASTER OF ENGINEERING

MANUFACTURING ENGINEERING

CURRICULUM AND SYLLABUS





**GOVERNMENTCOLLEGEOFTECHNOLOGY,**

**COIMBATORE-641013**

***An Autonomous Institution – Anna University***

Curriculum

&

Syllabus

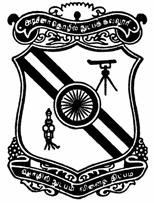
**CANDIDATES ADMITTED DURING 2016 - 2017 ONWARDS**

MASTER OF ENGINEERING

MANUFACTURING ENGINEERING

CURRICULUM AND SYLLABUS





GOVERNMENT COLLEGE OF TECHNOLOGY,

COIMBATORE - 641013

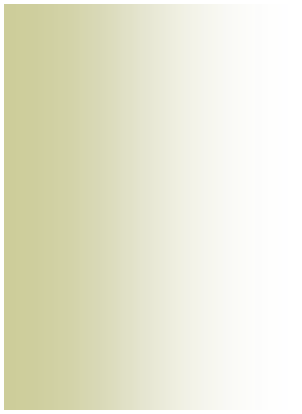
***An Autonomous Institution - Anna University***

Curriculum

&

Syllabus

**CANDIDATES ADMITTED DURING 2016 – 2017 ONWARDS**



**INSIDE .. .**

Curriculum for Full Time

Candidates

Curriculum for Part Time

Candidates

List of Elective Subjects

Syllabus for Core

Subjects

Syllabus for Elective

Subjects

**M.E. DEGREE :FULLTIME &PART TIME - MANUFACTURING ENGINEERING Page:1**

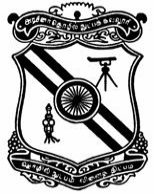
**CURRICULUM**

MASTER OF ENGINEERING

**MANUFACTURING ENGINEERING**

**FULLTIME**

**CURRICULUM**



***(Full Time Candidates admitted during 2016-2017 and onwards)***

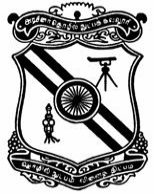
**FIRST SEMESTER**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S. No** | **Subject**  **Code** | **Course Title** | **Category** | **CA Marks** | **End Sem Marks** | **Total**  **Marks** | **CREDITS** | | | |
| **L** | **T** | **P** | **C** |
| 1. | 16MFFC01 | APPLIED PROBABILITY AND STATISTICS | FC | 50 | 50 | 100 | 3 | 2 | 0 | 4 |
| 2. | 16MFFC02 | DESIGN FOR MANUFACTURE, ASSEMBLY AND ENVIRONMENT | FC | 50 | 50 | 100 | 3 | 2 | 0 | 4 |
| 3. | 16MFPC01 | [AUTOMATED COMPUTER INTEGRATED MANUFACTURING SYSTEMS](file:///C:\Users\RAJESH\Downloads\ME%20MANUFACTURING%20CURRICULUM.doc#MF9112) | PC | 50 | 50 | 100 | 3 | 0 | 0 | 3 |
| 4. | 16MFPC02 | [ADVANCED MACHINING](file:///C:\Users\RAJESH\Downloads\ME%20MANUFACTURING%20CURRICULUM.doc#MF9113) PROCESSES AND AUTOMATION | PC | 50 | 50 | 100 | 3 | 0 | 0 | 3 |
| 5. | 16MFPC03 | ADDITIVE MANUFACTURING | PC | 50 | 50 | 100 | 3 | 0 | 0 | 3 |
| 6 | 16MFPC04 | [OPTIMIZATION TECHNIQUES IN ENGINEERING](file:///C:\Users\RAJESH\Downloads\ME%20MANUFACTURING%20CURRICULUM.doc#MF9158) | PC | 50 | 50 | 100 | 3 | 2 | 0 | 4 |
|  |  | **TOTAL** |  |  |  | **600** |  |  |  | **21** |

**SECOND SEMESTER**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S. No** | **Subject**  **Code** | **Course Title** | **Category** | **CA Marks** | **End Sem Marks** | **Total**  **Marks** | **CREDITS** | | | |
| **L** | **T** | **P** | **C** |
| 1. | 16MFPC05 | ADVANCED ENGINEERING MATERIALS AND METALLURGY | PC | 50 | 50 | 100 | 3 | 0 | 0 | 3 |
| 2. | 16MFPC06 | SUPPLY CHAIN MANAGEMENT | PC | 50 | 50 | 100 | 3 | 2 | 0 | 4 |
| 3. | 16MFPC07 | THEORY OF METAL CUTTING | PC | 50 | 50 | 100 | 3 | 2 | 0 | 4 |
| 4. | E1 | ELECTIVE 1 | PE | 50 | 50 | 100 | 3 | 0 | 0 | 3 |
| 5. | E2 | ELECTIVE 2 | PE | 50 | 50 | 100 | 3 | 0 | 0 | 3 |
| 6. | E3 | ELECTIVE 3 | PE | 50 | 50 | 100 | 3 | 0 | 0 | 3 |
| **PRACTICAL** | | | | | | | | | | |
| 7 | 16MFPC08 | AUTOMATION AND MATERIAL PROCESSING LAB | PC | 50 | 50 | 100 | 0 | 0 | 4 | 2 |
|  |  | **TOTAL** |  |  |  | **700** |  |  |  | **22** |

**MANUFACTURING ENGINEERING**



**FULLTIME**

**CURRICULUM**

***(Full Time Candidates admitted during 2016-2017 and onwards)***

**THIRDSEMESTER**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S.**  **No** | **Subject**  **Code** | **Course Title** | **Category** | **CA Marks** | **End Sem Marks** | **Total**  **Marks** | **CREDITS** | | | |
| **L** | **T** | **P** | **C** |
| 1. | E4 | elective 4 | PE | 50 | 50 | 100 | 3 | 0 | 0 | 3 |
| 2. | E5 | elective 5 | PE | 50 | 50 | 100 | 3 | 0 | 0 | 3 |
| 3. | E6 | elective 6 | PE | 50 | 50 | 100 | 3 | 0 | 0 | 3 |
| 4. | 16MFEE01 | PROJECT- PHASE I | EEC | 100 | 100 | 200 | 0 | 0 | 12 | 6 |
|  |  | **tOTAL** |  |  |  | **500** |  |  |  | **15** |

**FOURTH SEMESTER**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S.**  **No** | **Subject**  **Code** | **Course Title** | **Category** | **CA Marks** | **End Sem Marks** | **Total**  **Marks** | **CREDITS** | | | |
| **L** | **T** | **P** | **C** |
| 1. | 16MFEE02 | PROJECT- PHASE II | EEC | 200 | 200 | 400 | 0 | 0 | 24 | 12 |
|  |  | **TOTAL** |  |  |  | **400** |  |  |  | **12** |

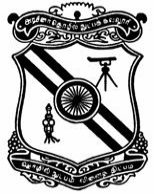
**LIST OF ONE CREDIT COURSES**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S. No** | **Subject**  **Code** | **Course Title** | **Category** | **CA Marks** | **End Sem Marks** | **Total**  **Marks** | **CREDITS** | | | |
| **L** | **T** | **P** | **C** |
| 1. | 16MFOC01 | TECHNICAL SEMINAR | OC | 100 | - | 100 | 0 | 0 | 2 | 1 |
| 2. | 16MFOC02 | ENTERPRENEURSHIPSKILLS | OC | 100 | - | 100 | 0 | 0 | 2 | 1 |
| 3. | 16MFOC03 | HUMAN VALUES AND PROFESSIONAL ETHICS | OC | 100 | - | 100 | 1 | 0 | 0 | 1 |

**MANUFACTURING ENGINEERING**

**PARTTIME**

**CURRICULUM**



***(Part Time Candidates admitted during 2016-2017 and onwards)***

**FIRST SEMESTER**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S. No** | **Subject**  **Code** | **CourseTitle** | **Category** | **CA Marks** | **End Sem Marks** | **Total**  **Marks** | **CREDITS** | | | |
| **L** | **T** | **P** | **C** |
| 1. | 16MFFC01 | APPLIED PROBABILITY AND STATISTICS | FC | 50 | 50 | 100 | 3 | 2 | 0 | 4 |
| 2. | 16MFFC02 | DESIGN FOR MANUFACTURE, ASSEMBLY AND ENVIRONMENT | FC | 50 | 50 | 100 | 3 | 2 | 0 | 4 |
| 3. | 16MFPC01 | [AUTOMATED COMPUTER INTEGRATED MANUFACTURING SYSTEMS](file:///C:\Users\RAJESH\Downloads\ME%20MANUFACTURING%20CURRICULUM.doc#MF9112) | PC | 50 | 50 | 100 | 3 | 0 | 0 | 3 |
|  |  | **TOTAL** |  |  |  | **300** |  |  |  | **11** |

**SECOND SEMESTER**

**FOURTHS**

**EMEST**

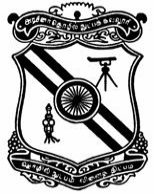
**ER**

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| **S. No** | **Subject**  **Code** | **CourseTitle** | **Category** | **CA Marks** | **End Sem Marks** | **Total**  **Marks** | **CREDITS** | | | |
| **L** | **T** | **P** | **C** |
| 1. | 16MFPC05 | ADVANCED ENGINEERING MATERIALS AND METALLURGY | PC | 50 | 50 | 100 | 3 | 0 | 0 | 3 |
| 2. | 16MFPC06 | SUPPLY CHAIN MANAGEMENT | PC | 50 | 50 | 100 | 3 | 2 | 0 | 4 |
| 3. | 16MFPC07 | THEORY OF METAL CUTTING | PC | 50 | 50 | 100 | 3 | 2 | 0 | 4 |
| 4. | 16MFPC08 | AUTOMATION AND MATERIAL PROCESSING LAB | PC | 50 | 50 | 100 | 0 | 0 | 4 | 2 |
|  |  | **TOTAL** |  | 200 | 200 | **400** |  |  |  | **13** |

**MANUFACTURING ENGINEERING**

**PARTTIME**

**CURRICULUM**



***(Part Time Candidates admitted during 2016-2017 and onwards)***

**THIRD SEMESTER**

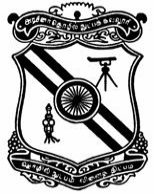
|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S. No** | **Subject**  **Code** | **CourseTitle** | **Category** | **CA Marks** | **End Sem Marks** | **Total**  **Marks** | **CREDITS** | | | |
| **L** | **T** | **P** | **C** |
| 1. | 16MPCF02 | [ADVANCED MACHINING](file:///C:\Users\RAJESH\Downloads\ME%20MANUFACTURING%20CURRICULUM.doc#MF9113) PROCESSES AND AUTOMATION | PC | 50 | 50 | 100 | 3 | 0 | 0 | 3 |
| 2. | 16MFPC03 | ADDITIVE MANUFACTURING | PC | 50 | 50 | 100 | 3 | 0 | 0 | 3 |
| 3. | 16MFPC04 | [OPTIMIZATION TECHNIQUES IN ENGINEERING](file:///C:\Users\RAJESH\Downloads\ME%20MANUFACTURING%20CURRICULUM.doc#MF9158) | PC | 50 | 50 | 100 | 3 | 2 | 0 | 4 |
|  |  | **TOTAL** |  |  |  | **300** |  |  |  | 10 |

**FOURTH SEMESTER**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S. No** | **Subject**  **Code** | **CourseTitle** | **Category** | **CA Marks** | **End Sem Marks** | **Total**  **Marks** | **CREDITS** | | | |
| **L** | **T** | **P** | **C** |
| 1. | E1 | ELECTIVE 1 | PE | 50 | 50 | 100 | 3 | 0 | 0 | 3 |
| 2. | e2 | ELECTIVE 2 | PE | 50 | 50 | 100 | 3 | 0 | 0 | 3 |
| 3. | e3 | ELECTIVE 3 | PE | 50 | 50 | 100 | 3 | 0 | 0 | 3 |
|  |  | **TOTAL** |  |  |  | **300** |  |  |  | **9** |

**MANUFACTURING ENGINEERING PARTTIME**

**CURRICULUM**



***(Part Time Candidates admitted during 2016-2017 and onwards)***

**FIFTH SEMESTER**

**FOURTHS**

**EMEST**

**ER**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S. No** | **Subject**  **Code** | **CourseTitle** | **Category** | **CA Marks** | **End Sem Marks** | **Total**  **Marks** | **CREDITS** | | | |
| **L** | **T** | **P** | **C** |
| 1. | E4 | ELECTIVE 4 | PE | 50 | 50 | 100 | 3 | 0 | 0 | 3 |
| 2. | E5 | ELECTIVE 5 | PE | 50 | 50 | 100 | 3 | 0 | 0 | 3 |
| 3. | E6 | ELECTIVE 6 | PE | 50 | 50 | 100 | 3 | 0 | 0 | 3 |
| 4. | 16MFEE01 | PROJECT - PHASE I | EEC | 100 | 100 | 200 | 0 | 0 | 12 | 6 |
|  |  | **TOTAL** |  |  |  | **400** |  |  |  | **15** |

**SIXTH SEMESTER**

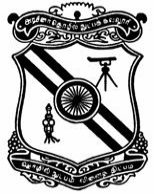
|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S. No** | **Subject**  **Code** | **Course Title** | **Category** | **CA Marks** | **End Sem Marks** | **Total**  **Marks** | **CREDITS** | | | |
| **L** | **T** | **P** | **C** |
| 1. | 16MFEE02 | PROJECT- PHASE II | EEC | 200 | 200 | 400 | 0 | 0 | 24 | 12 |
|  |  | **TOTAL** |  |  |  | **400** |  |  |  | **12** |

**LIST OF ONE CREDIT COURSES**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **S. No** | **Subject**  **Code** | **Course Title** | **Category** | **CA Marks** | **End Sem Marks** | **Total**  **Marks** | **CREDITS** | | | |
| **L** | **T** | **P** | **C** |
| 1. | 16MFOC01 | TECHNICAL SEMINAR | OC | 100 | - | 100 | 0 | 0 | 2 | 1 |
| 2. | 16MFOC02 | ENTREPRENEURSHIP SKILLS | OC | 100 | - | 100 | 0 | 0 | 2 | 1 |
| 3. | 16MFOC03 | HUMAN VALUES AND PROFESSIONAL ETHICS | OC | 100 | - | 100 | 1 | 0 | 0 | 1 |

**MANUFACTURING ENGINEERING**

**CURRICULUM**



***(Full Time and Part Time Candidates admitted during 2016-2017 and onwards)***

**LIST OF ELECTIVE SUBJECTS**

|  |  |  |
| --- | --- | --- |
| **S. No** | **Subject**  **Code** | **CourseTitle** |
|
|  | 16MFPE01 | INDUSTRIAL ROBOTICS AND ROBOT APPLICATIONS |
|  | 16MFPE02 | MATERIALS TESTING AND CHARACTERIZATION TECHNIQUES |
|  | 16MFPE03 | DIAGNOSTIC TECHNIQUES |
|  | 16MFPE04 | ADVANCED FINITE ELEMENT METHODS |
|  | 16MFPE05 | NON DESTRUCTIVE EVALUATION |
|  | 16MFPE06 | FLUID POWER CONTROL AND AUTOMATION |
|  | 16MFPE07 | [INDUSTRIAL ERGONOMICS](file:///C:\Users\RAJESH\Downloads\ME%20MANUFACTURING%20CURRICULUM.doc#MF9159) |
|  | 16MFPE08 | [MANUFACTURING METROLOGY AND QUALITY CONTROL](file:///C:\Users\RAJESH\Downloads\MANU\COMPUTER%20AIDED%20INSPECTION%20AND%20METROLOGY.doc) |
|  | 16MFPE09 | ARTIFICIAL INTELLIGENCE AND EXPERT SYSTEMS |
|  | 16MFPE10 | RELIABILITY AND QUALITY ENGINEERING |
|  | 16MFPE11 | ADVANCED TOOL DESIGN |
|  | 16MFPE12 | [COMPOSITE MATERIALS](file:///C:\Users\RAJESH\Downloads\ME%20MANUFACTURING%20CURRICULUM.doc#MF9160) AND PROCESSING |
|  | 16MFPE13 | CORROSION AND SURFACE ENGINEERING |
|  | 16MFPE14 | [ADVANCES IN CASTING AND WELDING PROCESSES](file:///C:\Users\RAJESH\Downloads\ME%20MANUFACTURING%20CURRICULUM.doc#MF9154) |
|  | 16MFPE15 | INDUSTRIAL SAFETY MANAGEMENT |
|  | 16MFPE16 | [MEMS AND NANOTECHNOLOGY](file:///C:\Users\RAJESH\Downloads\ME%20MANUFACTURING%20CURRICULUM.doc#MF9124) |
|  | 16MFPE17 | GREEN MANUFACTURING |
|  | 16MFPE18 | [LEAN MANUFACTURING SYSTEMS AND IMPLEMENTATION](file:///C:\Users\RAJESH\Downloads\ME%20MANUFACTURING%20CURRICULUM.doc#MF9163) |
|  | 16MFPE19 | VIBRATION CONTROL AND CONDITION MONITORING |
|  | 16MFPE20 | FINANCIAL MANAGEMENT AND COST ACCOUNTING |

L: LectureHours P: Practical Hours

T: Tutorial Hours C: Number of Credits

**16MFFC01 APPLIED PROBABILITY AND STATISTICS**

|  |  |  |  |
| --- | --- | --- | --- |
| ***L*** | ***T*** | ***P*** | ***C*** |
| ***3*** | ***2*** | ***0*** | ***4*** |

**COURSE OBJECTIVES:**

* To acquire knowledge to understand the basics of Probability
* To develop an understanding of decision-making problems.
* To acquire knowledge to understand the designed experiments in manufacturing and development.

**UNIT - I PROBABILITY AND RANDOM VARIABLES (9)**

Sample Space and Events – Axiomatic Definition of probability – Properties of Probability –Conditional Probability – Total Probability and Baye’s Theorem – Independent Events – Random variables: Discrete and Continuous Random variables – Probability mass and density functions – Moments – Moment Generating Functions.

**UNIT - II STANDARD PROBABILITY DISTRIBUTIONS (9)**

Distributions: Binomial, Poisson, Geometric, Uniform, Exponential, Normal, Gamma – Chebyshev’sinequality(Simple problems) – Two dimensional random variable – Jointly probability mass function – Marginal and conditional probability density functions.

**UNIT – III TEST OF HYPOTHYSIS**   **(9)**

Tests for Means, Variances and Proportions – Tests for Means, Variances and Attributes using t, F, Chi square distribution– Goodness of fit –Interval estimation for mean-Standard deviation –Proportion.

**UNIT – IV DESIGN OF EXPERIMENTS (9)**

Randomized Block Design – One-way classification, two-way classification– Latin Square Design.

**UNIT – V STATISTICAL QUALITY CONTROL AND CORRELATION ANALYSIS (9)**

Statistical basis for Control charts – Control limits – Control charts for variables:R– charts Control chart for defective: P, np charts – Control charts for defects: C– chart. Correlation –Regression – Multiple and Partial Correlation – Partial Regression (Problems only).

**Contact Periods:**

LECTURE: 45 PERIODS TUTORIAL:30 PERIODS TOTAL: 75 PERIODS

**REFERENCE BOOKS:**

1. *S.C. Gupta and V. K. Kapoor, “****Fundamentals of Mathematical Statistics****”, Sultan Chand & Sons, New Delhi – 2014.*
2. *S. P. Gupta, “****Statistical Methods****”, Sultan Chand & Sons, New Delhi – 2012.*
3. *Miller and Freud “****Probability and Statistics forEngineers****”,Prentice Hall ofIndia Ltd., New Delhi, Seventh Edition,2015.*
4. *T. Veerarajan, “****Probability , Statistics and Random Processes (with Queueing Theory and Queueing Networks***)*” , Tata McGraw Hill Publishing Company Ltd., Fourth Edition, New Delhi – 2008.*
5. *P. Kandasamy, K.Thilagavathy and K.Gunavathy, “****Probability and Random Process****”, S.Chand and Co. Ltd., New Delhi – 2010.*
6. *Richard A.Johnson and Dean W.Wichem****, “Applied Multivariate Statistical Analysis”,*** *Pearson Education, Asia, Fifth Edition, 2011.*

**COURSE OUTCOMES:**

Learners will be able to

**CO1**: Understand axioms of probability, discrete and continuous probability distributions.

**CO2**: Understand test of hypothesis for both small and large samples based on normal distribution.

**CO3**: Develop analysis and conclusions for design of experiment problems and evaluate control limits using control charts to examine whether the product is within control.

**CO4:** Understand multivariate correlation analysis and forming regression plane.

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **CO/ PO** | **PO 1** | **PO 2** | **PO 3** | **PO 4** | **PO 5** | **PO 6** | **PO 7** | **PO 8** | **PO 9** | **PO 10** | **PO 11** |
| **CO 1** | **\*\*** | **\*** | **\*\*** | **\*\*\*** | **\*\*\*** | **\*\*\*** | **\*\*** | **\*\*** | **\*** | **\*** | **\*** |
| **CO 2** | **\*\*** | **\*** | **-** | **\*\*** | **\*\*** | **-** | **-** | **-** | **\*** | **\*** | **-** |
| **CO 3** | **\*\*** | **\*\*** | **\*\*\*** | **\*** | **\*\*** | **\*\*** | **\*** | **\*** | **\*\*\*** | **\*\*\*** | **\*\*** |
| **CO4** | **\*\*** | **\*** | **\*\*** | **\*\*\*** | **\*** | **\*\*** | **-** | **-** | **\*** | **\*\*** | **\*\*** |

**16MFFC02 DESIGN FOR MANUFACTURE, ASSEMBLY AND ENVIRONMENT**

|  |  |  |  |
| --- | --- | --- | --- |
| ***L*** | ***T*** | ***P*** | ***C*** |
| ***3*** | ***2*** | ***0*** | ***4*** |

**COURSE OBJECTIVES:**

* To acquire knowledge about design principles and possible methodology to accomplish feasibility in manufacturing environment.
* To enhance specified design concepts and skill in material selection, form design of castings and machining process.

**UNIT – I INTRODUCTION (9)**

General design principles for manufacturability –Factors influencing design-Types of problems to be solved- evaluation of customer’s requirements-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.

**UNIT – II FACTORS INFLUENCING FORM DESIGN (9)**

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

**UNIT – III COMPONENT DESIGN – CASTING CONSIDERATION (9)**

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-case studies

**UNIT – IV COMPONENT DESIGN - MACHINING CONSIDERATION (9)**

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- case studies

**UNIT – V DESIGN FOR ENVIRONMENT (9)**

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.

**Contact Periods:**

LECTURE: 45 PERIODS TUTORIAL:30 PERIODS TOTAL: 75 PERIODS

**REFERENCE BOOKS:**

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 Structural Approach”****, 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.RobertMatouslk,* ***“Engineering Design****”.BlackieAND son limited, 1962.*
9. *Harry peck,* ***“Designing for Manufacture”****,Pitman publishing.*

**COURSE OUTCOMES**

Learners will be able to

**CO1**: Formulate the feasibility of design features in manufacturing arena and smart development in manufacturability.

**CO2**: Capable in developing new concepts and methods for re-design of castings and simplified machining process.

**CO3**: Develop artifact and translate the concepts of economics in design, optimization of design and human factors approach in manufacturing.

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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**16MFPC01 AUTOMATED COMPUTER INTEGRATED MANUFACTURING SYSTEMS**

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**COURSE OBJECTIVE:**

To comprehend about the issues of computer integrated manufacturing and integration of automated process within a modern manufacturing environment.

**UNIT – I PRODUCTION PLANNING AND CONTROL (9)**

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 in CIM systems - Major modules of MRP software.

**UNIT – II CNC SYSTEMS (9)**

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 of CNC machine - Capabilities of a typical NC - CAM software – Integration of computers in CIM environment

**UNIT - III NETWORKING (9)**

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

**UNIT – IV FLEXIBLE MANUFACTURING SYSTEMS (9)**

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.

**UNIT – V ROBOTICS AND ARTIFICIAL INTELLIGENCE (9)**

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.

**Contact Periods:**

LECTURE: 45 PERIODS TOTAL: 45 PERIODS

**REFERENCE BOOKS:**

1. *Mikell P Groover, "****Automation, Production Systems, andComputer Integrated Manufacturing****", Pearson education (Singapore) Pvt. Ltd., New Delhi, 2003.*
2. *Chris McMahon, and Jimmie Browne, "****CAD/CAM Principles, Practice and manufacturing Management****", 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*

**COURSE OUTCOMES**

Learners will be able to

**CO1:** Apply knowledge of manufacturing engineering and management principles to design and evaluate automated manufacturing system.

**CO2:** Analyse problems of industrial and manufacturing systems to formulate design requirements for CIM system.

**CO3:** Apply professional, ethical, legal, security and social issues in design of manufacturing systems

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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**16MFPC02** [**ADVANCED MACHINING**](file:///G:\M.E\SEMESTER%202\TEQIP\ME%20MANUFACTURING%20CURRICULUM.doc#MF9113) **PROCESSES AND AUTOMATION**

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**COURSE OBJECTIVE:**

To learn about various machining process parameters, influence on performance, applications and simulation software’s.

**UNIT – I MECHANICAL MACHINING PROCESSES (9)**

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

**UNIT – II CHEMICAL AND ELECTRO CHEMICAL MACHINING PROCESSES (9)**

chemical machining – electro chemical machining-electro chemical grinding(ECG),electrical discharge grinding(EDG),electro chemical discharge grinding(ECDG) – construction working principle – steps - types – process parameters – derivations – problems, merits, demerits and applications.

**UNIT – III ELECTRO-THERMAL ANDELECTRIC MACHINING PROCESSES (9)**

Electro discharge machining(EDM),Wire cut EDM–Laser beam machining – Electron beam machining – Plasma arc machining – Ion beam machining –construction – principle – types – control - circuits – tool design – merits, demerits and applications.

**UNIT – IV MICROFABRICATION TECHNOLOGY (9)**

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

**UNIT – V SIMULATION IN MACHINING PROCESSES (9)**

Architecture of CAE-ECM, EDM, USM – CNC-ECM, EDM – Factory automation of ECM, EDM – Integration of computers in non-traditional machining environment.

**Contact Periods:**

LECTURE: 45 PERIODS TOTAL: 45 PERIODS

**REFERENCE BOOKS:**

1. *V.K. Jain,* ***“Advanced machining processes”****Allied publishers.*
2. *Seropekelpekijianand StevanRSchmid****“Manufacturing Process Engg Material”,*** *2003*
3. *Carl sommer,* ***“Nontraditional machining processes handbook”*** *advance publishing inc,2000.*
4. *Brahem T. Smith “****Advanced Machining”,*** *I.F.S. UK 1989*
5. *Pandey P.C. and Shan HS,* ***“Modern Machining Processes”****, Standard Publishing Co., 1980*
6. *Hassan abdel and gaward EI-Hofy,”****Advanced Machining Processes****” McGraw hills,2005.*
7. *P.K.Mishra “****Unconventional Machining Method****”Allied publishers.*
8. *McGeough,”****Advanced Method of Machining****”Chaoman and hall, London.,1998*

**COURSE OUTCOMES:**

Learners will be able to

**CO1**: Relate distinctive knowledge of unconventional machining processes and performance parameters.

**CO2**: Apply unconventional machining process in various industrial applications.

**CO3**: Analyse and simulate various industrial problems in advanced machining processes.

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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**16MFPC03 ADDITIVE MANUFACTURING**

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**COURSE OBJECTIVE:**

To learn the concepts of rapid product development, apply acquired knowledge to meet global challenges in changing design in time compressed mode

**UNIT – I INTRODUCTION (9)**

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

**UNIT – II ADDITIVE MANUFACTURING (AM) (9)**

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

**UNIT – III ENGINEERING PROCESS** **(9)**

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

**UNIT – IV PROCESSING POLYHEDRAL DATA (9)**

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

**UNIT – V ADDITIVE TOOLING (AT) (9)**

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

**Contact Periods:**

LECTURE: 45 PERIODS TOTAL: 45 PERIODS

**REFERENCE BOOKS:**

1. *C K Chua, K F Leong, C S Lim, Rapid Prototyping Principles and Applications, World Scientific, New Delhi, 2010.*
2. *Frank W.Liou,* ***Rapid Prototyping and Engineering Applications****, CRC Press, UK, 2011.*
3. *Terry wohlers, Wohlers Report 2000, Wohlers Associates, USA, 2000.*
4. *Chua Chee Kai and Leong Kah Fai, 1997,* ***“Rapid Prototyping: Principles and Applications inManufacturing”****, John Wiley and Sons*
5. *Paul F. Jacobs, 1996,* ***“Stereo-lithography and Other RP AND M Technologies”****: from Rapid Prototyping to Rapid Tooling, SME/ASME*
6. *D. Faux and M. J. Pratt, 1979, “****Computational Geometry for design and manufacture”****, John Wiley and Sons*
7. *Pham, D.T. and Dimov.S.S.,****“Rapid Manufacturing”****, Springer-Verlag, London, 2001.*

**COURSE OUTCOMES:**

At the end of the course the learner should be able to

**CO1**: Apply the concept of liquid, solid and powder based rapid prototyping techniques for rapid product development.

**CO2**: Apply the rapid tooling and software for rapid manufacturing to meet international needs

**CO3**: Select appropriate process for production of a part/component that meet international standards of quality and time constraints*.*

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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**16MFPC04 OPTIMIZATION TECHNIQUES IN ENGINEERING**

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**COURSE OBJECTIVE:**

To explain the theory of optimization methods and algorithms developed for solving various types of optimization problems

**UNIT – I EVOULUTIONOF OPTIMISATION (5)**

Optimization – Historical Development – Engineering applications of optimization – Statement of an Optimization problem – classification of optimization problems.

**UNIT – II CLASSIC OPTIMIZATION TECHNIQUES (10)**

Linear programming - Graphical method – simplex method – dual simplex method – revised simplex method – duality in LP – Parametric Linear programming – Goal Programming.

**UNIT – III NON-LINEAR PROGRAMMING (9)**

Introduction – Lagrangeon Method – Kuhn-Tucker conditions – Quadratic programming – Separable programming – Stochastic programming – Geometric programming

**UNIT - IV INTEGER PROGRAMMING, AND DYNAMIC PROGRAMMING NETWORK TECHNIQUES (12)**

Integer programming - Cutting plane algorithm, Branch and bound technique, Zero-one implicit enumeration – Dynamic Programming – Formulation, Various applications using Dynamic Programming.Network Techniques – Shortest Path Model – Minimum Spanning Tree Problem – Maximal flow problem.

**UNIT - V ADVANCES IN SIMULATION (9)**

Genetic algorithms – Simulated annealing – Neural Network, Fuzzy systems and Particle swam optimization

**Contact Periods:**

LECTURE: 45 PERIODS TUTORIAL:30 PERIODS TOTAL: 75 PERIODS

**REFERENCE BOOKS:**

*1. R. Panneerselvam, “****Operations Research****”, Prentice Hall of India Private Limited, New Delhi L, 2005*

*2. P.K. Guptha and Man-Mohan****, “Problems in Operations Research”*** *– Sultan Chand & Sons, 1994*

*3. Ravindran, Philips and Solberg, “****Operations Research Principles and Practice”****, John Wiley & Sons, Singapore, 1992*

*4. J.K.Sharma, “****Operations Research – Theory and Applications”*** *– Macmillan India Ltd., 1997*

*5. Hamdy A. Taha “****Operations Research – An Introduction”****, Prentice Hall of India, 1997*

**COURSE OUTCOMES:**

At the end of the course the learner should be able to

**CO 1:** Apply basic theoretical principles in optimization and formulate the optimization models

**CO 2:** Implement optimization techniques in engineering problems

**CO3:** Solve the constraints for optimal solution to interface in industrial scenario

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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**16MFPC05 ADVANCED ENGINEERING MATERIALS AND METALLURGY**

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**COURSE OBJECTIVE:**

To acquire the concepts and interpret the engineering materials that governs the design and selection of materials based on their processing, properties and stability.

**UNIT – I ELASTIC AND PLASTIC BEHAVIOUR (9)**

Elasticity in metals and polymers An elastic and visco-elastic behavior – Mechanism of plastic deformation and non metallic shear strength of perfect and real crystals –Strengthening mechanisms, work hardening, solid solutioning, grain boundary strengthening, poly phase mixture, precipitation, particle, fiber and dispersion strengthening. Effect of temperature, strain and strain rate on plastic behavior – Super plasticity – Deformation of non crystalline materials.

**UNIT – II FRACTURE BEHAVIOUR (9)**

Griffith’s theory, stress intensity factor and fracture toughness – Toughening mechanisms – Ductile, brittle transition in steel – High temperature fracture, creep –Larson Miller parameter – Deformation and fracture mechanism maps – Fatigue, low and high cycle fatigue test, crack initiation and propagation mechanisms and Paris law. Effect of surface and metallurgical parameters on fatigue – Fracture of non metallic materials – Failure analysis, sources of failure, procedure of failure analysis.

**UNIT – III SELECTION OF MATERIALS (9)**

Motivation for selection, cost basis and service requirements – Selection for mechanical properties, strength, toughness, fatigue and creep – Selection for surface durabilityCorrosion and wear resistance – Relationship between materials selection and processing – Case studies in materials selection with relevance to aero, auto, marine, machinery and nuclear applications – Computer aided materials selection.

**UNIT – IV MODERN METALLIC MATERIALS (9)**

Dual phase steels, High strength low alloy (HSLA) steel, Transformation induced plasticity (TRIP) Steel, Maraging steel, Nitrogen steel – Intermetallics, Ni and Tialuminides – smart materials, shape memory alloys – Metallic glass and nano crystalline materials.

**UNIT – V NON - METALLIC MATERIALS (9)**

Polymeric materials – Formation of polymer structure – Production techniques of fibers, foams, adhesives and coating – structure, properties and applications of engineering polymers – Advanced structural ceramics, WC, TiC, TaC, Al2O3, SiC, Si3N4 CBN and diamond – properties, processing and applications.

**Contact Periods:**

LECTURE: 45 PERIODS TOTAL: 45 PERIODS

**REFERENCE BOOKS:**

1. *George E.Dieter, “****Mechanical Metallurgy****”, McGraw Hill, 2001*
2. *Thomas H. Courtney, “****Mechanical Behavior of Materials****”, (2nd edition), McGraw Hill,2000*
3. *Charles, J.A., Crane, F.A.A. and Fumess, J.A.G., “****Selection and use of engineeringmaterials****”, (3rd edition), Butterworth-Heiremann, 2001.*
4. *Flinn, R.A., and Trojan, P.K., “****Engineering Materials and their Applications****”, (4thEdition) Jaico, 1999*
5. *ASM Hand book, Vol.LL, “****Failure Analysis and Prevention****”, L0th Edition), ASM, 2002.*
6. *Ashby M.F., “****Material Selection in Mechanical Design****”, 3rd Edition, Butter Worth 2005*
7. *Brian cantor, “****Automotive Engineering: Light weight, functional and novel materials”, Taylor and Francis, 2010.***

**COURSE OUTCOMES**

Learners will be able to

**CO1**: Analyze the concepts of material behavior for specific applications.

**CO2**: Identify the performance requirements of a desired material for a specific engineering application

**CO3:** Select modern materials for automotive and aerospace applications

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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**16MFPC06 SUPPLY CHAINMANAGEMENT**

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# COURSE OJECTIVE:

To learn the importance of terminologies and major decisions in supply chain management for gaining competitive advantage.

**UNIT – I INTRODUCTION (6)**

Definition of Logistics and SCM: Evolution, Scope, Importance and Decision Phases – process view of a supply chain - Supply chain flows- Examples of supply chains- Competitive and supply chain strategies- Achieving strategic fit- Expanding strategic scope- Drivers of supply chain performance- Framework for structuring drivers –Obstacles to achieving fit.

**UNIT – II LOGISTICS MANAGEMENT (10)**

Factors – Modes of Transportation - Design options for Transportation Networks-Routing and Scheduling – Inbound and outbound logistics- Reverse Logistics – 3PL- Integrated Logistics Concepts- Integrated Logistics Model – Activities - Measuring logistics cost and performance – Warehouse Management - Case Analysis

**UNIT – III SUPPLY CHAIN NETWORK DESIGN (10)**

Distribution in Supply Chain – Factors in Distribution network design –Design options-Network Design in Supply Chain – Framework for network Decisions - Managing cycle inventory and safety.

**UNIT – IV SOURCING AND PRICING IN SUPPLY CHAIN (9)**

Supplier selection and Contracts - Design collaboration - Procurement process.Revenue management in supply chain.

**UNIT – V COORDINATION AND TECHNOLOGY IN SUPPLY CHAIN (10)**

Supply chain coordination - Bullwhip effect – Effect of lack of co-ordination and obstacles – IT and SCM - supply chain IT frame work. E-Business and SCM. Metrics for SC performance – Case Analysis

**Contact Periods:**

LECTURE: 45 PERIODS TUTORIAL:30 PERIODS TOTAL: 75 PERIODS

**REFERENCE BOOKS:**

1. *Sunil Chopra and Peter Meindl* ***“Supply Chain Management Strategy, Planning, and Operation”,*** *PHI, Second edition, 2007*
2. *David J.Bloomberg, Stephen Lemay and Joe B.Hanna “****Logistics”****,, PHI 2002*
3. *Martin Christopher,* ***“Logistics and Supply Chain Management”****, Strategies for Reducing Cost and Improving Service. Pearson Education Asia, Second Edition*
4. *Jeremy F.Shapiro, Thomson Duxbury,* ***"Modeling the Supply Chain”****, 2002*
5. *James B.Ayers,* ***“Handbook of Supply Chain Management”****, St.Lucle Press, 2000*

**COURSE OUTCOMES:**

Learners will be able to

**CO1**: Identify and analyze supply chain problems in various business sectors.

**CO2:** Devise strategies, plans and operations to solve supply chain problems and/or to improve supply chain efficiency

**CO3:** Apply information technology in e-business for corporate demand

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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**16MFPC07THEORY OF METAL CUTTING**

[Use of approved data book is permitted]

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**COURSE OBJECTIVE:**

To acquire advanced information about the metal cutting theory and to enlarge knowledge in metal cutting theory.

**UNIT - I ORTHOGONAL CUTTING (10)**

Introduction - Machining fundamentals – Metal Cutting - Chip formation - types of chips - Chip breakers - Expression for Shear plane angle - Cutting force and velocity relationship - Ernst and Merchant Upper bound solution - Lee and Shaffer Lower bound solution - Oxley's thin shear zone model - Stress and Strain in the chip - Energy consideration in machining.

**UNIT – II OBLIQUE CUTTING (8)**

Direction of Chip flow - Normal, Velocity and Effective Rake angles - Relationship between rake angles - Cutting ratios in oblique cutting - Shear angle and Velocity relationship - Stabler's rule.

**UNIT – III THERMAL ASPECTS AND CUTTING FLUIDS (7)**

Heat distributions in machining - Experimental determination and Analytical calculation of cutting tool temperature - Cutting fluids - Effects of cutting fluid - Functions - Requirements - Types and Selection of Cutting Fluids.

**UNIT – IV CUTTING TOOL MATERIALS, TOOL LIFE AND TOOL WEAR (10)**

Essential requirements of tool materials – development of tool materials - Tool wear and Tool life - Machinability - Economics of metal machining - Theory of Chatter – ISO specifications for inserts and tool holders.

**UNIT – V DESIGN OF CUTTING TOOLS (10)**

Nomenclature of Single point and Multi point cutting tools - Design of Turning tool, Drills and Milling cutters.

**Contact Periods:**

LECTURE: 45 PERIODS TUTORIAL:30 PERIODS TOTAL: 75 PERIODS

**REFERENCE BOOKS:**

1. *Bhattacharyya A.,* ***"Metal Cutting Theory and Practice"****, Central Book Publishers, Calcutta, 1984*
2. *Juneja B L., Sekhon G. S.,* ***"Fundamentals of Metal Cutting and Machine Tools"****, New Age International (P) Limited, 1995*
3. *Shaw M C.,* ***"Metal Cutting Principles"****, Oxford Press, 1984*
4. *Armarego E.J.A., Brown R.H.,* ***"The Machining of Metals"****, Prentice Hall Inc., 1969*
5. *Geoffrey Boothroyd, Knight W.A.,* ***"Fundamentals of Machining and Machine Tools"****, Marcel Dekkor, New York, 1989*
6. *Rodin P.,* ***"Design and Production of Cutting Tools"****, MIR Publishers, 1968*

**COURSE OUTCOMES:**

Learners will be able to

**CO1:** Apply the metal cutting theory in engineering materials and employ the various aspects in manufacturing activities

**CO2:** Select tool materials and cutting fluids for machinabilty and economics

**CO3:** Design the cutting tools for metal removal process.

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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**16MFPC08 AUTOMATION AND MATERIAL PROCESSING LAB**

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**COURSE OBJECTIVES:**

* To acquire knowledge of robot operation and CNC programming
* To prepare castings, analyze micro structure and evaluate dry sliding wear characteristics of different materials

**COURSE CONTENT:**

1. Study of Automation system and its description.
2. Study the major equipment/Software/Components in Robotics Lab, Robotic Arm components, IGRIP.
3. Recording Robot positions and its task. (Repeatability test, Absolute positions, Delete Positions, Save and load positions and Move the Robot to recorded positions)
4. Writing G code and M code for machining components in CNC machine.
5. Preparation and making castings from stir squeeze and vacuum casting equipment.
6. Preparation of specimen for microstructure analysis in inverted metallurgical microscope.
7. Micro structure analysis using image analysis software
8. Preparation and study of process parameters in pin-on-disc wear measuring machine
9. Analysis of wear characteristics from pin-on-disc wear measuring machine.

**Contact Periods:**

PRACTICAL: 60 PERIODS TOTAL: 60 PERIODS

**COURSE OUTCOMES:**

Learners will be able to

**CO1:** Apply robotic systems and CNC programming of real time control.

**CO2:** Select special casting techniques for the composite materials.

**CO3:** Analyze micro structures of materials and wear characteristics of engineering materials.

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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| **CO/ PO** | **PO 1** | **PO 2** | **PO 3** | **PO 4** | **PO 5** | **PO 6** | **PO 7** | **PO 8** | **PO 9** | **PO 10** | **PO 11** |
| **CO 1** | **\*\*\*** | **\*** | **\*** | **\*\*** | **\*\*** | **\*** | **\*** | **\*\*** | **\*** | **-** | **\*** |
| **CO 2** | **\*\*\*** | **\*\*** | **\*** | **\*\*** | **\*\*\*** | **\*\*** | **\*** | **\*\*** | **\*** | **-** | **\*** |
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**16MFEE01 PROJECT- PHASE I**

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**COURSE OBJECTIVE:**

To identify a specific problem for the current need of the society and collecting information related to the same through detailed review of literature and to develop the methodology to solve the identified problem then publish paper at least in conference.

**COURSE CONTENT:**

1. The learner individually works on a specific topic approved by the head of the division under the guidance of a faculty member who is familiar in this area of interest.
2. The student can select the specific topic related to the area of manufacturing engineering. The topic may be theoretical or industrial case studies.
3. At the end of the semester, a detailed report on the work done should be submitted which contains clear definition of the identified problem, detailed literature review related to the area of work and methodology for carrying out the work.
4. The learners will be evaluated through a viva-voce examination by a panel of examiners including one external examiner.

**COURSE OUTCOMES:**

Learners will be able to

**CO1:** Identify the project work scientifically in a systematic way

**CO2:**Analyze the problem and data of literatures clearly to explore the ideas and methods.

**CO3:** Formulate the objectives and methodology to solve the identified problem.

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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| **CO/ PO** | **PO 1** | **PO 2** | **PO 3** | **PO 4** | **PO 5** | **PO 6** | **PO 7** | **PO 8** | **PO 9** | **PO 10** | **PO 11** |
| **CO 1** | **\*\*\*** | **\*\*** | **\*\*\*** | **\*\*\*** | **\*\*** | **\*** | **\*\*\*** | **\*\*\*** | **\*\*** | **\*** | **\*** |
| **CO 2** | **\*\*\*** | **\*\*** | **\*\*\*** | **\*\*\*** | **\*\*** | **\*** | **\*\*** | **\*\*\*** | **\*\*** | **\*** | **\*\*** |
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**16MFEE02 PROJECT - PHASE II**

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**COURSE OBJECTIVE:**

To solve the identified problem based on the formulated methodology, develop skills to analyze, discuss the test results and make conclusions.

**COURSE CONTENT:**

1. The learner should continue the phase I work on the selected topic as per the formulate methodology under the same supervisor.
2. At the end of the semester, after completing the work to the satisfaction of the supervisor and review committee, a detailed report should be prepared and submitted to the head of the department.
3. The learners will be evaluated based on the report submitted and the viva-voce examination by a panel of examiners including one external examiner

**COURSE OUTCOMES:**

Learners will be able to

**CO1:** Execute the project work on challenging practical problem in a structured manner

**CO2:** Investigate the finding sand infer observations logically

**CO3**: Evaluate the results and confirm the solution to the practical application and social benefit

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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| **CO/ PO** | **PO 1** | **PO 2** | **PO 3** | **PO 4** | **PO 5** | **PO 6** | **PO 7** | **PO 8** | **PO 9** | **PO 10** | **PO 11** |
| **CO 1** | **\*\*\*** | **\*\*** | **\*\*\*** | **\*\*\*** | **\*\*** | **\*** | **\*\*\*** | **\*\*\*** | **\*\*** | **\*** | **\*\*** |
| **CO 2** | **\*\*\*** | **\*\*** | **\*\*\*** | **\*\*\*** | **\*\*\*** | **\*** | **\*\*\*** | **\*\*\*** | **\*\*** | **\*** | **\*\*** |
| **CO 3** | **\*\*\*** | **\*\*\*** | **\*\*\*** | **\*\*\*** | **\*\*\*** | **\*** | **\*\*\*** | **\*\*\*** | **\*\*** | **\*** | **\*\*** |

**16MFPE01 INDUSTRIAL ROBOTICS AND ROBOT APPLICATIONS**

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**COURSE OBJECTIVE:**

To familiarize with the concepts and techniques of robot manipulator, its kinematics, programming and build confidence to choose, evaluate and incorporate robots in engineering systems.

**UNIT – I ROBOTIC KINEMATICS (9)**

Definition need and scope of industrial robots-Robot anatomy-work volume-Precision movement-End effectors - sensors. Robot kinematics- Direct and inverse kinematics- Robot trajectories- Control of robot manipulators- Robot dynamics- Methods for orientation and location of objects.

**UNIT – II ROBOT DRIVES AND CONTROL (9)**

Controlling the robot motion-Position and velocity sensing devices-Design of drive systems-Hydraulic and Pneumatic drives-Linear and rotary actuators and control valves-Electro hydraulic servo valves, electric drives- Motors-designing of end effectors-Vacuum, magnetic and air operated grippers.

**UNIT – III ROBOT SENSORS (9)**

Transducers and sensors-Sensors in robot-Tactile sensor-Proximity and range sensors-Sensing joint forces- Robotic vision system-Image Gripping-Image processing and analysis-Image segmentation-Pattern recognition- Training of vision system

**UNIT – IV ROBOT CELL DESIGN AND APPLICATION (9)**

Robot work cell design and control-Safety in Robotics-Robot cell layouts-Multiple robots and machine Interference - Robot cycle time analysis - application of robotics in machine shop, assembly, automation, tele operated robot, MHS, Processing operation.

**UNIT – V ROBOT PROGRAMMING AND ARTIFICIAL INTELLIGENCE (9)**

Methods of robot programming-characteristics of task level languages lead through programming methods-Motion interpolation. Artificial intelligence- Basics- Goals of artificial intelligence- AI techniques.

**Contact Periods:**

LECTURE: 45 PERIODS TOTAL: 45 PERIODS

**REFERENCE BOOKS:**

1. *Mikell P Groover, Mitchell Weis, Roger N Nagel, Nicholas G Odrey, “****Industrial Robotics Technology, Programming and Applications”****, McGraw Hill, 2012.*
2. *Richard D Klafter, Thomas A Chmielewski, Machine Negin, “****Robotics Engineering - An Integrated Approach****”, Prentice Hall of India Pvt., Ltd., 1984*
3. *K.S.Fu, R.C.Gomaler, C.S.G.Lee, "****Robotics control, Sensing, Vision and Intelligence****”, McGraw Hill, 1987*
4. *Lorenzo Scarvicco “****Modelling and control of Robot Manipulator*** *", Tata McGraw Hill, 1999*
5. *James G Kerames, “****Robot technology fundamentals*** *", Delmia Publisher-2000.*

**COURSE OUTCOMES:**

On completion of this course, learners will be able to

**CO1:** Appreciate the importance of robot in the emerging trend of manufacturing and to select and design robots for various applications taking kinematic aspects and precision into account.

**CO2:** Apply production systems with sensors and advanced techniques such as machine vision.

**CO3:** Identify the potential applications of robots in industries at reasonable cost to meet challenges of globalisation.

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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| **CO/PO** | **PO 1** | **PO 2** | **PO 3** | **PO 4** | **PO 5** | **PO 6** | **PO 7** | **PO 8** | **PO 9** | **PO 10** | **PO 11** |
| **CO 1** | **\*\*** | **\*\*** | **\*** | **\*\*** | **\*** | **\*** | **\*** | **-** | **\*** | **\*\*** | **\*\*\*** |
| **CO 2** | **\*\*** | **\*\*\*** | **\*\*\*** | **\*\*** | **\*\*\*** | **\*** | **\*** | **-** | **\*** | **\*\*** | **\*\*\*** |
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**16MFPE02 MATERIALS TESTING AND CHARACTERIZATION TECHNIQUES**

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**COURSE OBJECTIVE:**

To evaluate the microstructure, crystal analysis, electron microscopy, chemical thermal analysis, static and dynamic mechanical testing methods.

**UNIT – I MICRO AND CRYSTAL STRUCTURE ANALYSIS (10)**

Principles of Optical Microscopy – Specimen Preparation Techniques – Polishing and Etching – Polarization Techniques – Quantitative Metallographic – Estimation of grain size – ASTM grain size numbers – Microstructure of Engineering Materials - Elements of Crystallography – X- ray Diffraction – Bragg‘s law – Techniques of X-ray Crystallography– Debye – Scherer camera – Geiger Diffractometer – analysis of Diffraction patterns –Inter planer spacing – Identification of Crystal Structure, Elements of Electron Diffraction.

**UNIT – II ELECTRON MICROSCOPY (9)**

Interaction of Electron Beam with Materials – Transmission Electron Microscopy –Specimen Preparation – Imaging Techniques – BF & DF – SAD – Electron Probe Microanalysis – Scanning Electron Microscopy – Construction & working of SEM –various Imaging Techniques – Applications- Atomic Force Microscopy- Construction &working of AFM - Applications .

**UNIT – III CHEMICAL AND THERMAL ANALYSIS (9)**

Basic Principles, Practice and Applications of X-Ray Spectrometry, Wave Dispersive X Ray Spectrometry, Auger Spectroscopy, Secondary Ion Mass Spectroscopy, Fourier Transform Infra-Red Spectroscopy (FTIR)- Proton Induced X-Ray Emission Spectroscopy, Differential Thermal Analysis, Differential Scanning Calorimetry (DSC)And Thermo Gravity metric Analysis (TGA) -and thermal electron Microscope(TEM).

**UNIT – I**V **MECHANICAL TESTING – STATIC TESTS (8)**

Hardness – Brinell, Vickers, Rockwell and Micro Hardness Test – Tensile Test – Stress– Strain plot – Proof Stress – Torsion Test - Ductility Measurement – Impact Test –Charpy&Izod – DWTT - Fracture Toughness Test, Codes and standards for testing metallic and composite materials.

**UNIT – V MECHANICAL TESTING – DYNAMIC TESTS (9)**

Fatigue – Low & High Cycle Fatigues – Rotating Beam & Plate Bending HCF tests – S-N curve – LCF tests – Crack Growth studies – Creep Tests – LM parameters – AE Tests modal analysis - Applications of Dynamic Tests.

**Contact Periods:**

LECTURE: 45 PERIODS TOTAL: 45 PERIODS

**REFERENCE BOOKS:**

*1. Goldsten,I.J., Dale.E., Echin.N.P.& Joy D.C.,* ***Scanning Electron Microscopy & X ray- Micro Analysis****, (2nd Edition), ISBN – 0306441756, Plenum Publishing Corp., 2000.*

*2. Newby J., Metals Hand Book-* ***Metallography & Micro Structures****, (9th Edition), ASM International, 1989.*

*3. Grundy P.J. and Jones G.A.,* ***Electron Microscopy in the Study of Materials****, Edward Arnold Limited, 1976.*

*4. Morita.S, Wiesendanger.R, and Meyer.E, ―****Non-contact Atomic Force Microscopy*** *Springer, 2002,*

*5. Davis J. R., Tensile Testing, 2nd Edition, ASM International, 2004.*

*6. ASM Hand book-Materials characterization, Vol – L0, 2004.*

*7. Angelo.P.C,”****Material Characterization”,*** *Reed Elsevier India Pvt.Ltd,2013.*

*8.Culity B.D., Stock S R”Elements of X-ray Diffraction”,PrenticeHall,Inc 2001.*

**COURSE OUTCOMES:**

On completion of this course, learners will be able to

**CO1:** Identify the test and quantify the mechanical properties of Engineering Materials.

**CO2:** Characterize the microstructure of various materials and apply various applications.

**CO3:**Analyse the behavior of various materials under static and dynamic condition.

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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| **CO L** | **\*\*** | **\*\*** | **\*\*** | **\*\*** | **\*\*\*** | **\*\*** | **-** | **-** | **\*** | **\*\*** | **\*\*\*** |
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**16MFPE03 DIAGNOSTICTECHNIQUES**

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**COURSE OBJECTIVE:**

To expose the learners to evaluate the defects and failure of the system components, computerized maintenance management system and various condition monitoring techniques.

**UNIT – I DEFECTS GENERATION AND FAILURE ANALYSIS (8)**

Defect generation-types of failures-Defects reporting and recording-Failure analysis- Fault and Event tree analysis- Root cause analysis- FMEA- FEA.

**UNIT – II MAINTENANCE SYSTEMS (8)**

Maintenance Strategy- Unplanned maintenance- Reactive maintenance, Opportunistic maintenance, Planned maintenance- Routine maintenance, Preventive maintenance, Predictive maintenance, Condition based maintenance, Design out maintenance-selection of maintenance system.

**UNIT – III SYSTEMATIC MAINTENANCE (9)**

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-Maintenance records and documentation.

**UNIT – IV COMPUTERIZED MAINTENANCE MANAGEMENT SYSTEM (8)**

Introduction of CMMS, Factors affecting selection of CMMS- Components of CMMS- Equipment classification- Work-order management- Material management- Captive Engineering- Benefits and Scope of CMMS.

**UNIT – V CONDITION MONITORING (12)**

Condition monitoring techniques- Temperature monitoring- Leakage monitoring-Vibration monitoring-Lubricant monitoring-Crack and Corrosion monitoring-Thickness monitoring- Acoustic monitoring-Condition monitoring of hydraulic system.Machine diagnostics-Objectives-Monitoring strategies-Examples of monitoring and Diagnosis - Control structures for machine diagnosis.

**Contact Periods:**

LECTURE: 45 PERIODS TOTAL: 45 PERIODS

**REFERENCE BOOKS:**

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

**COURSE OUTCOMES:**

On completion of this course, learners will be able to

**CO1**: Apply various maintenance system and the technologies to minimize failures.

**CO2:** Design control system to condition monitoring of machineries.

**CO3:** Apply computerized maintenance systems and store data*.*

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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| **CO/PO** | **PO 1** | **PO 2** | **PO 3** | **PO 4** | **PO 5** | **PO 6** | **PO 7** | **PO 8** | **PO 9** | **PO 10** | **PO 11** |
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**16MFPE04ADVANCED FINITE ELEMENT METHODS**

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**COURSE OBJECTIVE:**

To introduce non-linear computationnel methods to solve problems in solids and structure.

**UNIT – I MATHEMATICAL MODELS (9)**

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

**UNIT – II BASIC ELEMENTS (9)**

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.

**UNIT - III ISOPARAMETRIC ELEMENTS (9)**

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.

**UNIT – IV FINITE ELEMENT FORMULATION FOR STRUCTURAL APPLICATIONS (9)**

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

**UNIT – V HEAT TRANSFER AND FLUID MECHANICS APPLICATIONS (9)**

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

**Contact Periods:**

LECTURE: 45 PERIODS TOTAL: 45 PERIODS

**REFERENCE BOOKS:**

1. *Cook, Robert Davis et al* ***“Concepts and Applications of Finite Element Analysis”****, Wiley, John AND 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 of India Private Ltd., 2002.*

**COURSE OUTCOMES:**

Learners will be able to

**CO1**: Create mathematical models of physical systems and solve using numerical techniques

**CO2**: Appreciate the usage of the types of elements and apply them suitably for specific applications

**CO3**: Solve structural dynamics and non-linear problems through appropriate techniques

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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| **CO 1** | **\*\*** | **\*\*** | **\*\*\*** | **\*\*\*** | **\*** | **\*** | **\*** | **-** | **\*** | **\*\*** | **\*\*** |
| **CO 2** | **\*\*** | **\*\*** | **\*** | **\*** | **\*\*** | **\*** | **\*** | **-** | **\*\*** | **\*** | **\*\*** |
| **CO 3** | **\*\*** | **\*\*** | **\*\*** | **\*\*\*** | **\*\*** | **\*** | **\*** | **-** | **\*\*** | **\*** | **\*\*** |

**16MFPE05NON DESTRUCTIVE EVALUATION**

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**COURSE OBJECTIVE:**

To familiarize the principles of nondestructive material and to introduce non-destructive evaluation in engineering applications.

**UNIT - I CONCEPTS OF NDT (9)**

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

**UNIT – II LIQUID PENETRANT AND MAGNETIC PARTICLE TESTS (9)**

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

**UNIT - III RADIOGRAPHY (9)**

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

**UNIT – IV ULTRASONIC AND ACOUSTIC EMISSION TECHNIQUES (9)**

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.

**UNIT - V THERMOGRAPHY (9)**

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

**Contact Periods:**

LECTURE: 45 PERIODS TOTAL: 45 PERIODS

**REFERENCE BOOKS:**

1. *Barry Hull and Vernon John,* ***"Non Destructive Testing "****, MacMillan, 1988*
2. *American Society for Metals, “****Metals Hand Book "****, Vol.II, 1976*
3. *Hull.* ***“Non Destructive Testing”****. ELBS Edition. 1991*
4. *Baldevraj.,Jayakumar.T., Thavasimuthu. M.,* ***“Practical Non-destructive Testing”****.*

*Narosa Publishers. 1997*

1. *McGonnagle. W.T.* ***“Non-Destructive Testing”****, McGraw Hill. 1961*
2. *ASM Metals Hand Book. Vol. (9).* ***“Non-destructive Testing and Inspection”****, 1988*
3. *C.Hellier, Hand Book* ***“Non-Destructive Evaluation”,*** *McGraw-Hill Professional,1st Edition,2001.*

**COURSE OUTCOMES:**

Learners will be able to

**CO1**: Identify the difference in the different methods of nondestructive techniques,

**CO2**: Apply the appropriate technique for a given application.

**CO3:** Calibrate the instruments and evaluate the component for imperfections.

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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| **CO/ PO** | **PO 1** | **PO 2** | **PO 3** | **PO 4** | **PO 5** | **PO 6** | **PO 7** | **PO 8** | **PO 9** | **PO 10** | **PO 11** |
| **CO 1** | **\*\*** | **\*\*** | **\*\*** | **\*** | **\*\*** | **\*\*** | **\*** | **-** | **\*\*** | **\*\*** | **\*\*** |
| **CO 2** | **\*\*** | **\*\*** | **\*\*\*** | **\*\*** | **\*\*** | **\*\*** | **\*** | **-** | **\*** | **\*\*** | **\*\*** |
| **CO 3** | **\*\*** | **\*** | **\*\*** | **\*\*** | **\*\*** | **\*** | **\*** | **-** | **\*\*** | **\*\*** | **\*\*** |

**16MFPE06 FLUID POWER CONTROL AND AUTOMATION**

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**COURSE OBJECTIVE:**

To acquire the knowledge on advanced features and applications of fluid power engineering in automation of power transmission systems.

**UNIT – I OIL HYDRAULIC SYSTEMS AND HYDRAULIC ACTUATORS (8)**

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

**UNIT – II CONTROL AND REGULATION ELEMENTS (8)**

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

**UNIT - III HYDRAULIC CIRCUITS (10)**

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.

**UNIT – IV PNEUMATIC SYSTEMS AND CIRCUITS (10)**

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.

**UNIT – V INSTALLATION, MAINTENANCE AND SPECIAL CIRCUITS (9)**

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

**Contact Periods:**

LECTURE: 45 PERIODS TOTAL: 45 PERIODS

**REFERENCE BOOKS:**

1. *Antony Espossito, “****Fluid Power with Applications****”, Prentice Hall, 2000.*
2. *FESTO,* ***“Fundamentals of pneumatics”,****Vol I,II, and III*
3. *Dudleyt, A. Pease and John J. Pippenger, “****Basic fluid power****”, Prentice Hall, 1987*
4. *MajumderS.R.,”****OilHydraulics”****,Tata McGraw Hill,2002*
5. *Michael J., Pinches and John G.Ashby, “****Power Hydraulics****”, Prentice Hall, 1989*
6. *Bolton. W., “****Pneumatic and Hydraulic Systems****”, Butterworth –Heinemann, 1997*
7. *Joji P., “****Pneumatic Controls****”, Wiley India Pvt. Ltd., New Delhi, 2008*
8. *Andrew Parr, “****Hydraulic and Pneumatic****” (HB), Jaico Publishing House, 1999*
9. *http:// www.pneumatics .com*
10. *http://* [*www.fluidpower.com.tw*](http://www.fluidpower.com.tw)
11. *W.Boltan, Mechatronics, Electronic control systems in Mechanical and Electrical Engineering Pearson Education, 2003*

**COURSE OUTCOMES:**

Learners will be able to

**CO1**: Select the components for fluid power applications

**CO2**: Design the circuit building and interpretation with PLC programs.

**CO3**: Apply the knowledge on logic controls and troubleshooting of the components.

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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| **CO 2** | **\*\*** | **\*\*** | **\*\*** | **\*\*** | **\*\*** | **\*\*** | **\*** | **-** | **\*** | **\*** | **\*** |
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**16MFPE07 INDUSTRIAL ERGONOMICS**

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**COURSE OBJECTIVE:**

To learn concepts of ergonomics to design of man and machine system.

**UNIT – I INTRODUCTION (9)**

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

**UNIT - II ANTHROPOMETRY (9)**

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.

**UNIT – III DESIGN OF SYSTEMS (9)**

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

**UNIT – IV ENVIRONMENTAL FACTORS IN DESIGN (9)**

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.

**UNIT – V WORK PHYSIOLOGY (9)**

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.

**Contact Periods:**

LECTURE: 45 PERIODS TOTAL: 45 PERIODS

**REFERENCE BOOKS:**

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 1976*
3. *R.S. Bridger, “****Introduction to Ergonomics”****, McGraw Hill, 1995*

**COURSE OUTCOMES:**

Learners will be able to

**CO1:** Apply the ergonomic principle in various industries.

**CO2:** Design the ergonomic system for different industries.

**CO3:** Select the environmental factors in work place

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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**16MFPE08 MANUFACTURING METROLOGY AND QUALITY CONTROL**

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**COURSE OBJECTIVE:**

To learn the principle of light wave interference and applications of light wave interference for measurements, surface finish measurements, co-ordinate measuring machine and vision system and quality control.

**UNIT – I LASER METROLOGY**  **(9)**

Introduction – types of lasers – laser in engineering metrology – metrological laser methods for applications in machine systems – Interferometer applications – speckle interferometer – laser interferometers in manufacturing and machine tool alignment testing – calibration systems for industrial robots laser Doppler technique – laser Doppler anemometry.

**UNIT – II MEASUREMENT OF SURFACE FINISH AND MEASURING MACHINES (8)**

Definitions – Types of Surface Texture: Surface Roughness Measurement Methods- Comparison, Profilometer, 3D Surface Roughness Measurement – Instruments.

**UNIT - III CO-ORDINATE MEASURING MACHINE (10)**

Co-ordinate metrology – CMM configurations – hardware components – software –Probe sensors – displacement devices – Performance Evaluations – Software –Hardware – Dynamic errors – Thermal effects diagram – temperature variations environment control – applications.

**UNIT – IV OPTO ELECTRONICS AND VISION SYSTEM (9)**

Optoelectronic devices – CCD – On-line and in-process monitoring in production –applications image analysis and computer vision – Image analysis techniques – spatial feature – Image extraction – segmentation – digital image processing – Vision system for measurement – Comparison laser scanning with vision system.

**UNIT – V QUALITY IN MANUFACTURING ENGINEERING (9)**

Importance of manufacturing planning for quality – concepts of controllability – need for quality management system and models – quality engineering tools and techniques –statistical process control – six sigma concepts – Poka Yoke – Computer controlled systems used in inspection.

**Contact Periods:**

LECTURE: 45 PERIODS TOTAL: 45 PERIODS

**REFERENCE BOOKS:**

1. *John A. Bosch, Giddings and Lewis Dayton,”* ***Co-ordinate Measuring Machines and Systems”****, Marcel Dekker, Inc, 1999*
2. *Zuech, Nello “****Understanding and Applying Machine Vision****”, Marcel Dekker, Inc, 2000*
3. *Logothetis, N. “****Managing for total quality from Deming to Taguchi and SPC****”, PHI, 1997*
4. *Dale H.Besterfield,* ***“Quality Improvement”,*** *PHI, 2010*

**COURSE OUTCOMES:**

Learners will be able to

**CO1:** Apply principle, working of various measuring instruments

**CO2:** Select and use different measuring instruments to measure the qualitative and quantitative characteristics of components

**CO3:** Analyze the data statistically and decide action to be taken for controlling the quality complying with international standards

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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**16MFPE09 ARTIFICIAL INTELLIGENCE AND EXPERT SYSTEMS**

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**COURSE OBJECTIVE:**

To acquire the knowledge on concepts of artificial intelligence and different tools in expert system.

**UNIT – I KNOWLEDGE REPRESENTATION FOR SMART SYSTEMS (9)**

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.

**UNIT - II LANGUAGES USED IN AI**  **(9)**

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.

**UNIT - III EXPERT SYSTEM DEVELOPMENT (9)**

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 uncertainty, probability in expert systems-learning, forms of learning, inductive learning.

**UNIT - IV EXPERT SYSTEM TOOLS (9)**

Decision trees, knowledge in learning, heuristic classification, heuristic matching, case studies in expert systems, MYCIN, Meta- Dental, 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.

**UNIT - V INDUSTRIAL APPLICATION OF AI AND EXPERT SYSTEMS (9)**

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

**Contact Periods:**

LECTURE: 45 PERIODS TOTAL: 45 PERIODS

**REFERENCE BOOKS:**

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*

**COURSE OUTCOMES:**

Learners will be able to

**CO1**: Comprehend in solving the contemporary issues using Artificial Intelligence.

**CO2**: Develop the ability to use techniques in rules based systems

**CO3**: Apply knowledge on vision system, image processing in automotive and nuclear fields

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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| **CO 2** | **\*\*** | **\*\*** | **\*\*\*** | **\*\*** | **\*\*\*** | **\*\*** | **\*** | **-** | **\*** | **\*** | **\*\*** |
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**16MFPE10 RELIABILITY AND QUALITY ENGINEERING**

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**COURSE OBJECTIVE:**

To learn the quality control techniques, control charts and concepts for reliable system and maintenance aspects in industries.

**UNIT – I QUALITY CONCEPTS (6)**

Quality objectives - Quality control - Quality Assurance - Quality systems, economics, Statistical tolerance - Quality loss functions.

**UNIT - II STATISTICAL PROCESS CONTROL (10)**

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

**UNIT - III DESIGN OF EXPERIMENTS (10)**

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

**UNIT - IV RELIABILITY AND QUALITY MANAGEMENT (10)**

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 prediction and testing - Quality circles - Zero defects program - ISO 9000 and TQM - Total quality organization.

**UNIT – V RELIABILITY MANAGEMENT AND RISK ASSESSMENT (9)**

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.

**Contact Periods:**

LECTURE: 45 PERIODS TOTAL: 45 PERIODS

**REFERENCE BOOKS:**

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 &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.L993*
6. *Dale H.Besterfield,* ***“Quality Improvement”,*** *PHI, 2010*

**COURSE OUTCOMES:**

Learners will be able to

**CO1:** Identify quality concepts and process controls tools

**CO2:** Design the experiments and quality management.

**CO3:** Analyze techniques and assess risk in industries.

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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16MFPE11 ADVANCED TOOL DESIGN

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**COURSE OBJECTIVE:**

To conquer design of moulds, jigs, fixtures, dies and applies the technology in industrial applications

**UNIT - I TOOL-DESIGN METHODS (6)**

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.

**UNIT – II TOOLING MATERIALS AND HEAT TREATMENT (9)**

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.

**UNIT – III DESIGN OF DRILL JIGS (8)**

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.

**UNIT – IV DESIGN OF FIXTURES AND DIES (13)**

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.

**UNIT – V TOOL DESIGN FOR NUMERICALLY CONTROLLED MACHINE TOOLS (9)**

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 petitioners – Tool presetting – Introduction – General explanation of the Brown and sharp machine – tooling for Automatic screw machines

**Contact Periods:**

LECTURE: 45 PERIODS TOTAL: 45 PERIODS

**REFERENCE BOOKS:**

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*
3. *www.irdi.on.ca/irdi/front.htm*
4. *www.techsolve.org/flashhome.htm*

**COURSE OUTCOMES:**

Learners will be able to

**CO1:** Relate tool design solutions and select tooling materials

**CO2:** Design press tools, plastic moulds, die casting dies, jigs and fixtures

**CO3:** Develop modern tool design for automatic operations

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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**16MFPE12 COMPOSITE MATERIALS AND PROCESSING**

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**COURSE OBJECTIVE:**

To learn the different composite materials preparation, analysis and applications.

**UNIT – I CLASSIFICATION OF COMPOSITES (9)**

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.

**UNIT - II BASIC CONCEPTS (9)**

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.

**UNIT - III ANALYSIS OF LAMINATED COMPOSITES (9)**

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

**UNIT - IV ANALYSIS AND FAILURE THEORY (9)**

Netting analysis- Failure criteria- Sandwich construction.

**UNIT - V PROCESSING OF METAL MATRIX COMPOSITES AND CERAMIC MATRIX COMPOSITES (9)**

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.

**Contact Periods:**

LECTURE: 45 PERIODS TOTAL: 45 PERIODS

**REFERENCE BOOKS:**

1. *R.M. Jones, “****Mechanics of Composite Materials****”, 2nd Edition, Taylor AND 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., New York, 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****”,SecondEdition,CRC Press,NY,2006.*
6. *Sanjay K Mazumdar,”****Composites Manufacturing:Materials,Product, and Process Engineering****”,CRC Press,NY,2002.*

**COURSE OUTCOMES:**

Learners will be able to

**CO1:** Relate the types of applications and concepts of composite materials.

**CO2:** Analyze problems on macro mechanical and micromechanical behavior of lamina and laminates.

**CO3:** Select the fabrication process techniques for composite materials.

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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**16MFPE13 CORROSION AND SURFACE ENGINEERING**

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**COURSE OBJECTIVE:**

To learn the type of corrosions, behavior of materials and prevention of corrosion for improving wear resistance.

**UNIT – I MECHANISMS AND TYPES OF CORROSION (9)**

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

**UNIT – II TESTING AND PREVENTION OF CORROSION (9)**

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

**UNIT – III CORROSION BEHAVIOR OF MATERIALS (9)**

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

**UNIT – IV SURFACE ENGINEERING FOR WEAR AND CORROSION RESISTANCE (9)**

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.

**UNIT – V THIN LAYER ENGINEERING PROCESSES (9)**

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, Al2O3 and Diamond coating – Properties and applications of thin coatings.

**Contact Periods:**

LECTURE: 45 PERIODS TOTAL: 45 PERIODS

**REFERENCE BOOKS:**

1. *Fontana. G.,* ***“Corrosion Engineering”****, McGraw Hill, 2008*
2. *SeropeKalpakjian,* ***“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*

**COURSE OUTCOMES:**

Learners will be able to

**CO1:** Identify the types of corrosion occurring in materials and choose appropriate protective surface coating.

**CO2:** Test the corrosion of ferrous, non-ferrous alloy, ceramics and composites.

**CO3:** Select appropriate protective surface coatings to improve corrosion resistance.

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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| **CO 1** | **\*\*** | **\*\*** | **\*** | **\*\*** | **\*** | **\*** | **\*\*** | **-** | **\*\*** | **\*** | **\*\*** |
| **CO 2** | **\*\*** | **\*** | **\*\*** | **\*\*\*** | **\*** | **\*** | **\*\*** | **-** | **\*\*** | **\*\*** | **\*\*** |
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**16MFPE14 ADVANCES IN CASTING AND WELDING PROCESSES**

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**COURSE OBJECTIVE:**

To acquire the metallurgical concepts during solidification of metals and alloys in recent casting and welding processes.

**UNIT – I CASTING METALLURGY AND DESIGN (9)**

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

**UNIT – II SPECIAL CASTING PROCESSES (9)**

Shell moulding – Precision investment casting – CO2 – moulding – centrifugal casting – Die casting – Continuous casting.

**UNIT – III WELDING METALLURGY AND DESIGN (12)**

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.

**UNIT – IV UNCONVENTIONAL AND SPECIAL WELDING PROCESSES (6)**

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

**UNIT – V RECENT ADVANCES IN CASTING AND WELDING (9)**

Layout of mechanized 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.

**Contact Periods:**

LECTURE: 45 PERIODS TOTAL: 45 PERIODS

**REFERENCE BOOKS:**

1. *R. W. Ruddle, “****Solidification of Castings, Institute of Metals”****, London, 1957*
2. *J. Campbell, “****Casting”****, Elsevier Publishing Amsterdam,2011*
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*
6. *Cornu. J.,* ***"Advanced Welding systems"****, Volumes I,II and III, JAICO Publishers, 1994*
7. *Lancaster. J.F.,* ***"Metallurgy of Welding"****, George Allen AND Unwin Publishers, 1980*
8. *SeropeKalpakjian****, "Manufacturing Engineering and Technology”*** *Third Edition, Addison Wesley Publishing Co.1995*
9. *P.N.Rao,* ***"Manufacturing Technology (Foundry, Forming and Welding)",*** *Second Edition****,*** *Tata McGraw Hill Pub.Co. Ltd, 2004.*
10. *John Campbell,”10 rules of casting”Elsevier Publications,Boston,2004.*
11. *Chakrabarti A K “Casting technology and casting alloys,” PHI Publishing co, New Delhi 2009.*

**COURSE OUTCOMES:**

Learners will be able to

**CO1:** Analyze the thermal, metallurgical aspects during solidification in casting and welding.

**CO2:** Relate the casting methods for industrial production of components.

**CO3:** Apply on special welding process for specific applications.

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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**16MFPE15 INDUSTRIAL SAFETY MANAGEMENT**

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**COURSE OBJECTIVES:**

To acquire knowledge of safety management and hazards in industries, safety audit, safety promotion and safety training.

**UNIT – I SAFETY MANAGEMENT CONCEPTS AND TECHNIQUES (9)**

Evaluation of modern safety concepts - Safety policy - Safety Organization - line and staff functions for safety- Safety Committee- budgeting for safety. Safety management functions - safety organization, safety department - safety committee, safety audit - performance measurements and motivation - employee participation in safety-Incident Recall Technique (IRT), disaster control, Job Safety Analysis (JSA), safety survey, safety inspection, safety sampling, Safety Audit.

**UNIT - II FUNCTIONL SAFETY (9)**

Hot metal process - 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.

**UNIT - III SAFETY MEASURES AND MONITORING (9)**

Layout design and material handling - Use of electricity - Management of toxic gases and chemicals - Industrial fires and prevention - Road safety - highway and urban safety - Control of environmental pollution - Managing emergencies in Industries - planning, security and risk assessments, on- site and off site. Control of major industrial hazards. Reactive and proactive monitoring techniques - Permanent total disabilities, permanent partial disabilities, temporary total disabilities.

**UNIT - IV ACCIDENT PREVENTION (9)**

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- Firefighting devices - Accident reporting, investigation.

**UNIT - V SAFETYSTANDARDS AND LAWS (9)**

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.

**Contact Periods:**

LECTURE: 45 PERIODS TOTAL: 45 PERIODS

**REFERENCE BOOKS:**

1. *Lees, F.P and M. Sam Mannan ,* ***“Loss Prevention in Process Industries: Hazard Identification, Assessment and Control”***  *Butterworth Heinemann publications, London, 4thedition, 2012*
2. *L M Deshmukh* ***“Industrial safety management”,*** *, TATA McGraw Hill, 2010*
3. *Philip Hagan* ***“Accident Prevention Manual for Business and Industry”****, N.S.C.Chicago, L3th edition, 2010.*
4. *Ray Asfahl. C* ***“Industrial Safety and Health management”*** *Pearson Prentice Hall,2003*
5. *Krishnan N.V.* ***“Safety Management in Industry”*** *Jaico Publishing House, Bombay, 1997*
6. ***Occupational Safety Manual*** *BHEL.*
7. *Singh,U.K and Dewan.J.M, "****Safety, Security and risk management****", APH Publishing Company, New Delhi, 1996*

**COURSE OUTCOMES:**

Learners will be able to

**CO1:** Apply safety concepts and organize of safety engineering department towards safety management.

**CO2:** Monitor and control safety through safety audit and accident investigations

**CO3:** Evaluate safety performance and comply with safety standards

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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**16MFPE16 MEMS AND NANOTECHNOLOGY**

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**COURSE OBJECTIVE:**

To learn the evolution of micro electromechanical systems, fabrication techniques of micro actuators, nano materials and nano measurements techniques.

**UNIT – I MEMS AND MICROSYSTEMS (8)**

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

**UNIT – II MATERIALS, FABRICATION PROCESSES AND MICRO SYSTEM PACKAGING**

**(11)**

Substrates and wafers, silicon as substrate material, mechanical properties of Si, Silicon Compounds silicon piezo resistors, Gallium 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.

**UNIT – III MICRO DEVICES (7)**

Sensors – classification – signal conversion ideal characterization of sensors micro actuators, mechanical sensors – displacement sensors, pressure and flow sensors- sensitivity, reliability and response of micro-sensor- applications of micro actuators.

**UNIT – IV SCIENCE OF SYNTHESIS OF NANO MATERIALS (9)**

Classification of nano structures – Effects of nano scale dimensions on various properties – structural, thermal, chemical, mechanical, magnetic, optical and electronic properties. Nano particles- Sol-Gel synthesis- plasma synthesis- Synthesis of carbon nano tubes- Fabrication methods – Top down processes – bottom up process.

**UNIT – V CHARACTERIZATION OF NANO MATERIALS (10)**

Nano-processing systems – Nano measuring systems – characterization – analytical imaging techniques – microscopy techniques, scanning 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.

**Contact Periods:**

LECTURE: 45 PERIODS TOTAL: 45 PERIODS

**REFERENCE BOOKS:**

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*
7. *Stephen Beeby, Graham Ensell, Michael Kraft and Neil White,* ***“MEMS Mechanical Sensors”****Artech House, Inc. Boston 2003.*

**COURSE OUTCOMES:**

Learners will be able to

**CO1:** Comprehend the trends in manufacturing of micro components and measuring systems to nano scale.

**CO2:** Applythe operation of micro- and nano-scale devices, applications.

**CO3:** Analyze the nano materials using advanced microscopy

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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**16MFPE17 GREEN MANUFACTURING**

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**COURSE OBJECTIVE:**

To learn on green manufacturing, recycling and life cycle assessment for environment.

**UNIT – I SUSTAINABLE MANUFACTURING AND EMS (9)**

Sustainable Manufacturing - Concepts and Methodologies to Help Promote Industrial Ecology - ISO L4000 series standards - Concepts of ISO 14001 - requirements of ISO 14001 – Environmental Management System benefits - Environmentally Conscious Manufacturing.

**UNIT - II GREEN MANUFACTURING (9)**

Green Design and Quality Initiatives - Environmental Cost Accounting and Business Strategy - Accounting for an Environmentally Conscious Setting - The Development of Eco labeling Schemes

**UNIT - III RECYCLING (9)**

Recycling as Universal Resource Policy - Innovation towards Environmental Sustainability in Industry - A Systematic Framework for Environmentally Conscious Design

**UNIT – IV ENVIRONMENTAL ATTRIBUTES OF MANUFACTURING (10)**

Environmental Attributes of Manufacturing Processes - Environmental Decision Support Systems - Decision Models for Reverse Production System Design - Environmentally Sound Supply Chain Management

**UNIT - V LIFE CYCLE ASSESSMENT (8)**

Life Cycle Assessment - Multipath way and Cumulative Risk Assessment - Reclamation and Recycling of Waste

**Contact Periods:**

LECTURE: 45 PERIODS TOTAL: 45 PERIODS

**REFERENCE BOOKS:**

*L.Madu, C.N.,* ***“Handbook of Environmentally Conscious Manufacturing”****, Kluwer Academic Publisher, 2001.*

*2. Besterfield, D.H., Besterfield, C.M., Besterfield, G.H. and Besterfield, M.S.,****“Total Quality Management ",*** *Pearson Education, 2002.*

*3. Gupta, S.M. and Lambert, A.J.D****., “Environment Conscious Manufacturing”****, CRC Press, 2008.*

*4. Swamidass, P.M.,* ***“Encyclopedia of Production and Manufacturing Management”,*** *Kluwer Academic Publisher, 2000*

**COURSE OUTCOMES:**

Learners will be able to

**CO1**: Comprehend the green manufacturing tools and sustainable engineering concepts.

**CO2:** Evaluate the environmental attributes of manufacturing

**CO3:** Create eco-friendly products and processes by life cycle assessment

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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**16MFPE18 LEAN MANUFACTURING SYSTEMS AND IMPLEMENTATION**

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**COURSE OBJECTIVE:**

To acquire the concepts of lean manufacturing tools and implementation for productivity increase.

**UNIT – I LEAN MANUFACTURING (7)**

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.

**UNIT – II DESIGN - VALUE STREAM MANAGEMENT (9)**

Definition, VSM Types, Product Family Selection, Value Stream Manager; Current State Map, Process Box, Value Stream Icons, 3 MS - Muda, Mura, Muri - Types of Muda, Future State Map, Value Stream Plan, Process Stability - Loss Reduction -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.

**UNIT – III FUNDAMENTAL LEAN TOOLS (11)**

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.

**UNIT – IV LEAN IMPLEMENTATION (9)**

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.

**UNIT – V LEAN METRICS AND LEAN SUSTENANCE (9)**

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.

**Contact Periods:**

LECTURE: 45 PERIODS TOTAL: 45 PERIODS

**REFERENCE BOOKS:**

*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****”, Publisher: Lean Enterprise Institute, Inc., 2003.*

*6. Micheal Wader, “****Lean Tools: A Pocket guide to Implementing Lean Practices****”, Productivity and Quality Publishing Pvt Ltd, 2002.*

**COURSE OUTCOME:**

Learners will be able to

**CO1:** Identify the production system and value stream mapping

**CO2:** Apply lean tools in manufacturing sector to face globalization and competitiveness

**CO3:** Implement the lean against the bench mark the targets for sustainable business growth

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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**16MFPE19 VIBRATION CONTROL AND CONDITION MONITORING**

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**COURSE OBJECTIVE:**

To learn the operations, applications of vibration measuring instruments and its control strategies.

**UNIT – I INTRODUCTION (9)**

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.

**UNIT – II VIBRATION CONTROL (9)**

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

**UNIT - III ACTIVE VIBRATION CONTROL (9)**

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

**UNIT – IV CONDITION BASED MAINTENANCE PRINCIPLES AND APPLICATIONS (9)**

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.

**UNIT – V DYNAMIC BALANCING AND ALLIGNMENT OF MACHINERY (9)**

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.

**Contact Periods:**

LECTURE: 45 PERIODS TOTAL: 45 PERIODS

**REFERENCE BOOKS:**

1. *SingiresuS.Rao, “****Mechanical vibrations****", Addison - Wesley Publishing Co., 1995*
2. *K.J.Bathe and F.I., Wilson, “"****Numerical Methods in Finite Element Analysis****" - Prentice Hall of India Pvt.m, Ltd., 1978*
3. *J.O.DenHartog, “****Mechanical Vibrations****"-McGraw Hill, NewYork, L985*
4. *Rao J S, “****Vibratory Condition Monitoring of Machines****”, NarosaPublishing House, 2000.*
5. *Collacot R.A.-* ***Mechanical fault diagnosis and condition monitoring*** *, Chapman and Hall, Ltd*.,*, John Wiley & Sons, 1977*
6. *Hunt, T.M, Handbook of wear debris analysis and particle detection in liquids, Elsevier applied science, London and New York*
7. *Rao, B. Handbook of condition monitoring, Elsevier advanced technology, Oxford.*
8. *A Davis – Handbook of condition monitoring.*
9. *P Girdhar –* ***Machinery vibration analysis and predictive maintenance****, Elsevier publications 2012*
10. *R G Eisenmann –* ***Machinery malfunction diagnosis and correction****.*
11. *John S Mitchell –* ***Machinery analysis and monitoring.***

**COURSE OUTCOMES:**

Learners will be able to

**CO1**: Analyze the importance of vibration in engineering field.

**CO2:** Select vibration measuring instruments and techniques in the operating machines.

**CO3:** Identify the maintenance and balancing techniques of different machineries.

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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**16MFPE20 FINANCIAL MANAGEMENT AND COST ACCOUNTING**

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**COURSE OBJECTIVE:**

To acquire the concepts to evaluate information for product cost ascertainment, planning,decision making and profit maximization.

**UNIT – I TECHNIQUES OF INVESTMENT ANALYSIS (9)**

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.

**UNIT - II FINANCING DECISION (9)**

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.

**UNIT – III DIVIDEND DECISION**  **(9)**

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

**UNIT – IV WORKING CAPITAL MANAGEMENT (9)**

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

**UNIT – V COST ACCOUNTING (9)**

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

**Contact Periods:**

LECTURE: 45 PERIODS TOTAL: 45 PERIODS

**REFERENCE BOOKS:**

1. *Pandey, I.M, “****Financial Management****”, Vikas Publishing House Pvt. Ltd., (8)th 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 (Low priced edition) 12th edition 2002.*
4. *Khan and Jain, “****Basic Financial Management AND Practice****”, Tata McGraw Hill – 5th Edition 2001.*
5. *S.K Bhattacharyya., John Dearden., “****Costing for Management****”, Vikas Publishing 2002*
6. *Khan MY., Jain P.K., “****Management Accounting : Text, Problems and Cases****”, 4th Edition, Tata McGraw Hill 2007*

**COURSE OUTCOMES:**

Learners will be able to

**CO1**: Select the sources of finance which a business house can mobilize.

**CO2**: Evaluate the risk and return of the various portfolio.

**CO3**: Plan the working capital, budget and cost statement

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

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**16MFOC01 TECHNICAL SEMINAR**

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**COURSE OBJECTIVE:**

To work on a specific technical topic in engineering fields in order to acquire the skills of oral presentation.

**COURSE CONTENT**

1. Prepare on the specific topic related to developments and innovations in engineering
2. Present the seminar for fifteen minutes to thirty minutes on the technical topic
3. Engage in group discussion with the learners
4. Interact with learners and answer the queries on the topic
5. Submit the summary of discussions
6. Evaluation based on the technical presentation, the report and on the interaction during the seminar

**Contact Periods:**

PRACTICAL: 30 PERIODS TOTAL: 30 PERIODS

**COURSE OUTCOMES:**

Learners will be able to

**CO1:** Comprehend concepts and methods adequate to apply inductive and deductive reasoning for enhancing the problem solving skills.

**CO2**: Develop communicative capabilities in speaking, listening, reading and writing

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **CO/ PO** | **PO 1** | **PO 2** | **PO 3** | **PO 4** | **PO 5** | **PO 6** | **PO 7** | **PO 8** | **PO 9** | **PO 10** | **PO 11** |
| **CO 1** | **\*\*** | **\*\*\*** | **\*\*\*** | **\*** | **-** | **\*\*** | **\*\*\*** | **\*\*\*** | **\*** | **\*\*** | **\*\*** |
| **CO 2** | **\*\*** | **\*\*\*** | **\*\*\*** | **\*** | **-** | **\*\*\*** | **\*\*\*** | **\*\*\*** | **\*** | **\*\*** | **\*\*** |

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| --- | --- | --- | --- | --- |
| **16MFOC02 ENTREPRENEURSHIPSKILLS** | | | | |
|  | ***L*** | ***T*** | ***P*** | ***C*** |
|  | ***0*** | ***0*** | ***2*** | ***1*** |
| **COURSE OBJECTIVE:** | | | | |
| To provide learners with skills needed to effectively organize, develop, create, evaluate and manage an event or business. | | | | |
| **COURSE CONTENT:**   1. 1. Event management and entrepreneurship, communication and interpersonal skills, 2. 2. Economics, trading and project related business ownerships. 3. 3. Developing an enterprise, computer and technology applications, real and simulated occupational experiences. 4. 4. Developing leadership abilities, expand workplace- readiness skills, and broaden opportunities for personal and professional growth   **Contact Periods:**  PRACTICAL: 30 PERIODS TOTAL: 30 PERIODS  **COURSE OUTCOMES:**  Learners influenced and enhanced with skill development on self-employability and able to achieve attitudes necessary to become successful in business or event management.  **CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**   |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | **CO/ PO** | **PO 1** | **PO 2** | **PO 3** | **PO 4** | **PO 5** | **PO 6** | **PO 7** | **PO 8** | **PO 9** | **PO 10** | **PO 11** | | **CO 1** | **\*\*** | **\*\*\*** | **\*\*** | **\*\*\*** | **\*\*** | **\*\*\*** | **\*\*\*** | **\*\*** | **\*\*** | **\*\*** | **\*\*** | | | | | |

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| --- | --- | --- | --- | --- |
| **16MFOC03 HUMAN VALUES AND PROFESSIONAL ETHICS** | | | | |
|  | ***L*** | ***T*** | ***P*** | ***C*** |
|  | ***1*** | ***0*** | ***0*** | ***1*** |
| **COURSE OBJECTIVE:** | | | | |

To acquire the concepts of Engineering Ethics and Human Values with Social responsibility of an Engineer and the Ethical dilemma while discharging duties in Professional life.

**UNIT - I ENGINEERING ETHICS (5)**

Senses of Engineering Ethics- variety of moral issues- types of inquiry – moral dilemmas- moral autonomy- Kohiberg’s Theory- Gilligen’s Theory- Consensus and controversy- Models of Professional roles- theories about right actions- self-interest – customs and religion – uses of ethical theories- Valuing time- cooperation- commitment.

**UNIT - II ENGINEERING AS SOCIAL EXPERIMENTATION (5)**

Engineering as experimentation- engineers as responsible experimenters- codes of ethics- a balanced outlook on law – the challenger case study – engineers as managers – consulting engineers – Moral leadership.

**UNIT - III SAFETY, RESPONSIBILITIES, RIGHTS AND GLOBAL ISSUES (5)**

Safety and risk – assessment of safety and risk – risk benefit analysis and reducing risk – the three-mile island and Chernobyl case studies – Environmental ethics – computer ethics – weapons development – Multinational corporations – engineers as expert witness and advisors.

**Contact Periods:**

LECTURE: 30 PERIODS TOTAL: 30 PERIODS

**REFERENCE BOOKS:**

1. *Mike Martin and Roland Schinzinger, “****Ethics in Engineering****” , McGraw Hill, New York, 1996*
2. *M. Govindarajan, S. Natarajan and V.S. Senthil Kumar, “****Engineering Ethics(including human values)****”, Eastern Economy Edition, Printice Hall of India Ltd.,2004*
3. *Charles D.Fleddermann, “****Engineering Ethics****”, Pearson Education, 2004*
4. *Edmund G Seebauer and Robert L. Berry,“****Fundementals of Ethics for Scientists and Engineers****”, 2001, Oxford University Press*
5. *Charles E. Harris, Micheal S. Protchard and MichealJ.Rabins, “****Engineering Ethics- Concepts and Casses****”, Thomson Leaning , 2000.*
6. *John R. Boatright, “****Ethics and Conduct of Business****”, Pearson Education, 2003.*

**COURSE OUTCOMES:**

Learners will be able to

**CO1:** Understand and appreciate Human Values, exhibit self-confidence and develop good character

**CO2:** Sense engineering ethics, professional roles and valuing time, co-operation and commitment.

**CO3:** Understand and practice code of ethics.

**CO4:** Assess safety and risk thereby capable of doing risk benefit analysis.

**CO5:** Develop and exhibit moral leadership qualities in exercising Engineering Consultations without compromising environmental, legal and ethical issues.

**CORRELATION BETWEEN COURSE OUTCOMES AND PROGRAMME OUTCOMES**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **CO/ PO** | **PO 1** | **PO 2** | **PO 3** | **PO 4** | **PO 5** | **PO 6** | **PO 7** | **PO 8** | **PO 9** | **PO 10** | **PO 11** |
| **CO 1** | **\*\*** | **\*\*** | **\*** | **\*\*** | **-** | **\*** | **\*** | **-** | **\*\*** | **\*\*\*** | **\*\*\*** |
| **CO 2** | **\*\*\*** | **\*\*** | **\*\*** | **\*\*** | **-** | **\*\*** | **\*** | **-** | **\*\*** | **\*\*\*** | **\*\*\*** |
| **CO 3** | **\*\*\*** | **\*** | **\*\*** | **\*\*** | **-** | **\*\*** | **\*** | **-** | **\*\*** | **\*\*\*** | **\*\*\*** |
| **CO 4** | **\*\*** | **\*\*** | **\*\*** | **\*\*** | **-** | **\*\*** | **\*** | **-** | **\*\*** | **\*\*\*** | **\*\*\*** |
| **CO 5** | **\*\*** | **\*\*** | **\*\*** | **\*\*** | **-** | **\*\*\*** | **\*** | **-** | **\*\*** | **\*\*\*** | **\*\*\*** |