UNIVERSITY DEPARTMENTS

ANNA UNIVERSITY CHENNAI : : CHENNAI 600 025

REGULATIONS - 2009

CURRICULUM I TO IV SEMESTERS (FULL TIME)

M.E. PRODUCT DESIGN & DEVELOPMENT

SEMESTER I

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1	MA 9106	Applied Mathematics for Engineering Design	3	1	0	4
2	ED 9111	Concepts of Engineering Design	3	0	0	3
3	CD 9111	Computer Applications in Design	3	0	2	4
4	PD 9111	Quality Concepts in Design	3	0	0	3
5	E1	Elective I	3	0	0	3
6	E2	Elective II	3	0	0	3
PRACTICAL						
7	PD 9112	Digital Product Development Lab-I	0	0	2	1
8	PD 9113	Digital Product Development Lab-III	0	0	2	1
		TOTAL	18	1	6	**22**

SEMESTER II

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1	ED 9121	Finite Element Methods in Mechanical Design	3	1	0	4
2	PD 9121	Integrated Product Design and Process Development**	3	1	0	4
3	PD 9122	Product and Process Engineering Tools	3	0	0	3
4	PD 9123	Materials for Product Design**	3	1	0	4
5	E3	Elective III	3	0	0	3
6	E4	Elective IV	3	0	0	3
PRACTICAL						
7	PD 9124	Digital Product Development Lab-II	0	0	2	1
8	PD 9125	New Product Design Studio Lab	0	0	2	1
		TOTAL	18	3	4	**23**

SEMESTER III

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1	E5	Elective V	3	0	0	3
2	E6	Elective VI	3	0	0	3
3	E7	Elective VII	3	0	0	3
PRACTICAL						
4	PD 9131	Project Work – Phase I	0	0	12	6
		TOTAL	18	3	4	**23**

SEMESTER IV

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
PRACTICAL						
1	PD 9141	Project Work – Phase II	0	0	24	12
		TOTAL	0	0	24	12

** a Term Project must be given for Assessment – 3 (Compulsory)

(Total number of credits: 22 + 23 + 15 + 12 = **72**)

UNIVERSITY DEPARTMENTS

ANNA UNIVERSITY CHENNAI : : CHENNAI 600 025

REGULATIONS - 2009

CURRICULUM I TO VI SEMESTERS (PART TIME)

M.E. PRODUCT DESIGN & DEVELOPMENT

SEMESTER I

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1	MA9106	Applied Mathematics for Engineering Design	3	1	0	4
2	ED9111	Concepts of Engineering Design	3	0	0	3
3	CD9111	Computer Applications in Design	3	0	2	4
PRACTICAL						
4	PD9112	Digital Product Development Lab-I	0	0	2	1
		TOTAL	9	1	4	**12**

SEMESTER II

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1	ED9121	Finite Element Methods in Mechanical Design	3	1	0	4
2	PD9121	Integrated Product Design and Process Development**	3	1	0	4
3	PD9122	Product and Process Engineering Tools	3	0	0	3
PRACTICAL						
4	PD9124	Digital Product Development Lab-II	0	0	2	1
		TOTAL	18	3	4	**23**

SEMESTER III

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1	PD9111	Quality Concepts in Design	3	0	0	3
2	E1	Elective I	3	0	0	3
3	E2	Elective II	3	0	0	3
PRACTICAL						
4	PD9113	Digital Product Development Lab-III	0	0	2	1
		TOTAL	18	1	6	**22**

SEMESTER IV

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1	PD9123	Materials for Product Design**	3	1	0	4
2	E3	Elective III	3	0	0	3
3	E4	Elective IV	3	0	0	3
PRACTICAL						
4	PD9125	New Product Design Studio Lab	0	0	2	1
		TOTAL	18	3	4	**23**

SEMESTER V

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
THEORY						
1	E5	Elective V	3	0	0	3
2	E6	Elective VI	3	0	0	3
3	E7	Elective VII	3	0	0	3
PRACTICAL						
4	PD9131	Project Work – Phase I	0	0	12	6
		TOTAL	18	3	4	**23**

SEMESTER VI

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
PRACTICAL						
1	PD9141	Project Work – Phase II	0	0	24	12
		TOTAL	0	0	24	12

** a Term Project must be given for Assessment – 3 (Compulsory)

(Total number of credits: 22 + 23 + 15 + 12 = **72**)

COMMON ELECTIVES (M.E. – ENGINEERING DESIGN/COMPUTER AIDED DESIGN/PRODUCT DESIGN AND DEVELOPMENT)

SL. NO	COURSE CODE	COURSE TITLE	L	T	P	C
1	ED 9150	Optimization Techniques in Design	3	0	0	3
2	PD 9150	Design Paradigm	3	0	0	3
3	ED 9151	Engineering Fracture Mechanics	3	0	0	3
4	ED 9172	Design for Manufacture Assembly & Environments	3	0	0	3
5	ED 9152	Tribology in Design	3	0	0	3
6	ED 9153	Advanced Mechanics of Materials	3	0	0	3
7	ED 9154	Composite Materials and Mechanics	3	0	0	3
8	ED 9155	Applied Engineering Acoustics	3	0	0	3
9	ED 9156	Advanced Tool Design	3	0	0	3
10	ED 9157	Productivity Management and Re-Engineering	3	0	0	3
11	ED 9158	Industrial Robotics and Expert systems	3	0	0	3
12	EY 9156	Design of Heat Exchangers	3	0	0	3
13	ED9171	Rapid Prototyping and Tooling	3	0	0	3
14	ED 9159	Design of Material Handling Equipments	3	0	0	3
15	ED 9160	Plasticity and Metal Forming	3	0	0	3
16	ED 9161	Theory of Plates and Shells	3	0	0	3
17	ED 9162	Design of Pressure Vessel and Piping	3	0	0	3
18	CI 9122	Mechatronics in Manufacturing systems	3	0	0	3
19	ED 9163	Modal Analysis of Mechanical Systems	3	0	0	3
20	ED 9164	Design of Hydraulic and Pneumatic Systems	3	0	0	3
21	ED 9165	Experimental Stress Analysis	3	0	0	3
22	ED 9173	Integrated Manufacturing Systems	3	0	0	3
23	ED 9166	Maintenance Engineering	3	0	0	3
24	ED 9169	Bearing Design and Rotor Dynamics	3	0	0	3
25	PD 9151	Micro Electro Mechanical Systems	3	0	0	3
26	PD 9152	Creativity in Design	3	0	0	3
27	PD 9153	Reverse Engineering	3	0	0	3
28	ED 9174	Supply Chain Management	3	0	0	3
29	PD 9154	Enterprise Resource Planning	3	0	0	3
30	IC 9162	Computational Fluid Dynamics	3	0	0	3
31	ED 9170	Mini Project	3	0	0	3

MA 9106 APPLIED MATHEMATICS FOR ENGINEERING DESIGN
Common to M.E. (Engg. Design)/M.E. (CAD)/M.E. (PDD)

L	T	P	C
3	1	0	4

UNIT I D RANDOM VARIABLES 9

Joint distributions – Marginal and Conditional distributions – functions of two – dimensional random variables – Regression curve - Correlation.

UNIT II COMPUTATIONAL METHODS IN ENGINEERING 9

Boundary value problems for ODE – Finite difference methods – Numerical solution of PDE – Solution of Laplace's and Poisson equation – Liebmann's iteration process – Solution of heat conduction equation by Schmidt explicit formula and Crank-Nicolson implicit scheme – Solution of wave equation

UNIT III TENSOR ANALYSIS 9

Summation convention – Contravariant and covariant vectors – contraction of tensors – inner product – quotient law – metric tensor – Christoffel symbols – covariant differentiation – gradient, divergence and curl

UNIT IV CALCULUS OF VARIATION 9

Variation and its properties – Euler's equation – functionals dependent on first and higher order derivatives – functionals dependent on functions of several independent variables – problems with moving boundaries – direct methods – Ritz and Kantorovich methods

UNIT V FAST FOURIER TRANSFORMS 9

Discrete Fourier transform – linearity and periodicity – inverse N-point DFT – DFT approximation of Fourier coefficients – sampled Fourier series – Approximation of Fourier transform by an N-point DFT – FFT – Computational efficiency of FFT

Total: L: 45 + T: 15 = 60

REFERENCES:

1. James, G., Advanced Modern Engineering Mathematics, 3rd edition, Pearson Education, 2004.
2. Grewal, B.S., Numerical methods in Engineering and Science, 7th edition, Khanna Publishers, 2005.
3. Grewal, B.S., Higher Engineering Mathematics, 40th edition, Khanna Publishers, 2007.
4. Gupta, A.S., Calculus of variations with applications, Prentice-Hall of India, New Delhi, 1997.
5. O'Neil, P.V., Advanced Engineering Mathematics, Thomson Asia Pvt. Ltd., Singapore, 2003.
6. Andrews, L.C. and Philips, R. L. Mathematical Techniques for Engineers and Scientists, Prentice Hall of India, 2006.

ED 9111 CONCEPTS OF ENGINEERING DESIGN

L	T	P	C
3	0	0	3

UNIT I DESIGN FUNDAMENTALS 9

Importance of design- The design process-Considerations of Good Design – Morphology of Design –Organization for design– Computer Aided Engineering – Designing to codes and standards – Concurrent Engineering – Product and process cycles – Technological Forecasting – Market Identification – Competition Bench marking.

UNIT II CUSTOMER ORIENTED DESIGN & SOCIETAL CONSIDERATIONS 9

Identification of customer needs- customer requirements- Quality Function Deployment-Product Design Specifications- Human Factors in Design – Ergonomics and Aesthetics.

Societal consideration - Contracts – Product liability – Protecting intellectual property – Legal and ethical domains – Codes of ethics - Ethical conflicts – Environment responsible design-future trends in interaction of engineering with society.

UNIT III DESIGN METHODS 9

Creativity and Problem Solving –Creativity methods-Theory of Inventive Problem Solving (TRIZ) – Conceptual decomposition-Generating design concepts-Axiomatic Design – Evaluation methods-Embodiment Design-Product Architecture-Configuration Design-Parametric Design. Role of models in design-Mathematical Modeling – Simulation – Geometric Modeling –Rapid prototyping- Finite Element Analysis– Optimization – Search Methods.

UNIT IV MATERIAL SELECTION PROCESSING AND DESIGN 9

Material Selection Process – Economics – Cost Vs Performance – Weighted property Index – Value Analysis – Role of Processing in Design – Classification of Manufacturing Process – Design for Manufacture – Design for Assembly –Designing for castings, Forging, Metal Forming, Machining and Welding – Residual Stresses – Fatigue, Fracture and Failure.

UNIT V PROBABILITY CONCEPTS IN DESIGN FOR RELIABILITY 9

Probability – Distributions – Test of Hypothesis – Design of Experiments – Reliability Theory – Design for Reliability – Reliability centered Maintenance-Robust Design-Failure mode Effect Analysis.

Total 45

TEXT BOOKS:

1. Dieter, George E., “Engineering Design - A Materials and Processing Approach”, McGraw Hill, International Editions, Singapore, 2000.

REFERENCES:

1. Pahl, G, and Beitz, W.,” Engineering Design”, Springer – Verlag, NY. 1984.
2. Ray, M.S., “Elements of Engg. Design”, Prentice Hall Inc. 1985.
3. Suh, N.P., “The principles of Design”, Oxford University Press, NY.1990.
4. Karl T. Ulrich and Steven D. Eppinger “Product Design and Development” McGraw Hill Edition 2000.

CD 9111 COMPUTER APPLICATIONS IN DESIGN L T P C
3 0 2 4

UNIT I INTRODUCTION TO COMPUTER GRAPHICS FUNDAMENTALS 11

Output primitives (points, lines, curves etc.,), 2-D & 3-D transformation (Translation,scaling,rotators) windowing - view ports - clipping transformation.

Representation of curves – Bezier curves - cubic spline curve - B – Spline curves - Rational curves –Surface Modeling techniques - surface patch – Coons patch- bi-cubic patch – Bezier and B-spline surfaces – Volume modeling – Boundary models – CSG-other modeling techniques.

UNIT II INTRODUCTION TO CAD SOFTWARE 8

Writing interactive programs to solve design problems and production of drawings - using any languages like Auto LISP/C/FORTRAN etc.- creation of surfaces - solids etc. using solid modeling packages (prismatic and revolved parts).

UNIT III SOLID MODELING 8

Regularized Boolean set operations - primitive instancing - sweep representations - boundary representations - constructive solid Geometry - comparison of representations - user interface for solid modeling.
Graphics and computing standards– Open GL Data Exchange standards – IGES, STEP etc– Communication standards.

UNIT IV VISUAL REALISM 9

Hidden – Line – Surface – solid removal algorithms shading – coloring. Introduction to parametric and variational geometry based software's and their principles creation of prismatic and lofted parts using these packages.

UNIT V ASSEMBLY OF PARTS 9

Assembly modeling - interferences of positions and orientation - tolerances analysis - mass property calculations - mechanism simulation.

Note: Lab Practice of 30 hrs. Total 45 + 30 = 75 Hours

REFERENCES:

1. William M Neumann and Robert F.Sproul "Principles of Computer Graphics", Mc Graw Hill Book Co. Singapore, 1989.
2. Donald Hearn and M. Pauline Baker "Computer Graphics", Prentice Hall, Inc., 1992.
3. Ibrahim Zeid Mastering CAD/CAM – McGraw Hill, International Edition, 2007.
4. Foley, Wan Dam, Feiner and Hughes – Computer graphics principles & practices, Pearson Education – 2003.
5. Donald Heam and M. Pauline Baker "Computer Graphics", Prentice Hall, Inc., 1992.

PD 9111 QUALITY CONCEPTS IN DESIGN

L T P C
3 0 0 3

AIM

To study about robust design, embodiment principles, various methods in design of experiments, reliability charts and histograms and six sigma techniques.

UNIT I DESIGN FOR QUALITY 9

Quality Function Deployment -House of Quality-Objectives and functions-Targets-Stakeholders-Measures and Matrices-Design of Experiments –design process-Identification of control factors, noise factors, and performance metrics - developing the experimental plan- experimental design –testing noise factors- Running the experiments –Conducting the analysis-Selecting and conforming factor-Set points-reflecting and repeating.

UNIT II FAILURE MODE EFFECT ANALYSIS 9

Basic methods: Refining geometry and layout, general process of product embodiment-Embodiment checklist- Advanced methods: systems modeling, mechanical embodiment principles-FMEA method- linking fault states to systems modeling-Case study- computer monitor stand for a docking station.

UNIT III DESIGN OF EXPERIMENTS 9

Design of experiments-Basic methods- Two factorial experiments-Extended method-reduced tests and fractional experiments, orthogonality, base design method, higher dimensional fractional factorial design-Statistical analysis of experiments: Degree of freedom, correlation coefficient, standard error of the residual t-test, ANOVA-ratio test, other indicators-residual plots, Advanced DOE method for product testing-Product applications of physical modeling and DOE, Blender panel display evaluation, coffee grinder experimental optimization-Taguchi method.

UNIT IV STATISTICAL CONSIDERATION AND RELIABILITY 9

Frequency distributions and Histograms- Run charts –stem and leaf plots- Pareto diagrams-Cause and Effect diagrams-Box plots- Probability distribution-Statistical Process control–Scatter diagrams –Multivariable charts –Matrix plots and 3-D plots.-Reliability-Survival and Failure-Series and parallel systems-Mean time between failure-Weibull distributions

UNIT V DESIGN FOR SIX SIGMA 9

Basis of SIX SIGMA –Project selection for SIX SIGMA- SIX SIGMA problem solving- SIX SIGMA in service and small organizations - SIX SIGMA and lean production –Lean SIX SIGMA and services

L -45

REFERENCES:

1. Product Design Techniques in Reverse Engineering and New Product Development, KEVIN OTTO & KRISTIN WOOD, *Pearson Education (LPE), 2001.*
2. Product Design And Development, KARL T. ULRICH, STEVEN D. EPPINGER, TATA McGRAW-HILL- 3rd Edition, 2003.
3. The Management and control of Quality-6th edition-James R. Evens, William M Lindsay Pub:son south-western(www.swlearning.com)
4. Fundamentals of Quality control and improvement 2nd edition, AMITAVA MITRA, Pearson Education Asia, 2002.

PD9112 DIGITAL PRODUCT DEVELOPMENT LAB –I

L	T	P	C
0	0	2	1

- **CAD** Introduction.
- **Sketcher**
- **Solid modeling** –Extrude, Revolve, Sweep, etc and Variational sweep, Loft ,etc
- **Surface modeling** –Extrude, Sweep, Trim...etc and Mesh of curves, Free form etc
- **Feature manipulation** – Copy, Edit, Pattern, Suppress, History operations etc.
- **Assembly**-Constraints, Exploded Views, Interference check
- **Drafting**-Layouts, Standard & Sectional Views, Detailing & Plotting.

Exercises in Modeling and drafting of Mechanical Components - Assembly using Parametric and feature based Packages like PRO-E / SOLID WORKS /CATIA / NX etc

- Introduction to Rapid Prototyping – Conversion of PRT file to STL file -Slicing Software

Total-45 hr

PD9113 DIGITAL PRODUCT DEVELOPMENT LAB-III

L	T	P	C
0	0	2	1

Analysis of Mechanical Components – Use of FEA Packages like ANSYS/ NASTRAN etc., Exercises shall include analysis of

i) Machine elements under Static loads
ii) Thermal Analysis of mechanical systems
iii) Modal Analysis
iv) Machine elements under Dynamic loads
v) Non-linear systems

- Rapid Prototyping – Making RP component – Study on RP tooling

Total 45 Hrs

ED 9121 FINITE ELEMENT METHODS IN MECHANICAL DESIGN
(Common for M.E Degree Programs in Engineering Design, CAD & PDD streams)

L	T	P	C
3	1	0	4

OBJECTIVE:
At the end of this course the students would have developed a thorough understanding of the basic principles of the finite element analysis techniques with an ability to effectively use the tools of the analysis for solving practical problems arising in engineering design

UNIT-I: GENERAL INTRODUCTION * 10

Introduction- structural element and system- assembly and analysis of a structure- boundary conditions- general pattern- standard discrete system- transformation of coordinates- examples – direct physical approach to problems in elasticity- direct formulation- displacement approach – minimization of total potential- convergence criteria – discretization error- nonconforming elements and patch test- solution process- numerical examples

UNIT-II: GENERALIZATION OF FINITE ELEMENT CONCEPTS AND ELEMENT SHAPE FUNCTIONS* 7

Boundary value problems – integral or weak statements- weighted residual methods- Galerkin method- virtual work as weak form of equations in solid and fluid mechanics- variational principles – establishment of natural variational principles for linear self-adjoint differential equations –standard and hierarchical elements- shape functions- rectangular elements- completeness of polynomials- Lagrange family- Serendipity family- rectangular prisms- tetrahedral elements- global and local finite element approximation- mapped elements- coordinate transformations- geometrical conformity of elements- evaluation of element matrices- transformation in $\xi, \eta \, and \, \zeta -$ coordinates- order of convergence- numerical integration –example problems

UNIT-III: APPLICATIONS TO FIELD PROBLEMS * 9

Solution to problems in linear elasticity- plane problems in elasticity- plates and shells- solution of problems in heat-transfer and fluid mechanics- numerical examples- discussion on error estimates

UNIT-IV: FINITE ELEMENTS IN STRUCTURAL DYNAMICS AND VIBRATIONS ** 10

Dynamic equations- stiffness, mass and damping matrices- consistent and diagonal mass matrices- Extraction of natural frequencies and modes- Reduction of number of degrees of freedom - modal methods - component mode synthesis- harmonic analysis- response history- explicit and implicit direct integration- stability and accuracy- analysis of response spectra- example problems

UNIT-V: NON-LINEAR ANALYSIS * 9**

Non-linear problems in elasticity- some solution methods- plasticity: introduction, general formulation for small strains- formulation for von Mises theory- computational procedure- problems of gaps and contact- geometric non-linearity- modelling considerations

Note

At the post-graduate level of instruction the contact hours are to be supplemented by self study by students. As for the examination, modelling considerations, choice of elements, boundary conditions, loading conditions, and basic procedures only need to be emphasized without expecting a complete numerical solution to practical problems.

REFERENCES

1. *Zienkiewicz.O.C, Taylor.R.L,& Zhu,J.Z "The Finite Element Method: Its Basis & Fundamentals", Butterworth-Heinemann (An imprint of Elsevier), First printed in India 2007, India Reprint ISBN:978-81-312-1118-2, published by Elsevier India Pvt. Ltd., New Delhi.
2. **Cook, R.D., Malkus, D. S., Plesha,M.E., and Witt,R.J " Concepts and Applications of Finite Element Analysis", Wiley Student Edition, 4th Edition, First Reprint 2007, Authorized reprint by Wiley India(P) Ltd., New Delhi, ISBN-13 978-81-265-1336-9
3. *** Zienkiewicz.O.C, Taylor.R.L "The Finite Element Method" McGraw Hill International Editions, Fourth Edition, 1991, Volume 2 (Chapters 7&8)
4. Reddy, J.N., "Introduction to Non-Linear Finite Element Analysis", Oxford Uniiversity Press, 2008
5. Rao,S.S., "The Finite Element Method in Engineering", Butterworth-Heinemann (An imprint of Elsevier), reprinted 2006, 2007, published by Elsevier India Pvt. Ltd., New Delhi, Indian Reprint ISBN: 978-81-8147-885-6
6. Huebner,K.H., Dewhirst,D.L.,Smith,D.E & Byron,T.G., "The Finite Element Method for Engineers", Wiley Student Edition, Fourth Edition 2004,John Wiley&Sons(Asia)Pve.Ltd., ISBN: 9812-53-154-8
7. Ramamurthi, V., "Finite Element Method in Machine Design", Narosa Publishing House, January 2009, ISBN: 978-81-7319-965-3

PD 9121 INTEGRATED PRODUCT DESIGN AND PROCESS DEVELOPMENT** **L T P C**
3 1 0 4

UNIT I INTRODUCTION 8

Need for IPPD-Strategic importance of Product development - integration of customer, designer, material supplier and process planner, Competitor and customer - behavior analysis. Understanding customer-promoting customer understanding-involve customer in development and managing requirements - Organization process management and improvement

UNIT II CONCEPT GENERATION, SELECTION AND TESTING 10

Plan and establish product specifications. Task - Structured approaches - clarification - search-externally and internally-Explore systematically - reflect on the solutions and processes - concept selection - methodology - benefits. Implications - Product change - variety - component standardization - product performance - manufacturability – Concept Testing Methodologies.

UNIT III PRODUCT ARCHITECTURE 8

Product development management - establishing the architecture - creation - clustering - geometric layout development - Fundamental and incidental interactions - related system level design issues - secondary systems -architecture of the chunks - creating detailed interface specifications-Portfolio Architecture.

UNIT IV INDUSTRIAL DESIGN 8

Integrate process design - Managing costs - Robust design - Integrating CAE, CAD, CAM tools – Simulating product performance and manufacturing processes electronically - Need for industrial design-impact – design process - investigation of customer needs - conceptualization - refinement - management of the industrial design process - technology driven products - user - driven products - assessing the quality of industrial design.

UNIT V DESIGN FOR MANUFACTURING AND PRODUCT DEVELOPMENT 11

Definition - Estimation of Manufacturing cost-reducing the component costs and assembly costs – Minimize system complexity - Prototype basics - Principles of prototyping - Planning for prototypes - Economic Analysis - Understanding and representing tasks-baseline project planning - accelerating the project-project execution.

Total No of periods: 45+15=60

**** a Term Project/Presentation must be given for Assessment – 3 (Compulsory)**

TEXT BOOK

1. Product Design and Development, Karl T.Ulrich and Steven D.Eppinger, McGraw –Hill International Edns.1999

REFERENCES:

1. Concurrent Engg./Integrated Product Development. Kemnneth Crow, DRM Associates, 6/3,Via Olivera, Palos Verdes, CA 90274(310) 377-569,Workshop Book
2. Effective Product Design and Development, Stephen Rosenthal, Business One Orwin, Homewood, 1992,ISBN, 1-55623-603-4
3. Tool Design – Integrated Methods for successful Product Engineering, Stuart Pugh, Addison Wesley Publishing,Neyourk,NY,1991, ISBN 0-202-41639-5
4. www.me.mit/2.7444

PD 9122 PRODUCT and PROCESS ENGINEERING TOOLS L T P C
3 0 0 3

OBJECTIVES
To study about the tools required for various design activities, improvement methodologies and quality control charts and other standards.

UNIT I TOOLS FOR CONCEPT DEVELOPMENT 9

Products division, Quality function Deployment, concept engineering –Tools for Design Development: design failure mode and design analysis, Reliability prediction- Tools for Design Optimization: The Taguchi Loss Function, Optimizing Reliability- Tools for Design Verification: Reliability Testing,.

UNIT II TOOLS FOR PROCESS IMPROVEMENT 9

Process improvement methodologies, The Deming Cycle-FADE-Basic tools for process improvement: flow charts, run charts and control charts, check sheets, histograms, Pareto diagrams, Cause and Effect Diagrams-Scatter Diagrams-Other tools for process improvement: Kaizen Blitz, Poka-yoke (mistake proofing), process simulation-Engaging the work force in process improvement.

UNIT III STATISTICAL PROCESS CONTROL 9

Quality control measurements-SPC Methodology-Process capacity evaluation- Control charts for variables data-Special Control charts for variables data- Process Capability Evaluation- Control Charts for Attributes- Summary of control charts construction chart, np-charts,c & u charts –Designing control charts: sampling , size, frequency-SPC,ISO 9000:2000, AND SIX SIGMA-Pre control- Measurement system Evaluation.

UNIT IV BENCHMARKING AND ESTABLISHING ENGINEERING SPECIFICATIONS 9

A Benchmarking Approach – Support tools for the benchmarking process: intended assembly cost analysis, form diagram, trend analysis- Setting product specifications: Basic & Advanced method.

UNIT V PROJECT MANAGEMENT 9

Understanding and representing tasks: Tasks, charts- Baseline project planning – Accelerating projects-project execution- Postmortem execution.

T-45

TEXT BOOK:
1. Product Design & Development, KARL T. ULRICH, STEVEN D. EPPINGER, TATA McGRAW-HILL- 3rd Edition, 2003

REFERENCES:
1. Product Design Techniques in Reverse Engineering and New Product Development, KEVIN OTTO & KRISTIN WOOD, *Pearson Education (LPE), 2001.*
2. The Management and control of Quality-6th edition-James R. Evens, William M Lindsay Pub:son south-western(www.swlearning.com)

PD 9123 MATERIALS FOR PRODUCT DESIGN[**] L T P C
3 1 0 4

UNIT I MATERIAL BEHAVIOR AND SELECTION 12

Elastic and Plastic deformation- Mechanism of Plastic deformation-yield stress and shear strength-Perfect and Real crystals- Effect of strain rate and temperature on plastic behaviour- Super plasticity- Deformation of non crystalline materials- Material selection-Cost and service requirement- Recycling- Selection of material for mechanical properties- Strength, toughness and fatigue- Material selection for durability and surface wear and Corrosion resistance- Functional relation between materials and processing-Manufacturing characteristics of metals- Material selection charts and other aids-material selection for aero, auto and nuclear application-Structural Product analysis-End Use behavior – Tooling in product design- Case studies in material selection .

UNIT II PROCESS MODELING AND PRODUCT DESIGN 9

Methods of analysis- Slab, slip line and upper bound solutions- Numerical methods-Effect of Friction- Contact problem- Basic analysis of process- Forging, Drawing and sheet metal forming- machining- Turning- modern materials- micro alloyed and dual phase steel- High strength low alloy metals- Smart materials- Shape memory metals-Metallic Glasses- Nano Materials- Metal foams- Properties and applications for product design.

UNIT III NON METALS AND MANUFACTURING 9

General properties and its importance of polymers- Thermal and electrical properties-mechanical properties- Criteria for selection- Composite materials- fibers- Boron, glass, carbon, organic- Ceramic and metallic fibres- - Matrix materials- Polymer, metal and ceramics- properties and applications- Manufacturing methods of plastic products-Injection and blow moulding –Rotational mouding-Compression moulding-Transfer moulding- layering of composites

UNIT IV PRODUCT DESIGN AND ASSEMBLY REQUIREMENTS 8

Structural product analysis- End use behaviour- Effect of tooling in product design-Design for joining and assembling- Design for live hinges- Snap fits, design of corners, bushes and ribs- Design considerations- New product design-Methods of decoration-Bonding and cementing techniques- Thermal bonding- Machining of plastics-Parameters and effect- Case studies in material selection with relevance to product design and development

UNIT V DEVELOPMENT IN MATERIALS PROCESSING 7

Micro fabrication technologies- Tool for micro fabrication- Diamond and high speed machining- LIGA micro fabrication process- Multilayer X-ray lithography- Wire bonding packaging- Etching- Wet and dry etching techniques- Typical application

Total 45 + 15 = 60 Periods

[**] a Term Project must be given for Assessment – 3 (Compulsory)

TEXT BOOK

1. Serope Kalpakjian and Schmid- Manufacturing process for Engineering materials Pearson- 2005.

REFERENCES

1. Paul Degarmo, Black and Kohsher- Materials and processes in Manufacturing- Wiley Student Edition- 9th Edition- 2005
2. Sami Franssile- Introduction to Micro Fabrication- John Wiley and Sons- UK 2004
3. Harfold Belofsky- Plastic design and processing hand book, Hanser publication- 2005
4. Beck- Plastic Product Design- van Nostrand Reignhold 2nd Edition
5. Asbhay, Selection of Materials, El Sevier Publications, 2006

PD9124 **DIGITAL PRODUCT DEVELOPMENT LAB-II** **L T P C**
0 0 2 1

- CNC Machines – Features, Tooling
- **CNC program** simulation in **FANUC/SINUMERIC** systems.
- CAD/CAM connection & DNC link.
- **Cutter path generation** for Planar machining, Surface Machining, Cavity machining, Fixed & variable contour machining, Drilling,Turning, tool&die and mould machining
- Practical in Production CNC **Machining & Turning Centres** and **Rapid Prototyping** Machine
- Post processing & CNC code Generation for advanced machining.

Exercises in tool path and NC code generation using software such as NX

Total: 45 Hours

PD9125 **NEW PRODUCT DESIGN STUDIO** **L T P C**
0 0 2 1

The students in a group have to develop digital and physical prototype models using RP machine / clay models of a new product/ existing product with enhanced feature involving the following areas:

- Automotive components
- Tool and die components
- Press tool components
- Consumer product
- Injection moulded products.

The fabricated models may be in the form of RP models,clay models,sheet metal modelsor card-board models etc… The design and development of the product will be reviewed in two stages for awarding internal marks. The end semester examination mark will be based on the demonstration of the new product developed and oral examination on the same by internal examiners.

Practical 45 hrs

ED 9150 OPTIMIZATION TECHNIQUES IN DESIGN

L	T	P	C
3	0	0	3

UNIT I UNCONSTRAINED OPTIMIZATION TECHNIQUES 10

Introduction to optimum design - General principles of optimization – Problem formulation & their classifications - Single variable and multivariable optimization, Techniques of unconstrained minimization – Golden section, Random, pattern and gradient search methods – Interpolation methods.

UNIT II CONSTRAINED OPTIMIZATION TECHNIQUES 10

Optimization with equality and inequality constraints - Direct methods – Indirect methods using penalty functions, Lagrange multipliers - Geometric programming

UNIT III ADVANCED OPTIMIZATION TECHNIQUES 10

Multi stage optimization – dynamic programming; stochastic programming; Multi objective optimization, Genetic algorithms and Simulated Annealing techniques; Neural network & Fuzzy logic principles in optimization.

UNIT IV STATIC APPLICATIONS 8

Structural applications – Design of simple truss members - Design applications – Design of simple axial, transverse loaded members for minimum cost, weight – Design of shafts and torsionally loaded members – Design of springs.

UNIT V DYNAMIC APPLICATIONS 7

Dynamic Applications – Optimum design of single, two degree of freedom systems, vibration absorbers. Application in Mechanisms – Optimum design of simple linkage mechanisms.

Total 45

REFERENCES:

1. Rao, Singaresu, S., “Engineering Optimization – Theory & Practice”, New Age International (P) Limited, New Delhi, 2000.
2. Johnson Ray, C., “Optimum design of mechanical elements”, Wiley, John & Sons, 1990.
3. Kalyanamoy Deb, “Optimization for Engineering design algorithms and Examples”, Prentice Hall of India Pvt. 1995.
4. Goldberg, D.E., “Genetic algorithms in search, optimization and machine”, Barnen, Addison-Wesley, New York, 1989.

PD 9150 **DESIGN PARADIGM** **L T P C**
3 0 0 3

OBJECTIVE

Study about the design methodologies for manufacture and assembly, value engineering techniques and analysis of product development

UNIT I DESIGN FOR MANUFACTURE 8

General design principles for manufacturability - strength and mechanical factors, mechanisms selection, evaluation method, Process capability - Feature tolerances - Geometric tolerances - Assembly limits – Datum features - Tolerance stacks.

UNIT II FORM DESIGN OF CASTINGS AND WELDMENTS 9

Redesign of castings based on parting line considerations - Minimizing core requirements - Redesigning a cast members using weldments-factors influencing form design-Working principle, Material, Manufacture, Design - Possible solutions - Materials choice - Influence of materials-on from design - form design of welded members, forgings and castings.

UNIT III DESIGN FOR ASSEMBLY 6

Assembly processes-Handling and insertion process-Manual, automatic and robotic assembly-Cost of Assembly-Number of Parts-DFA guidelines

UNIT IV VALUE ENGINEERING 12

Value –types –functional –operational –aesthetic –cost- –material – Design process – value and worthiness –procedure -brainstorming sessions –evaluation –case studies – value estimation- Value analysis - Design for value - Selection of alternatives - optimization – Implementation

UNIT V PRODUCT DEVELOPMENT ECONOMICS 10

Elements of Economics analysis-Quantitative and qualitative analysis-Economic Analysis process-Estimating magnitude and time of future cash inflows and out flows-Sensitivity analysis-Project trade-offs-Trade-offs rules-Limitation of quantitative analysis-Influence of qualitative factors on project success

Total 45 hr

TEXT BOOK:

1. Harry Peck, Designing for Manufacture, Pitman Publications, 1983.
2. George E Dieter, Engineering Design, McGraw-Hill Int Editions, 2000

REFERENCES:

1. S.S.Iyer, Value Engineering, New Age International, 2000
2. Charles E. Ebeling, Reliability and Maintainability Engineering, , TMH, 2000

ED 9151 ENGINEERING FRACTURE MECHANICS L T P C
3 0 0 3

UNIT I ELEMENTS OF SOLID MECHANICS 9

The geometry of stress and strain, elastic deformation, plastic and elasto-plastic deformation - limit analysis – Airy's function – field equation for stress intensity factor.

UNIT II STATIONARY CRACK UNDER STATIC LOADING 9

Two dimensional elastic fields – Analytical solutions yielding near a crack front – Irwin's approximation - plastic zone size – Dugdaale model – determination of J integral and its relation to crack opening displacement.

UNIT III ENERGY BALANCE AND CRACK GROWTH 9

Griffith analysis – stable and unstable crack growth –Dynamic energy balance – crack arrest mechanism –K1c test methods - R curves - determination of collapse load.

UNIT IV FATIGUE CRACK GROWTH CURVE 9

Empirical relation describing crack growth law – life calculations for a given load amplitude – effects of changing the load spectrum -- rain flow method– external factors affecting the K1c values.- leak before break analysis.

UNIT V APPLICATIONS OF FRACTURE MECHANICS 9

Crack Initiation under large scale yielding – thickness as a design parameter – mixed mode fractures - crack instability in thermal and residual stress fields - numerical methods

Total 45

REFERENCES:

1. David Broek,"Elementary Engineering Fracture Mechanics ", Fifthoff and Noerdhoff International Publisher, 1978.
2. Kare Hellan, "Introduction of Fracture Mechanics", McGraw-Hill Book Company, 1985.
3. Preshant Kumar, "Elements of Fracture Mechanics", Wheeler Publishing, 1999.
4. John M.Barson and Stanely T.Rolfe Fatigue and fracture control in structures prentice hall Inc. Englewood cliffs. 1977

ED 9172 DESIGN FOR MANUFACTURE, ASSEMBLY AND ENVIRONMENTS

L	T	P	C
3	0	0	3

UNIT I INTRODUCTION 5

General design principles for manufacturability - strength and mechanical factors, mechanisms selection, evaluation method, Process capability - Feature tolerances - Geometric tolerances - Assembly limits -Datum features - Tolerance stacks.

UNIT II FACTORS INFLUENCING FORM DESIGN 13

Working principle, Material, Manufacture, Design- Possible solutions - Materials choice - Influence of materials on form design - form design of welded members, forgings and castings.

UNIT III COMPONENT DESIGN - MACHINING CONSIDERATION 8

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.

UNIT IV COMPONENT DESIGN – CASTING CONSIDERATION 10

Redesign of castings based on Parting line considerations - Minimizing core requirements, machined holes, redesign of cast members to obviate cores. Identification of uneconomical design - Modifying the design - group technology - Computer Applications for DFMA

UNIT V DESIGN FOR THE ENVIRONMENT 9

Introduction – Environmental objectives – Global issues – Regional and local issues – Basic DFE methods – Design guide lines – Example application – Lifecycle assessment – Basic method – AT&T's environmentally responsible product assessment - Weighted sum assessment method – Lifecycle 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.

Total 45

REFERENCES:

1. Boothroyd, G, 1980 Design for Assembly Automation and Product Design. New York, Marcel Dekker.
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.

ED9152 TRIBOLOGY IN DESIGN

L	T	P	C
3	0	0	3

UNIT I SURFACE INTERACTION AND FRICTION 7

Topography of Surfaces – Surface features-Properties and measurement – Surface interaction – Adhesive Theory of Sliding Friction –Rolling Friction-Friction properties of metallic and non-metallic materials – friction in extreme conditions –Thermal considerations in sliding contact

UNIT II WEAR AND SURFACE TREATMENT 8

Types of wear – Mechanism of various types of wear – Laws of wear –Theoretical wear models-Wear of Metals and Non metals – Surface treatments – Surface modifications – surface coatings methods- Surface Topography measurements –Laser methods – instrumentation - International standards in friction and wear measurements

UNIT III LUBRICANTS AND LUBRICATION REGIMES 8

Lubricants and their physical properties- Viscosity and other properties of oils – Additives-and selection of Lubricants- Lubricants standards ISO,SAE,AGMA, BIS standards – Lubrication Regimes –Solid Lubrication-Dry and marginally lubricated contacts- Boundary Lubrication- Hydrodynamic lubrication –– Elasto and plasto hydrodynamic - Magneto hydrodynamic lubrication – Hydro static lubrication – Gas lubrication.

UNIT IV THEORY OF HYDRODYNAMIC AND HYDROSTATIC LUBRICATION 12

Reynolds Equation,-Assumptions and limitations-One and two dimensional Reynolds Equation-Reynolds and Sommerfeld boundary conditions- Pressure wave, flow, load capacity and friction calculations in Hydrodynamic bearings-Long and short bearings-Pad bearings and Journal bearings-Squeeze film effects-Thermal considerations-Hydrostatic lubrication of Pad bearing- Pressure , flow , load and friction calculations-Stiffness considerations- Various types of flow restrictors in hydrostatic bearings

UNIT V HIGH PRESSURE CONTACTS AND ELASTO HYDRODYNAMIC LUBRICATION 10

Rolling contacts of Elastic solids**-** contact stresses – Hertzian stress equation- Spherical and cylindrical contacts-Contact Fatigue life- Oil film effects- Elasto Hydrodynamic lubrication Theory-Soft and hard EHL-Reynolds equation for elasto hydrodynamic lubrication- - Film shape within and outside contact zones-Film thickness and friction calculation- Rolling bearings- Stresses and deflections-Traction drives

Total 45

REFERENCES:

1. Rabinowicz.E, “Friction and Wear of materials”, John Willey & Sons, UK, 1995
2. Cameron, A. “Basic Lubrication Theory”, Ellis Herward Ltd., UK, 1981
3. Halling, J. (Editor) – “Principles of Tribology “, Macmillian – 1984.
4. Williams J.A. “Engineering Tribology”, Oxford Univ. Press, 1994.
5. S.K.Basu, S.N.Sengupta & B.B.Ahuja ,”Fundamentals of Tribology”, Prentice –Hall of India Pvt Ltd, New Delhi, 2005
6. G.W.Stachowiak & A.W .Batchelor, Engineering Tribology, Butterworth-Heinemann, UK, 2005

ED 9153 ADVANCED MECHANICS OF MATERIALS L T P C
3 0 0 3

UNIT I ELASTICITY 9

Stress-Strain relations and general equations of elasticity in Cartesian, Polar and curvilinear coordinates, differential equations of equilibrium-compatibility-boundary conditions-representation of three-dimensional stress of a tension generalized hook's law - St. Venant's principle - plane stress - Airy's stress function. Energy methods.

UNIT II SHEAR CENTER AND UNSYMMETRICAL BENDING 10

Location of shear center for various thin sections - shear flows. Stresses and deflections in beams subjected to unsymmetrical loading-kern of a section.

UNIT III CURVED FLEXIBLE MEMBERS AND STRESSES IN FLAT PLATES 10

Circumference and radial stresses – deflections - curved beam with restrained ends - closed ring subjected to concentrated load and uniform load - chain links and crane hooks. Solution of rectangular plates – pure bending of plates – deflection – uniformly distributed load – various end conditions

UNIT IV TORSION OF NON-CIRCULAR SECTIONS 7

Torsion of rectangular cross section - St.Venants theory - elastic membrane analogy - Prandtl's stress function - torsional stress in hollow thin walled tubes.

UNIT V STRESSES IN ROTARY SECTIONS AND CONTACT STRESSES 9

Radial and tangential stresses in solid disc and ring of uniform thickness and varying thickness allowable speeds. Methods of computing contact stress-deflection of bodies in point and line contact applications.

Total 45

REFERENCES:

1. Arthur P Boresi, Richard J. Schmidt, “Advanced mechanics of materials”, John Wiley, 2002.
2. Timoshenko and Goodier, "Theory of Elasticity", McGraw Hill.
3. Robert D. Cook, Warren C. Young, "Advanced Mechanics of Materials", Mc-millan pub. Co., 1985.
4. Srinath. L.S., “Advanced Mechanics of solids”, Tata McGraw Hill, 1992.
5. G H Ryder Strength of Materials Macmillan, India Ltd, 2007.

ED 9154 COMPOSITE MATERIALS AND MECHANICS L T P C
3 0 0 3

OBJECTIVE

i) To understand the fundamentals of composite material strength and its mechanical behavior

ii) Understanding the analysis of fiber reinforced Laminate design for different

Combinations of plies with different orientations of the fiber.

iii) Thermo-mechanical behavior and study of residual stresses in Laminates during processing.

iv) Implementation of Classical Laminate Theory (CLT) to study and analysis for residual stresses in an isotropic layered structure such as electronic chips.

UNIT I LAMINA CONSTITUTIVE RELATIONS 12

Definition –Need – General Characteristics, Applications. Fibers – Glass, Carbon, Ceramic and Aramid fibers. Matrices – Polymer, Graphite, Ceramic and Metal Matrices – Characteristics of fibers and matrices.

Lamina Constitutive Equations: Lamina Assumptions – Macroscopic Viewpoint. Generalized Hooke's Law. Reduction to Homogeneous Orthotropic Lamina – Isotropic limit case, Orthotropic Stiffness matrix (Q_{ij}), Typical Commercial material properties, Rule of Mixtures. Generally Orthotropic Lamina –Transformation Matrix, Transformed Stiffness. Manufacturing: Bag Moulding – Compression Moulding – Pultrusion – Filament Winding – Other Manufacturing Processes.

UNIT II FLAT PLATE LAMINATE CONSTITUTIVE RELATIONS 10

Definition of stress and Moment Resultants. Strain Displacement relations. Basic Assumptions of Laminated anisotropic plates. Laminate Constitutive Equations – Coupling Interactions, Balanced Laminates, Symmetric Laminates, Angle Ply Laminates, Cross Ply Laminates. Laminate Structural Moduli. Evaluation of Lamina Properties from Laminate Tests. Quasi-Isotropic Laminates. Determination of Lamina stresses within Laminates.

UNIT III LAMINA STRENGTH ANALYSIS 5

Introduction - Maximum Stress and Strain Criteria. Von-Misses Yield criterion for Isotropic Materials. Generalized Hill's Criterion for Anisotropic materials. Tsai-Hill's Failure Criterion for Composites. Tensor Polynomial (Tsai-Wu) Failure criterion. Prediction of laminate Failure

UNIT IV ANALYSIS OF LAMINATED FLAT PLATES 10

Equilibrium Equations of Motion. Energy Formulations. Static Bending Analysis. Buckling Analysis. Free Vibrations – Natural Frequencies

UNIT V EFFECT OF THERMAL PROPERTIES 8

Modification of Hooke's Law due to thermal properties - Modification of Laminate Constitutive Equations. Orthotropic Lamina - special Laminate Configurations – Unidirectional, Off-axis, Symmetric Balanced Laminates - Zero C.T.E laminates, Thermally Quasi-Isotropic Laminates

Total 45

TEXT BOOK:

1. Gibson, R.F., Principles of Composite Material Mechanics, McGraw-Hill, 1994, Second Edition - CRC press in progress.
2. Hyer, M.W., “Stress Analysis of Fiber – Reinforced Composite Materials”, McGraw-Hill, 1998

REFERENCES:

1. Issac M. Daniel and Ori Ishai, “Engineering Mechanics of Composite Materials”,
   Oxford University Press-2006, First Indian Edition - 2007
2. Mallick, P.K., Fiber –”Reinforced Composites: Materials, Manufacturing and Design”, Maneel Dekker Inc, 1993.
3. Halpin, J.C., “Primer on Composite Materials, Analysis”, Techomic Publishing Co., 1984.
4. Agarwal, B.D., and Broutman L.J., “Analysis and Performance of Fiber Composites”, John Wiley and Sons, New York, 1990.
5. Mallick, P.K. and Newman, S., (edition), “Composite Materials Technology: Processes and Properties”, Hansen Publisher, Munish, 1990.
6. Madhujit Mukhopadhyay, “Mechanics of Composite Materials and Structures”, University Press (India) Pvt. Ltd., Hyderabad, 2004 (Reprinted 2008)

ED 9155 APPLIED ENGINEERING ACOUSTICS L T P C
3 0 0 3

UNIT I BASIC CONCEPTS OF ACOUSTICS 9

Scope of Acoustics – Sound pressure – Sound intensity – Sound power level Sound power – Wave motion – Alteration of wave paths –Measurement of sound waves – sound spectra – Sound fields – Interference – Standing waves – Acoustic energy density and intensity – Specific acoustic impedance.

UNIT II CHARACTERISTICS OF SOUND 10

One dimensional wave equation – Solution of 1D wave equation – Velocity in gaseous medium – Velocity of plane progressive sound wave through a thin solid rod – Velocity of plane wave in a bulk of solid – Transverse wave propagation along a string stretched under tension – Wave equation in two dimension.

UNIT III TRANSMISSION PHENOMENA 6

Changes in media – Transmission from one fluid medium to another, normal incidence, oblique incidence - Reflection at the surface of a solid, normal incidence, oblique incidence – Standing wave pattern – Transmission through three media.

UNIT IV INTRODUCTION TO THE ASSESSMENT AND MEASUREMENT OF SOUND 10

Introduction – Decibel scale for the measurement of sound power – Sound level meter – Weighted sound pressure level – Equal Loudness contours – Perceived noisiness – Loudness, Loudness level, perceived noise, perceived noise level – Equivalent sound level – Identified level – Frequency and Amplitude measurement.

UNIT V BASICS OF NOISE CONTROL 10

Noise Control at source, path, receiver – Noise control by acoustical treatment – Machinery noise – Types of machinery involved – Determination of sound power and sound power level – Noise reduction procedures – Acoustic enclosures.

Total 45

REFERENCES:

1. Lawrence E. Kinsler, Austin R. Frey, “Fundamentals of Acoustics “– John Wiley and Sons Inc., 1986.
2. Bies, David, A. and Hansen, Colin H., “Engineering Noise Control – Theory and Practice”, E and FN Spon, Chapman-Hall, Second Edition, 1996.
3. Hansen C.H. and Snyder, S.D., “Active Control of Sound and Vibration”, E and FN Spon, London 1996.

ED 9156 ADVANCED TOOL DESIGN L T P C
3 0 0 3

UNIT I INTRODUCTION TO TOOL DESIGN 8

Introduction –Tool Engineering – Tool Classifications– Tool Design Objectives – Tool Design in manufacturing- Challenges and requirements- Standards in tool design-Tool drawings -Surface finish – Fits and Tolerances - Tooling Materials-Ferrous and Non ferrous Tooling Materials- Carbides, Ceramics and Diamond - Non metallic tool materials-Designing with relation to heat treatment

UNIT II DESIGN OF CUTTING TOOLS 9

Mechanics of Metal cutting –Oblique and orthogonal cutting- Chip formation and shear angle - Single-point cutting tools – Milling cutters – Hole making cutting tools- Broaching Tools - Design of Form relieved and profile relieved cutters-Design of gear and thread milling cutters

UNIT III DESIGN OF JIGS AND FIXTURES 10

Introduction – Fixed Gages – Gage Tolerances –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 –Thrust and Turning Moments in drilling - Drill jigs and modern manufacturing- Types of Fixtures – Vise Fixtures – Milling Fixtures – Boring Fixtures – Broaching Fixtures – Lathe Fixtures – Grinding Fixtures – Modular Fixtures – Cutting Force Calculations.

UNIT IV DESIGN OF PRESS TOOL DIES 10

Types of Dies –Method of Die operation–Clearance and cutting force calculations-Blanking and Piercing die design – Pilots – Strippers and pressure pads-Presswork materials – Strip layout – Short-run tooling for Piercing – Bending dies – Forming dies – Drawing dies-Design and drafting.

UNIT V TOOL DESIGN FOR CNC MACHINE TOOLS 8

Introduction –Tooling requirements for Numerical control systems – Fixture design for CNC machine tools- Sub plate and tombstone fixtures-Universal fixtures– Cutting tools– Tool holding methods– Automatic tool changers and tool positioners – Tool presetting– General explanation of the Brown and Sharp machine

Total 45

REFERENCES:

1. Cyrll Donaldson, George H.LeCain, V.C. Goold, “Tool Design”, Tata McGraw Hill Publishing Company Ltd., 2000.
2. E.G.Hoffman,” Jig and Fixture Design”, Thomson Asia Pvt Ltd, Singapore, 2004
3. Prakash Hiralal Joshi, “Tooling data”, Wheeler Publishing, 2000
4. Venkataraman K., “Design of Jigs, Fixtures and Presstools”, TMH, 2005
5. Haslehurst M., “Manufacturing Technology”, The ELBS, 1978

ED 9157 PRODUCTIVITY MANAGEMENT AND RE-ENGINEERING L T P C
3 0 0 3

UNIT I PRODUCTIVITY **9**

Productivity Concepts – Macro and Micro factors of productivity – Dynamics of Productivity - Productivity Cycle Productivity Measurement at International, National and Organisation level - Productivity measurement models

UNIT II SYSTEMS APPROACH TO PRODUCTIVITY MEASUREMENT **9**

Conceptual frame work, Management by Objectives (MBO), Performance Objectivated Productivity (POP) – Methodology and application to manufacturing and service sector.

UNIT III ORGANISATIONAL TRANSFORMATION **9**

Elements of Organisational Transformation and Reengineering-Principles of organizational transformation and re-engineering, fundamentals of process re-engineering, preparing the workforce for transformation and re-engineering, methodology, guidelines, LMI CIP Model – DSMC Q & PMP model.

UNIT IV RE-ENGINEERING PROCESS IMPROVEMENT MODELS **9**

PMI models, PASIM Model, Moen and Nolan Strategy for process improvement, LMICIP Model, NPRDC Model.

UNIT V RE-ENGINEERING TOOLS AND IMPLEMENTATION **9**

Analytical and process tools and techniques – Information and Communication Technology – Implementation of Reengineering Projects – Success Factors and common implementation Problem – Cases.

Total : 45

REFERENCES

1. Sumanth, D.J., 'Productivity Engineering and Management', TMH, New Delhi, 1990.
2. Edosomwan, J.A., "Organisational Transformation and Process Re-engineering", Library Cataloging in Pub. Data, 1996.
3. Rastogi, P.N., "Re-engineering and Re-inventing the Enterprise", Wheeler Pub. New Delhi, 1995.
4. Premvrat, Sardana, G.D. and Sahay, B.S., "Productivity Management – A Systems Approach", Narosa Publishing House. New Delhi, 1998.

ED 9158 INDUSTRIAL ROBOTICS AND EXPERT SYSTEMS L T P C
3 0 0 3

UNIT I INTRODUCTION AND ROBOT KINEMATICS 10

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 – Tactile sensor – Proximity and range sensors – Sensing joint forces – Robotic vision system – Image Representation - Image Grabbing –Image processing and analysis – Edge Enhancement – Contrast Stretching – Band Rationing - 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. Industrial application of robots.

UNIT V ROBOT PROGRAMMING, ARTIFICIAL INTELLIGENCE AND EXPERT SYSTEMS 8

Methods of Robot Programming – Characteristics of task level languages lead through programming methods – Motion interpolation. Artificial intelligence – Basics – Goals of artificial intelligence – AI techniques – problem representation in AI – Problem reduction and solution techniques - Application of AI and KBES in Robots.

Total 45

TEXT BOOK:

1. K.S.Fu, R.C. Gonzalez and C.S.G. Lee, “Robotics Control, Sensing, Vision and Intelligence”, Mc Graw Hill, 1987.

REFERENCES:

1. Yoram Koren,” Robotics for Engineers’ Mc Graw-Hill, 1987.
2. Kozyrey, Yu. “Industrial Robots”, MIR Publishers Moscow, 1985.
3. Richard. D, Klafter, Thomas, A, Chmielewski, Michael Negin, “Robotics Engineering – An Integrated Approach”, Prentice-Hall of India Pvt. Ltd., 1984.
4. Deb, S.R.” Robotics Technology and Flexible Automation”, Tata Mc Graw-Hill, 1994.
5. Mikell, P. Groover, Mitchell Weis, Roger, N. Nagel, Nicholas G. Odrey,” Industrial Robotics Technology, Programming and Applications”, Mc Graw-Hill, Int. 1986.
6. Timothy Jordanides et al,”Expert Systems and Robotics “, Springer –Verlag, New York, May 1991.

EY 9156 DESIGN OF HEAT EXCHANGERS L T P C
3 0 0 3

UNIT I FUNDAMENTALS OF HEAT EXCHANGER 9

Temperature distribution and its implications types – shell and tube heat exchangers – regenerators and recuperators – analysis of heat exchangers – LMTD and effectiveness method.

UNIT II FLOW AND STRESS ANALYSIS 9

Effect of turbulence – friction factor – pressure loss – stress in tubes – header sheets and pressure vessels – thermal stresses, shear stresses, types of failures.

UNIT III DESIGN ASPECTS 9

Heat transfer and pressure loss – flow configuration – effect of baffles – effect of deviations from ideality – design of double pipe, finned tube, shell and tube heat exchangers, simulation of heat exchangers.

UNIT IV COMPACT AND PLATE HEAT EXCHANGERS 9

Types – merits and demerits – design of compact heat exchangers, plate heat exchangers – performance influencing parameters, limitations.

UNIT V CONDENSERS & COOLING TOWERS 9

Design of surface and evaporative condensers – cooling tower – performance characteristics.

Total Periods 45

REFERENCES

1. P Arthur. Frass, Heat Exchanger Design, John Wiley & Sons, 1988.
2. Taborek.T, Hewitt.G.F and Afgan.N, Heat Exchangers, Theory and Practice, McGraw-Hill Book Co. 1980.
3. Hewitt.G.F, Shires.G.L, Bott.T.R, Process Heat Transfer, CRC Press, 1994.
4. Sadik Kakac, Hongtan Liu,Heat Exchangers Selection, Rating and Thermal Design,CRC Press,2002.

ED 9171 RAPID PROTOTYPING AND TOOLING L T P C
3 0 0 3

UNIT I INTRODUCTION 7

Need - Development of RP systems – RP process chain - Impact of Rapid Prototyping and Tooling on Product Development – Benefits- Applications – Digital prototyping - Virtual prototyping.

UNIT II LIQUID BASED AND SOLID BASED RAPID PROTOTYPING SYSTEMS 10

Stereolithography Apparatus, Fused deposition Modeling, Laminated object manufacturing, three dimensional printing: Working Principles, details of processes, products, materials, advantages, limitations and applications - Case studies.

UNIT III POWDER BASED RAPID PROTOTYPING SYSTEMS 10

Selective Laser Sintering, Direct Metal Laser Sintering, Three Dimensional Printing, Laser Engineered Net Shaping, Selective Laser Melting, Electron Beam Melting: Processes, materials, products, advantages, applications and limitations – Case Studies.

UNIT IV REVERSE ENGINEERING AND CAD MODELING 10

Basic concept- Digitization techniques – Model Reconstruction – Data Processing for Rapid Prototyping: CAD model preparation, Data Requirements – geometric modeling techniques: Wire frame, surface and solid modeling – data formats - Data interfacing, Part orientation and support generation, Support structure design, Model Slicing and contour data organization, direct and adaptive slicing, Tool path generation.

UNIT V RAPID TOOLING 8

Classification: Soft tooling, Production tooling, Bridge tooling; direct and indirect – Fabrication processes, Applications. Case studies - automotive, aerospace and electronic industries.

Total Periods: 45

TEXT BOOK:

1. Rapid prototyping: Principles and applications, second edition, Chua C.K., Leong K.F., and Lim C.S., World Scientific Publishers, 2003.
2. Rapid Tooling: Technologies and Industrial Applications, Peter D.Hilton, Hilton/Jacobs, Paul F.Jacobs, CRC press, 2000.

REFERENCES:

1. Rapid prototyping, Andreas Gebhardt, Hanser Gardener Publications, 2003.
2. Rapid Prototyping and Engineering applications: A tool box for prototype development, Liou W.Liou, Frank W.Liou, CRC Press, 2007.
3. Rapid Prototyping: Theory and practice, Ali K. Kamrani, Emad Abouel Nasr, Springer, 2006

ED 9159 DESIGN OF MATERIAL HANDLING EQUIPMENTS
(Use of Approved Data Book Is Permitted)

L	T	P	C
3	0	0	3

UNIT I MATERIALS HANDLING EQUIPMENT 5

Types, selection and applications

UNIT II DESIGN OF HOISTS 10

Design of hoisting elements: Welded and roller chains - Hemp and wire ropes - Design of ropes, pulleys, pulley systems, sprockets and drums, Load handling attachments. Design of forged hooks and eye hooks – crane grabs - lifting magnets - Grabbing attachments - Design of arresting gear - Brakes: shoe, band and cone types.

UNIT III DRIVES OF HOISTING GEAR 10

Hand and power drives - Traveling gear - Rail traveling mechanism - cantilever and monorail cranes - slewing, jib and luffing gear - cogwheel drive - selecting the motor ratings.

UNIT IV CONVEYORS 10

Types - description - design and applications of Belt conveyors, apron conveyors and escalators Pneumatic conveyors, Screw conveyors and vibratory conveyors.

UNIT V ELEVATORS 10

Bucket elevators: design - loading and bucket arrangements - Cage elevators - shaft way, guides, counter weights, hoisting machine, safety devices - Design of fork lift trucks.

Total 45

TEXT BOOKS

1. Rudenko, N., Materials handling equipment, ELnvee Publishers, 1970.
2. Spivakovsy, A.O. and Dyachkov, V.K., Conveying Machines, Volumes I and II, MIR Publishers, 1985.

REFERENCES

1. Alexandrov, M., Materials Handling Equipments, MIR Publishers, 1981.
2. Boltzharol, A., Materials Handling Handbook, The Ronald Press Company, 1958.
3. P.S.G. Tech., “Design Data Book”, Kalaikathir Achchagam, Coimbatore, 2003.
4. Lingaiah. K. and Narayana Iyengar, “Machine Design Data Hand Book”, Vol. 1 & 2, Suma Publishers, Bangalore, 1983

ED 9160 PLASTICITY AND METAL FORMING L T P C
3 0 0 3

UNIT I THEORY OF PLASTICITY 9

Theory of plastic deformation - Engineering stress and strain relationship – Stress tensor - Strain tensor - Yield criteria's - Plastic stress strain relationship – Plastic work - Equilibrium conditions - Incremental plastic strain

UNIT II CONSTITUTIVE RELATIONSHIPS AND INSTABILITY 7

Uniaxial tension test - Mechanical properties - Work hardening, Compression test, bulge test, plane strain compression stress, plastic instability in uniaxial tension stress, plastic instability in biaxial tension stress

UNIT III ANALYSIS OF METAL FORMING PROBLEMS 12

Slab analysis - Slip line method, upper bound solutions, statistically admissible stress field, numerical methods, contact problems, effect of friction, thermo elastic Elasto plasticity, elasto visco plasticity - Thermo mechanical coupling – Analysis of forging, rolling, extrusion and wire drawing processes - Experimental techniques of the evaluation of metal forming

UNIT IV ANALYSIS OF SHEET METAL FORMING 8

Bending theory - Cold rolling theory - Hill's anisotropic theory, Hill's general yield theory - Sheet metal forming - Elements used - Mesh generation and formulation Equilibrium equations - Consistent full set algorithm - Numerical solutions procedures - examples of simulation of simple parts - Bench mark tests – Forming limit diagrams

UNIT V ADVANCES IN METAL FORMING 9

Orbital forging, Isothermal forging, Warm forging, Hot and Cold isotropic pressing, high speed extrusion, rubber pad forming, micro blanking –Superplastic forming - Overview of Powder Metal techniques - Powder rolling - Tooling and process parameters

Total 45

REFERENCES:

1. Wagoner. R H., and Chenot. J.J., Metal Forming analysis,Cambridge University Press, 2002.
2. Slater. R A. C., Engineering Plasticity - Theory & Applications to Metal Forming, John Wiely and Sons, 1987.
3. Shiro Kobayashi, Altan. T, Metal Forming and Finite Element Method, Oxford University Press, 1989.
4. Narayanaswamy. R, Theory of Metal Forming Plasticity, Narosa Publishers, 1999.
5. Hosford. W. F and Caddell. RM., Metal Forming Mechanics and Metallurgy, Prentice Hall Eaglewood Cliffs, 1993.
6. Surender Kumar, " Technology of Metal Forming Processes", Prentice Hall of India, New Delhi, 2008

ED 9161 THEORY OF PLATES & SHELLS L T P C
3 0 0 3

OBJECTIVE:
After undergoing this course, the students would be in a position to understand the behaviour of these commonly occurring structural elements in engineering design and would have developed the capability to design and analyze them in their normal design practice.

UNIT I GENERAL INTRODUCTION 7
Review of equations of elasticity- kinematics, compatibility equations, stress measures- equations of motions- constitutive relations- transformation of stresses, strains and stiffness-energy principles and variational methods in elasticity- virtual work-external and internal virtual work- variational operator- functionals- Euler Lagrange equations- energy principles- Hamilton's principle- principle of minimum total potential- applications

UNIT II CLASSICAL THEORY OF PLATES 10
Plates as structural elements- stress and moment resultants- assumptions made in the classical theory- displacement fields and strains- equations of equilibrium in Cartesian coordinates and in polar coordinates- boundary conditions – bending of rectangular plates with various boundary conditions and loading- symmetrical and asymmetrical bending of circular plates-limitations of classical theory- finite element analysis(elementary treatment only; discussion of various elements used and their capabilities- not for examination)

UNIT III BUCKLING ANALYSIS OF RECTANGULAR PLATES 10
Buckling of simply supported plates under compressive forces- governing equations- the Navier solution- biaxial compression of a plate- uniaxial compression of a plate- buckling of plates simply supported on two opposite edges- Levy's solution- buckling of plates with various boundary conditions- general formulation- finite element analysis(elementary treatment only; discussion of various elements used and their capabilities- not for examination)

UNIT IV VIBRATION OF PLATES 9
Governing equations for natural flexural vibrations of rectangular plates- natural vibrations of plates simply supported on all edges- vibration of plates with two parallel sides simply supported- Levy's solution- vibration of plates with different boundary conditions- Rayleigh-Ritz method- Natural vibration of plates with general boundary conditions- transient analysis of rectangular plates- finite element analysis(elementary treatment only; discussion of various elements used and their capabilities- not for examination)

UNIT V ANALYSIS OF THIN ELASTIC SHELLS OF REVOLUTION 9
Classification of shell surfaces- geometric properties of shells of revolution- general strain displacement relations for shells of revolution- stress resultants- equations of motion of thin shells- analytical solution for thin cylindrical shells- membrane theory- flexure under axisymmetric loads- shells with double curvature- geometric considerations- equations of equilibrium- bending of spherical shells- vibration of cylindrical shells- finite element analysis(elementary treatment only; discussion of various elements used and their capabilities- not for examination)

Total: 45 periods

REFERENCES:

1. Reddy,J.N., “Theory and Analysis of Elastic Plates & Shells”, C.R.C.Press,NY,USA, 2nd Edition
2. Szilard, R., Theory and Analysis of Plates, Prentice Hall Inc., 1995
3. Timoshenko, S. and Krieger S.W. Theory of Plates and Shells, McGraw Hill Book Company, New York 1990.
4. Wilhelm Flügge, stresses in shells, Springer - Verlag
5. Timoshenko, S. Theory of Plates and Shells, McGraw Hill, 1990
6. Ramasamy, G.S., Design and Construction of Concrete Shells Roofs, CBS Publishers, 1986
7. Dr.N.Subramanian, Principles of Space Structures , Wheeler Publishing Co. 1999

ED 9162 DESIGN OF PRESSURE VESSELS AND PIPING L T P C
3 0 0 3

UNIT I INTRODUCTION 3

Methods for determining stresses – Terminology and Ligament Efficiency – Applications.

UNIT II STRESSES IN PRESSURE VESSELS 15

Introduction – Stresses in a circular ring, cylinder – Membrane stress Analysis of Vessel Shell components – Cylindrical shells, spherical Heads, conical heads – Thermal Stresses – Discontinuity stresses in pressure vessels.

UNIT III DESIGN OF VESSELS 15

Design of Tall cylindrical self supporting process columns – supports for short vertical vessels – stress concentration – at a variable Thickness transition section in a cylindrical vessel, about a circular hole, elliptical openings. Theory of Reinforcement – pressure vessel Design.

UNIT IV BUCKLING AND FRACTURE ANALYSIS IN VESSELS 8

Buckling phenomenon – Elastic Buckling of circular ring and cylinders under external pressure – collapse of thick walled cylinders or tubes under external pressure – Effect of supports on Elastic Buckling of Cylinders – Buckling under combined External pressure and axial loading.

UNIT V PIPING 4

Introduction – Flow diagram – piping layout and piping stress Analysis.

Total 45

TEXT BOOKS

1. John F. Harvey, Theory and Design of Pressure Vessels, CBS Publishers and Distributors, 1987.

REFERENCES

1. Henry H. Bedner, “Pressure Vessels, Design Hand Book, CBS publishers and Distributors, 1987.
2. Stanley, M. Wales, “Chemical process equipment, selection and Design. Buterworths series in Chemical Engineering, 1988.
3. William. J., Bees, “Approximate Methods in the Design and Analysis of Pressure Vessels and Piping”, Pre ASME Pressure Vessels and Piping Conference, 1997.

CI9122 MECHATRONICS IN MANUFACTURING SYSTEMS L T P C
3 0 0 3

OBJECTIVE

This syllabus is formed to create knowledge in Mechatronic systems and impart the source of concepts and techniques, which have recently been applied in practical situation. It gives a framework of knowledge that allows engineers and technicians to develop an interdisciplinary understanding and integrated approach to engineering.

UNIT I INTRODUCTION 5

Introduction to Mechatronics - Systems- Need for Mechatronics - Emerging area of Mechatronics - Classification of Mechatronics - Measurement Systems - Control Systems.

UNIT II SENSORS AND TRANSDUCERS 12

Introduction - Performance Terminology – Potentiometers - LVDT - Capacitance sensors - Strain gauges - Eddy current sensor - Hall effect sensor - Temperature sensors - Light sensors - Selection of sensors - Signal processing.

UNIT III ACTUATORS 12

Actuators – Mechanical - Electrical - Fluid Power - Piezoelectric – Magnetostrictive - Shape memory alloy - applications - selection of actuators.

UNIT IV PROGRAMMABLE LOGIC CONTROLLERS 8

Introduction - Basic structure - Input and output processing - Programming - Mnemonics-Timers, counters and internal relays - Data handling - Selection of PLC.

UNIT V DESIGN AND MECHATRONICS CASE STUDIES 8

Designing - Possible design solutions-Traditional and Mechatronics design concepts - Case studies of Mechatronics systems - Pick and place Robot - Conveyor based material handling system - PC based CNC drilling machine - Engine Management system - Automatic car park barrier - Data acquisition Case studies.

Total: 45

TEXT BOOK

1. Bolton.W, “Mechatronics” , Pearson education, second edition, fifth Indian Reprint, 2003
2. Smaili.A and Mrad.F , "Mechatronics integrated technologies for intelligent machines", Oxford university press, 2008

REFERENCES

1. Devadas Shetty and Richard A.Kolk, “Mechatronics systems design”, PWS Publishing company, 2007.
2. Godfrey C. Onwubolu, "Mechatronics Principles and Applications", Elsevier, 2006.
3. Nitaigour Premchand Mahalik, “Mechatronics Principles, Concepts and Applicatlions” Tata McGraw-Hill Publishing company Limited, 2003.
4. Michael B.Histand and Davis G.Alciatore,” Introduction to Mechatronics and Measurement systems”. McGraw Hill International edition, 1999.
5. Bradley D.A, Dawson.D, Buru N.C and Loader A.J, “Mechatronics” Nelson Thornes ltd, Eswar press, Indian print, 2004.
6. Lawrence J.Kamm, “Understanding Electro-Mechanical Engineering – An Introduction to Mechatronics”, Prentice Hall of India Pvt Ltd, 2000.
7. Dan Necsulescu, “Mechatronics”, Pearson education, 2002.
8. Newton C.Braga, “Mechatronics Sourcebook”, Thomson Delmar Learning, Eswar Press, 2003.

ED 9163 MODAL ANALYSIS OF MECHANICAL SYSTEMS L T P C
3 0 0 3

UNIT I OVERVIEW 6

Introduction to Modal Testing – Applications of Modal Testing – Philosophy of Modal Testing – Summary of Theory – Summary of Measurement Methods – Summary of Analysis – Review of Test Procedure.

UNIT II THEORETICAL BASIS 12

Introduction – Single Degree of Freedom (SDOF) System Theory – Presentation and Properties of FRF Data for SDOP System – Undamped Multi-degree of freedom (MDOF) system – Proportional Damping – Hysteretic Damping – General Case – Viscous Damping – General Case – Characteristics and presentation of MDOF – FRF Data – Complete and incomplete models - Non-sinusoidal vibration and FRF Properties – Analysis of Weakly Nonlinear Structures.

UNIT III MOBILITY MEASUREMENT TECHNIQUES 10

Introduction – Basic Measurement System – Structure preparation – Excitation of the Structure – Transducers and Amplifiers – Analyzers – Digital Signal Processing – Use of Different Excitation types – Calibration – Mass Cancellation – Rotational Mobility Measurement – Measurement on Non linear structures – Multi point excitation methods.

UNIT IV MODAL PARAMETER EXTRACTION METHODS 11

Introduction – Preliminary checks of FRF Data – SDOF Modal Analysis-I – Peak-amplitude – SDOF Modal Analysis-II – Circle Fit Method – SDOF Modal Analysis III – Inverse Method – Residuals – MDOF curve-fitting procedures – MDOF curve fitting in the Time Domain – Global or Multi-Curve fitting – Non linear systems.

UNIT V DERIVATION OF MATHEMATICAL MODELS 6

Introduction – Modal Models – Display of Modal Model – Response Models – Spatial Models – Mobility Skeletons and System Models.

Total 45

REFERENCES:

1. Ewins D J, “Modal Testing: Theory and Practice “, John Wiley & Sons Inc., 1988
2. Nuno Manuel Mendes Maia et al,” Theoretical and Experimental Modal Analysis”, Wiley John & sons, 1997.

ED 9164 DESIGN OF HYDRAULIC AND PNEUMATIC SYSTEMS L T P C
3 0 0 3

UNIT I OIL HYDRAULIC SYSTEMS AND HYDRAULIC ACTUATORS 5

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

UNIT II CONTROL AND REGULATION ELEMENTS 12

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

UNIT III HYDRAULIC CIRCUITS 5

Reciprocation, quick return, sequencing, synchronizing circuits - accumulator circuits - industrial circuits - press circuits - hydraulic milling machine - grinding, planning, copying, - forklift, earth mover circuits- design and selection of components - safety and emergency mandrels.

UNIT IV PNEUMATIC SYSTEMS AND CIRCUITS 16

Pneumatic fundamentals - control elements, position and pressure sensing - logic circuits - switching circuits - fringe conditions modules and these integration - sequential circuits - cascade methods - mapping methods - step counter method - compound circuit design - combination circuit design.

UNIT V INSTALLATION, MAINTENANCE AND SPECIAL CIRCUITS 7

Pneumatic equipments- selection of components - design calculations – application - fault finding - hydro pneumatic circuits - use of microprocessors for sequencing - PLC, Low cost automation - Robotic circuits.

Total 45

REFERENCES:

1. Antony Espossito, “Fluid Power with Applications”, Prentice Hall, 1980.
2. Dudleyt, A. Pease and John J. Pippenger, “Basic fluid power”, Prentice Hall, 1987.
3. Andrew Parr, “Hydraulic and Pneumatics” (HB), Jaico Publishing House, 1999.
4. Bolton. W., “Pneumatic and Hydraulic Systems “, Butterworth –Heinemann, 1997.
5. K.Shanmuga Sundaram, “Hydraulic and Pneumatic Controls: Understanding made Easy" S.Chand & Co Book publishers, New Delhi, 2006 (Reprint 2009)

ED 9165 EXPERIMENTAL STRESS ANALYSIS L T P C
3 0 0 3

UNITI FORCES AND STRAIN MEASUREMENT 9

Strain gauge, principle, types, performance and uses. Photo elasticity – Principle and applications - Moire Fringe - Hydraulic jacks and pressure gauges – Electronic load cells – Proving Rings – Calibration of Testing Machines.

UNIT II VIBRATION MEASUREMENTS 9

Characteristics of Structural Vibrations – Linear Variable Differential Transformer (LVDT) – Transducers for velocity and acceleration measurements. Vibration meter – Seismographs – Vibration Analyzer – Display and recording of signals – Cathode Ray Oscilloscope – XY Plotter – Chart Plotters – Digital data Acquisition systems.

UNIT III ACOUSTICS AND WIND FLOW MEASURES 9

Principles of Pressure and flow measurements – pressure transducers – sound level meter – venturimeter and flow meters – wind tunnel and its use in structural analysis – structural modeling – direct and indirect model analysis

UNIT IV DISTRESS MEASUREMENTS 9

Diagnosis of distress in structures – crack observation and measurements – corrosion of reinforcement in concrete – Half-cell, construction and use – damage assessment – controlled blasting for demolition.

UNIT V NON DESTRUCTIVE TESTING METHODS 9

Load testing on structures, buildings, bridges and towers – Rebound Hammer – acoustic emission – ultrasonic testing principles and application – Holography – use of laser for structural testing – Brittle coating

Total 45

REFERENCES:

1. Sadhu Singh – Experimental Stress Analysis, Khanna Publishers, New Delhi, 1996.
2. JW Dalley and WF Riley, Experimental Stress Analysis, McGraw Hill Book Company, N.Y. 1991
3. L.S.Srinath et al, Experimental Stress Analysis, Tata McGraw Hill Company, New Delhi, 1984
4. R.S.Sirohi, HC Radhakrishna, Mechanical Measurements, New Age International (P) Ltd. 1997
5. F.K Garas, J.L. Clarke and GST Armer, Structural assessment, Butterworths, London, 1987
6. D.E. Bray & R. K.Stanley, Non-destructive Evaluation, McGraw Hill Publishing Company, N.Y.1989

ED9173 INTEGRATED MANUFACTURING SYSTEMS L T P C
3 0 0 3

UNIT I INTRODUCTION 5

Objectives of a manufacturing system-identifying business opportunities and problems classification production systems-linking manufacturing strategy and systems analysis of manufacturing operations.

UNIT II GROUP TECHNOLOGY AND COMPUTER AIDED PROCESS PLANNING 5

Introduction-part families-parts classification and cooling - group technology machine cells-benefits of group technology. Process planning function CAPP - Computer generated time standards.

UNIT III COMPUTER AIDED PLANNING AND CONTROL 10

Production planning and control-cost planning and control-inventory management-Material requirements planning (MRP)-shop floor control-Factory data collection system-Automatic identification system-barcode technology- automated data collection system.

UNIT IV COMPUTER MONITORING 10

Types of production monitoring systems-structure model of manufacturing process-process control & strategies- direct digital control-supervisory computer control-computer in QC - contact inspection methods non-contact inspection method - computer-aided testing - integration of CAQC with CAD/CAM.

UNIT V INTEGRATED MANUFACTURING SYSTEM 15

Definition - application - features - types of manufacturing systems-machine tools-materials handling system- computer control system - DNC systems manufacturing cell. Flexible manufacturing systems (FMS) - the FMS concept-transfer systems - head changing FMS - variable mission manufacturing system - CAD/CAM system - human labor in the manufacturing system-computer integrated manufacturing system benefits. Rapid prototyping - Artificial Intelligence and Expert system in CIM.

Total 45

TEXT BOOKS:

1. Groover, M.P., "Automation, Production System and CIM", Prentice-Hall of India, 1998.

REFERENCES:

1. David Bedworth, "Computer Integrated Design and Manufacturing", TMH, New Delhi, 1998.
2. Yorem Koren, "Computer Integrated Manufacturing Systems", McGraw Hill, 1983.
3. Ranky, Paul G., "Computer Integrated Manufacturing", Prentice Hall International 1986.
4. R.W. Yeomamas, A. Choudry and P.J.W. Ten Hagen, "Design rules for a CIM system", North Holland Amsterdam, 1985.

ED 9166 MAINTENANCE ENGINEERING L T P C
3 0 0 3

UNIT I INTRODUCTION TO MAINTENANCE SYSTEMS 8

Introduction to repair and Maintenance -Maintenance as business - Maintenance systems such as reactive, preventive, predictive or proactive systems - Human resources management in Maintenance management -maintainability- Inherent and overall availability. - Mean time between failures, mean time to repairs and mean down time - Testability and supportability - “Design for Maintenance” - Poor maintainability aspects - Design for reliability.

UNIT II CONDITION BASED MAINTENANCE 7

Condition based monitoring of equipment and systems -condition monitoring techniques such as a) Vibration analysis, b) Ultrasonic detection techniques, c) Thermography, d) Oil and lubricant analysis, e) Motor condition monitoring (MCM) - Shaft alignments through laser - Vibration instruments -Outline on Thermography

UNIT III MAINTENANCE TECHNIQUES SUCH AS RELIABILITY CENTRED MAINTENANCE(RCM),TOTAL PRODUCTIVE MAINTENANCE(TPM) & CMMS 10

Reliability centred Maintenance-Failure Mode and Effect Analysis-Root cause Analysis-logic tree analysis-Criticality matrix - Total Productive Maintenance, Overall Equipment Effectiveness-Lean manufacturing- TPM and TPO- Relationship between OEE and world-class Maintenance- Ladder of Maintenance improvement- Computerized Maintenance management system in a business scenario- data acquisition for effective management of CMMS.

UNIT IV ASSET PLANNING AND SCHEDULING OF ACTIVITIES IN MAINTENANCE 10

Asset and spare part management, - Conventional spare Parts management techniques such as Economic Order Quantity, two bin systems - Latest trends in monitoring through bar codes, mobile computer and wireless data transmissions -. Different aspects of planning and scheduling of Maintenance, such as shutdowns- Critical aspects of both routine and shut down Maintenance -. bar charts - PERT network during shut down -Man power Training and utilization of skilled manpower - Sequencing of activities.

UNIT V SAFETY AND OTHER ASPECTS OF MAINTENANCE FUNCTIONS 10

Safety Engineering. - Hazard analysis -General rules and guidelines in safety and hazard prevention - Analytical tools - Hazard analysis- Fault Tree Analysis - Sneak Circuit analysis - Integrated approach to Maintenance- Statistical distributions such as normal, gamma and “Weibull” in Maintenance- Maintenance effectiveness.

Total: 45

TEXT BOOK:

1. “Maintenance Engineering and Management”: K.Venkataraman-PHI Learning-2007

REFERENCES:

1. Kelly. A and Harris, M. J, “Management of Industrial maintenance”, Butter worth & Co., 1978
2. David J. Smith, “Reliability and Maintainability in Perspective”, McMillan,2nd Edition, 1985.
3. Gwidon W Stachowiak and Andrew W. Batchelor, “Engineering Tribology”, Butterwork-Heinmann, 2001
4. John V.Grimaldi & Rollin H.Simonds, “Safety Management”, AITBS Publishers & Distributors, 2001

ED 9169 BEARING DESIGN AND ROTOR DYNAMICS L T P C
3 0 0 3

UNIT I CLASSIFICATION AND SELECTION OF BEARINGS 6

Selection criteria-Dry and Boundary Lubrication Bearings-Hydrodynamic and Hydrostatic bearings- Electro Magnetic bearings-Dry bearings-Rolling Element bearings- Bearings for Precision Applications-Foil Bearings-Special bearings- Selection of plain Bearing materials –Metallic and Non metallic bearings

UNIT II DESIGN OF FLUID FILM BEARINGS 10

Design and performance analysis of Thrust and Journal bearings – Full, partial, fixed and pivoted journal bearings design procedure-Minimum film thickness – lubricant flow and delivery – power loss, Heat and temperature distribution calculations- Design based on Charts & Tables and Experimental curves-Design of Foil bearings-Air Bearings-Design of Hydrostatic bearings-Thrust and Journal bearings- Stiffness consideration - flow regulators and pump design

UNIT III SELECTION AND DESIGN OF ROLLING BEARINGS 10

Contact Stresses in Rolling bearings- Centrifugal stresses-Elasto hydrodynamic lubrication- Fatique life calculations- Bearing operating temperature- Lubrication-Selection of lubricants- Internal clearance – Shaft and housing fit- -Mounting arrangements-Materials for rolling bearings- Manufacturing methods- Ceramic bearings-Rolling bearing cages-bearing seals selection

UNIT IV DYNAMICS OF HYDRODYNAMIC BEARINGS 10

Hydrodynamic Lubrication equation for dynamic loadings-Squeeze film effects in journal bearings and thrust bearings -Rotating loads , alternating and impulse loads in journal bearings – Journal centre Trajectory- Analysis of short bearings under dynamic conditions- Finite difference solution for dynamic conditions

UNIT V ROTOR DYNAMICS 9

Rotor vibration and Rotor critical speeds- support stiffness on critical speeds- Stiffness and damping coefficients of journal bearings-computation and measurements of journal bearing coefficients -Mechanics of Hydro dynamic Instability- Half frequency whirl and Resonance whip- Design configurations of stable journal bearings

Total 45

REFERENCES:

1. Neale, M.J. “Tribology Hand Book”, Butterworth Heinemann, United Kingdom 2001.
2. Cameron, A. “Basic Lubrication Theory”, Ellis Herward Ltd., UK, 1981
3. Halling, J. (Editor) – “Principles of Tribology “, Macmillian – 1984.
4. Williams J.A. “Engineering Tribology”, Oxford Univ. Press, 1994.
5. S.K.Basu, S.N.Sengupta & B.B.Ahuja ,”Fundamentals of Tribology”, Prentice –Hall of India Pvt Ltd, New Delhi, 2005
6. G.W.Stachowiak & A.W .Batchelor, Engineering Tribology, Butterworth-Heinemann, UK, 2005

PD 9151 MICRO ELECTRO MECHANICAL SYSTEMS L T P C
3 0 0 3

UNIT I INTRODUCTION 8

Introduction, Materials-substrates, Additive materials. Fabrication techniques-Deposition, Lithography, etching, Surface micro machining, Thick film screen-printing and electroplating

UNIT II MECHANICAL SENSOR PACKAGING 8

Introduction, Standard IC packages-ceramic, plastic and metal packages. Packaging process-Electrical interconnects, Methods of die attachment, sealing techniques. MEMS mechanical sensor packaging

UNIT III MECHANICAL TRANSDUCTION TECHNIQUES 9

Piezo resistivity, Piezoelectricity, Capacitive Techniques, Optical techniques, Resonant techniques. Actuation techniques, Smart Sensors. MEMS Simulation and Design tools-Behavioral model ling simulation tools and Finite element simulation tools.

UNIT IV PRESSURE SENSORS 12

Introduction. Techniques for sensing. Physics of pressure sensing-Pressure sensor specifications. Dynamic pressure sensing. Pressure sensor types. MEMS technology pressure sensors-Micro machined silicon diaphragms,

UNIT V FORCE, TORQUE AND INERTIAL SENSORS 8

Introduction-Silicon based devises-Optical devises-capacitive devises-Magnetic devices-Atomic force microscope and scanning probes- micro machined accelerometer-Micro machined Gyroscope-Future inertial micro machined sensors

TEXT BOOK:

1. Nadim Maluf and Kirt Williams,' An introduction to Micro electro mechanical System Engineering, Artech House, Inc. Boston.2003

REFERENCE:

1. Stephen Beeby, Graham Ensell, Michael Kraft and Neil White,' MEMS Mechanical sensors' Artech House, Inc. Boston 2003

PD 9152 CREATIVITY IN DESIGN L T P C
3 0 0 3

UNIT I INTRODUCTION 4

Need for design creativity – creative thinking for quality – essential theory about directed creativity –

UNIT II MECHANISM OF THINKING AND VISUALIZATION 11

Definitions and theory of mechanisms of mind heuristics and models : attitudes, Approaches and Actions that support creative thinking - Advanced study of visual elements and principles- line, plane, shape, form, pattern, texture gradation, color symmmetry.Spatial relationships and compositions in 2 and 3 dimensional space - procedure for genuine graphical computer animation – Animation aerodynamics – virtual environments in scientific Visualization – Unifying principle of data management for scientific visualization – Unifying principle of data management for scientific visualization - Visualization benchmarking

UNIT III CREATIVITY 11

Methods and tools for Directed Creativity – Basic Principles – Tools of Directed Creativity – Tools that prepare the mind for creative thought – stimulation of new ideas – Development and Actions: - Processes in creativity ICEDIP – Inspiration, Clarification, Distillation, Perspiration, Evaluation and Incubation – Creativity and Motivation The Bridge between man creativity and the rewards of innovativeness – Applying Directed Creativity to the challenge of quality management

UNIT IV DESIGN 9

Process Design, Emotional Design – Three levels of Design – Viceral, Behavioral and Reflective- Recycling and availability-Creativity and customer needs analysis – Innovative product and service designs, future directions in this application of creativity thinking in quality management

UNIT V INNOVATION 10

Achieving Creativity – Introduction to TRIZ methodology of Inventive Problem Solving - the essential factors – Innovator's solution – creating and sustaining successful growth – Disruptive Innovation model – Segmentive Models – New market disruption - Commoditation and DE-commoditation – Managing the Strategy Development Process – The Role of Senior Executive in Leading New Growth – Passing the Baton

Total 45

REFERENCES

1. Rousing Creativity: Think New NowFloyd Hurr, ISBN 1560525479, Crisp Publications Inc. 1999
2. Geoffrey Petty," how to be better at Creativity", The Industrial Society 1999
3. Donald A. Norman," Emotional Design", Perseus Books Group New York , 2004
4. Clayton M. Christensen Michael E. Raynor," The Innovator's Solution", Harvard Business School Press Boston, USA, 2003
5. Semyon D. Savransky," Engineering of Creativity – TRIZ", CRC Press New York USA," 2000

PD 9153	REVERSE ENGINEERING	L T P C 3 0 0 3

UNIT I INTRODUCTION 5

Scope and tasks of RE - Domain analysis- process of duplicating

UNIT II TOOLS FOR RE 8

Functionality- dimensional- developing technical data - digitizing techniques - construction of surface model - solid-part material- characteristics evaluation -software and application- prototyping - verification

UNIT III CONCEPTS 12

History of Reverse Engineering – Preserving and preparation for the four stage process – Evaluation and Verification- Technical Data Generation, Data Verification, Project Implementation

UNIT IV DATA MANAGEMENT 10

Data reverse engineering – Three data Reverse engineering strategies – Definition – organization data issues - Software application – Finding reusable software components – Recycling real-time embedded software – Design experiments to evaluate a Reverse Engineering tool – Rule based detection for reverse Engineering user interfaces – Reverse Engineering of assembly programs: A model based approach and its logical basics

UNIT V INTEGRATION 10

Cognitive approach to program understated – Integrating formal and structured methods in reverse engineering – Integrating reverse engineering, reuse and specification tool environments to reverse engineering -–coordinate measurement – feature capturing – surface and solid members

Total: 45

REFERENCES:

1. Design Recovery for Maintenance and Reuse, T J Biggerstaff, IEEE Corpn. July 1991
2. White paper on RE, S. Rugaban, Technical Report, Georgia Instt. of Technology, 1994
3. Reverse Engineering, Katheryn, A. Ingle, McGraw-Hill, 1994
4. Data Reverse Engineering, Aiken, Peter, McGraw-Hill, 1996
5. Reverse Engineering, Linda Wills, Kluiver Academic Publishers, 1996
6. Co-ordinate Measurment and reverse engineering, Donald R. Honsa, ISBN 1555897, American Gear Manufacturers Association

ED 9174	SUPPLY CHAIN MANAGEMENT	L	T	P	C
		3	0	0	3

UNIT I INTRODUCTION 5

Logistics- concepts, definitions, approaches, factors affecting logistics. Supply chain - basic tasks of the supply chain - the new corporate model.

UNIT II SUPPLY CHAIN MANAGEMENT 10

The new paradigm, the modular company, the network relations, supply process, procurement process - Distribution management.

UNIT III EVOLUTION OF SUPPLY CHAIN MODELS 10

Strategy and structure - factors of supply chain - Manufacturing strategy stages, supply chain progress - model for competing through supply chain management - PLC grid, supply chain redesign - Linking supply chain with customer.

UNIT IV SUPPLY CHAIN ACTIVITY SYSTEMS 10

Structuring the SC, SC and new products, functional roles in SC, SC design framework, collaborative product commerce (CPC)

UNIT V SCM ORGANISATIONA ND INFORMATION SYSTEM 10

The management task, logistics organisation, the logistics information systems- topology of SC application- MRP, ERP, Warehouse management system, product data management- cases.

Total = 45

REFERENCES:

1. Scharj, P.B., Lasen, T.S., Managing the global supply chain, Viva Books, New Delhi, 2000.
2. Ayers, J.B., Hand book of Supply Chain Management, The St. Lencie press, 2000.
3. Nicolas, J.N., Competitive manufacturing management- continuous improvement, Lean production, customer focused quality, McGraw-Hill, NY, 1998.
4. Steudel, H.J. and Desruelle, P., Manufacturing in the nintees- How to become a mean, lean and world class competitor, Van Nostrand Reinhold, NY, 1992.

PD 9154 ENTERPRISE RESOURCE PLANNING L T P C

3 0 0 3

UNIT I ENTERPRISE RESOURCE PLANNING 10

Principle – ERP framework – Business Blue Print – Business Engineering vs Business process Re-Engineering – Tools – Languages – Value chain – Supply and Demand chain – Extended supply chain management – Dynamic Models –Process Models

UNIT II TECHNOLOGY AND ARCHITECTURE 10

Client/Server architecture – Technology choices – Internet direction – Evaluation framework – CRM – CRM pricing – chain safety – Evaluation framework.

UNIT III ERP SYSTEM PACKAGES 10

SAP,. People soft, Baan and Oracle – Comparison – Integration of different ERP applications – ERP as sales force automation – Integration of ERP and Internet – ERP Implementation strategies – Organisational and social issues.

UNIT IV 7

Overview – Architecture – AIM – applications – Oracle SCM. SAP: Overview – Architecture – applications -Before and after Y2K – critical issues – Training on various modules of IBCS ERP Package-Oracle ERP and MAXIMO, including ERP on the NET

UNIT V ERP PROCUREMENT ISSUES 8

Market Trends – Outsourcing ERP – Economics – Hidden Cost Issues – ROI – Analysis of cases from five Indian Companies.

Total = 45

REFERENCES:

1. Sadagopan.S , ERP-A Managerial Perspective, Tata Mcgraw Hill, 1999.
2. Jose Antonio Fernandez, the SAP R/3 Handbook, Tata Mcgraw Hill, 1998.
3. Vinod Kumar Crag and N.K.Venkitakrishnan , Enterprise Resource Planning – Concepts and Practice, Prentice Hall of India, 1998.
4. ERPWARE , ERP Implementation Framework, Garg & Venkitakrishnan, Prentice Hall, 1999.
5. Thomas E Vollmann and Bery Whybark , Manufacturing and Control Systems, Galgothia Publications, 1998.

IC 9162 COMPUTATIONAL FLUID DYNAMICS L T P C
3 0 0 3

UNIT I GOVERNING DIFFERENTIAL EQUATION AND FINITE DIFFERENCE METHOD 10

Classification, Initial and Boundary conditions – Initial and Boundary Value problems – Finite difference method, Central, Forward, Backward difference, Uniform and non-uniform Grids, Numerical Errors, Grid Independence Test.

UNIT II CONDUCTION HEAT TRANSFER 10

Steady one-dimensional conduction, Two and three dimensional steady state problems, Transient one-dimensional problem, Two-dimensional Transient Problems.

UNIT III INCOMPRESSIBLE FLUID FLOW 10

Governing Equations, Stream Function – Verticity method, Determination of pressure for viscous flow, SIMPLE Procedure of Patankar and Spalding, Computation of Boundary layer flow, finite difference approach.

UNIT IV CONVECTION HEAT TRANSFER AND FEM 10

Steady One-Dimensional and Two-Dimensional Convection – diffusion, unsteady one-dimensional convection – diffusion, unsteady two-dimensional convection – Diffusion – Introduction to finite element method – solution of steady heat conduction by FEM – Incompressible flow – simulation by FEM.

UNIT V TURBULENCE MODELS 5

Algebraic Models – One equation model, K – ϵ Models, Standard and High and Low Reynolds number models, Prediction of fluid flow and heat transfer using standard codes.

Total = 45 hrs.

REFERENCES

1. Muralidhar, K., and Sundararajan, T., “Computational Fluid Flow and Heat Transfer”, Narosa Publishing House, New Delhi, 1995.
2. Ghoshdasdidar, P.S., “Computer Simulation of flow and heat transfer” Tata McGraw-Hill Publishing Company Ltd., 1998.
3. Subas, V.Patankar “Numerical heat transfer fluid flow”, Hemisphere Publishing Corporation, 1980.
4. Taylor, C and Hughes, J.B. “Finite Element Programming of the Navier-Stokes Equation”, Pineridge Press Limited, U.K., 1981.
5. Anderson, D.A., Tannehill, J.I., and Pletcher, R.H., “Computational fluid Mechanics and Heat Transfer “Hemisphere Publishing Corporation, New York, USA, 1984.
6. Fletcher, C.A.J. “Computational Techniques for Fluid Dynamics 1” Fundamental And General Techniques, Springer – Verlag, 1987.
7. Fletcher, C.A.J. “Computational Techniques for fluid Dynamics 2” Specific Techniques for Different Flow Categories, Springer – Verlag, 1987.

8 Bose, T.X., “Numerical Fluid Dynamics” Narosa Publishing House, 1997.