Semester I

Discipline: MECHANICAL ENGINEERING

Stream: ME4

CODE	COMPUTATIONAL METHODS FOR ENGINEERS	CATEGORY	L	T	P	CREDIT
221TME100		Discipline Core	3	0	0	3

Preamble:

Numerical simulations are the most reliable tool of mechanical engineers to solve the problems in the domain and advanced computational methods are a critical component of that. This course targets to introduce the advanced numerical techniques required to solve the mechanical engineering problems.

Course Outcomes:

After the completion of the course the student will be able to

CO 1	Solve system of equations using numerical techniques
CO 2	Apply numerical schemes to integrate, differentiate and curve fit
CO 3	Determine solutions of ODE and PDE using computational methods
CO 4	Formulate a Mechanical Engineering problem and solve that using computer based numerical procedure and submit micro-project
CO 5	Apply two different numerical methods to solve (manual/computer) a problem and compare the merits and demerits of those schemes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1			3	2	3	2
CO 2			3	2	3	2
CO 3			3	2	3	2
CO 4	3	2		2	3	2
CO 5	2	2		2	3	2

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	20%
Analyse	60%
Evaluate	20%
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation: 40 Marks

Micro project/Course based project : 20 marks

(Formulate a mechanical engineering problem and solve that using computer based numerical procedure and submit as project. The project shall be done individually. Group projects not permitted.)
Course based task (programming)/Seminar/Quiz: 10 marks Test

paper, 1 No. : 10 marks

Test paper shall include minimum 80% of the syllabus.

End Semester Examination: 60 Marks

The end semester examination will be conducted by the University for Core Courses. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Model Question paper

QP Code: **Total Pages:**

Reg No.:_________ **Name:___________________**

APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY
FIRST SEMESTER M.TECH DEGREE EXAMINATION, Month & Year
Discipline: Mechanical Engineering
Course Code:
Course Name: Computational Methods for Engineers

Max. Marks: 60 **Duration: 2.5 Hours**

PART A

Answer all questions, each carries 5 marks. **Marks**

1	Use Gauss elimination to solve $3x_1 - 0.1x_2 - 0.2x_3 = 7.85$ $0.1x_1 + 7x_2 - 0.3x_3 = -19.3$ $0.3x_1 - 0.2x_2 + 10x_3 = 71.4$	**(5)**
2	Explain the procedure of Newton-Raphson method and draw a flowchart.	**(5)**
3	Explain the Trapezoidal rule and derive the equation for the same.	**(5)**
4	Use the classical fourth-order RK method to integrate $f(x, y) = -2x^3 + 12x^2 - 20x + 8.5$ using a step size of h = 0.5 and an initial condition of y = 1 at x = 0.	**(5)**
5	Write a short note on any simple implicit method.	**(5)**

PART B

Answer any 5 full questions, each question carries 7 marks.

6	Use Newton- Raphson method to determine a root of the equation $f(x) = x^3-13x-12$	**(7)**

7 Given these data, **(7)**

x	1.6	2	2.5	3.2	4	4.5
f(x)	2	8	14	15	8	2

Calculate f(2.8) using Newton's interpolating polynomials of order 1 through 3. Choose the sequence of the points for your estimates to attain the best possible accuracy.

8 Evaluate the following integral: **(7)**

$$\int_0^{\pi/2} (6 + 3\cos x)\,dx$$

(a) single application of Simpson's 1/3 rule

(b) multiple-application Simpson's 1/3 rule, with n = 4.

9 Solve the following initial value problem over the interval from t = 0 to 2 where y(0) = 1. Display all your results on the same graph. **(7)**

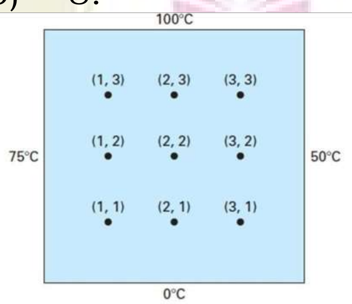
$$\frac{dy}{dt} = yt^2 - 1.1y$$

(a) Euler's method with h = 0.5 and 0.25.

(b) Fourth-order RK method with h = 0.5.

10 Use the shooting method to solve $7\,d^2y/dx^2 - 2\,dy/dx - y + x = 0$ with the boundary conditions y(0) = 5 and y(20) = 8. **(7)**

11 **(7)**



Use Liebmann's method (Gauss-Seidel) to solve for the temperature of the heated plate in figure. Employ overrelaxation with a value of 1.5 for the weighting factor and iterate to es $\varepsilon_s = 1\%$.

12 Use the simple implicit method to solve for the temperature distribution of a long, thin rod with a length of 10 cm and the following values: k’ = 0.49 cal/(s . cm . ºC), Δx = 2 cm, and Δt =
0.1 s. At t =- 0, the temperature of the rod is zero and the boundary conditions are fixed for all times at T(0) = 100ºC and T(10) = 50ºC. Note that the rod is aluminium with C = 0.2174 cal/(g . ºC) and ρ = 2.7 g/cm^3 . Therefore, k = 0.49/ (2.7 . 0.2174) 5 0.835 cm^2 /s and λ = 0.835(0.1)/(2)^2 = 0.020875. **(7)**

Syllabus

Module 1

Introduction to Computational methods, system of equations-Revision - Formulation of engineering problems and solution using computational methods; significant figures, accuracy, precision, round off error, truncation error,Taylor series expansion of a polynomial. Roots of equation - Bisection, Newton-Raphson, and Bairstow methods. Linear algebraic equations - Gauss Elimination method, LU decomposition. Non-linear equation- Gauss-Jordan method, Newton- Raphson for simultaneous equations. Case studies with computer programs (Python/Scilab/ C++/Fortran/other).

Module 2

Curve fitting- Linear regression- linearization of non linear relation, linear least squares, multiple linear regression. Non linear regression- polynomial regression, Gauss- Newton method. Case studies with computer programs (Python/Scilab/ C++/Fortran/other).

Module 3

Numerical differentiation and integration- Derivatives- Newton's forward, backward, divided difference and Sterling formula. Integration -Trapezoidal rule, Simpsons one third, Simpsons three eighth, Gauss quadrature-two & three point. Case studies with computer programs (Python/Scilab/ C++/Fortran/other).

Module 4

Numerical solutions to ordinary differential equations- Taylors method, Eulers method, Runge-Kutta method fourth order, simultaneous first order, Milne's predictor corrector. Initial value problem - shooting method, Eigen values - polynomial method, power method. Case studies with computer programs (Python/Scilab/ C++/Fortran/other).

Module 5

Solution of partial differential equation & Interpolation-

Interpolation - Newtons forward and backward, divided difference linear & quadratic, Lagrange interpolation, cubic splines, Hermites interpolation. Solution of partial differential equation - Difference equations, Elliptic equation- Laplace equation, Poisson equation, Liebmann's iterative methods, Parabolic equation- Bender-Schmidt method, simple implicit, Crank-Nicolson scheme, Solution of hyperbolic equation. Case studies with computer programs (Python/Scilab/ C++/Fortran/other).

Course Plan

No	Topic	No. of Lectures - 40 Hrs
1	**Introduction to Computational methods, system of equations**	
1.1	Revision - Formulation of engineering problems and solution using computational methods; significant figures, accuracy, precision, round off error, truncation error, Taylor series expansion of a polynomial	2
1.2	Roots of equation - Bisection, Newton Raphson, and Bairstow methods	2
1.3	Linear algebraic equations - Gauss Elimination method, LU decomposition. Non-linear equation- Gauss-Jordan method, Newton- Raphson for simultaneous equations	3
1.4	Case studies with computer programs (Python/Scilab/ C++/Fortran/other) (Not for End Semester Examination)	2
2	**Curve fitting**	
2.1	Linear regression- linearization of non linear relation, linear least squares, multiple linear regression	2
2.2	Non linear regression- polynomial regression, Gauss- Newton method	3
2.3	Case studies with computer programs (Python/Scilab/C++/Fortran/other) (Not for End Semester Examination)	2

3	**Numerical differentiation and integration**	
3.1	Derivatives - Newton's forward, backward, divided difference and Sterling formula	3
3.2	Integration -Trapezoidal rule, Simpsons one third, Simpsons three eighth, Gauss quadrature-two & three point.	3
3.3	Case studies with computer programs (Python/Scilab/ C++/Fortran/other) (Not for End Semester Examination)	2
4	**Numerical solutions to ordinary differential equations**	
4.1	Taylors method, Eulers method, Runge-Kutta method fourth order, simultaneous first order, Milne's predictor corrector	3
4.2	Initial value problem - shooting method, Eigen values -polynomial method, power method	3
4.3	Case studies with computer programs (Python/Scilab/C++/Fortran/other)(Not for End Semester Examination)	2
5	**Solution of partial differential equation & Interpolation**	
5.1	Interpolation - Newtons forward and backward, divided difference linear & quadratic, Lagrange interpolation, cubic splines, Hermites interpolation	3
5.2	Solution of partial differential equation - Difference equations, Elliptic equation- Laplace equation, Poisson equation, Liebmann's iterative methods, Parabolic equation- Bender-Schmidt method, simple implicit, Crank-Nicolson scheme, Solution of hyperbolic equation	3

5.3	Case studies with computer programs (Python/Scilab/ C++/Fortran/other)(Not for End Semester Examination)	2

Reference Books

1. Steven C. Chapra, Raymond P Canale, Numerical Methods for Engineering, 8e, Mc-Graw Hill Education (2020)
2. B.S. Grewal, numerical methods in engineering science with programs in C, C++ and MATLAB(10th edition) Khanna Publisher (2020)
3. E Balaguruswamy, Numerical Methods, McGraw Hill (2017)
4. P. Kandasamy , K. Thilagavathy and K. Gunavathy., Numerical Methods, S Chand & Co Ltd (2016)
5. S. P. Venkateshan, Prasanna Swaminathan, Computational Methods in Engineering, Ane Books (2014)
6. VN Vedamurthy & SN Iyengar, Numerical Methods, S Chand & Co Ltd (2014)
7. AK Jaiswal and Anju Khandelwal, Computer Based Numerical and Statistical Techniques, New Age International (2009)
8. Gilbert Strang, Computational Science and Engineering, Wellesley-Cambridge Press (2007)
9. Joe D Hoffman, Numerical Methods for Engineers and Scientists, Second Edition, Marcel Dekker (2001)

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221TME007	ROBOTICS AND AUTOMATION	PROGRAMME CORE	3	0	0	3

Preamble: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Understand the basics about an industrial robot and to perform basic transformations of robot frames
CO 2	Perform forward and inverse kinematics of industrial robots
CO 3	Perform velocity and force analysis of industrial robots
CO 4	Control the trajectory of industrial robots and to program the robot
CO 5	Understand the industrial applications of robots.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	✓	✓	✓	✓		
CO 2	✓	✓	✓			
CO 3	✓	✓	✓	✓		
CO 4	✓	✓	✓	✓		
CO 5	✓	✓	✓			

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	20%
Analyse	60%
Evaluate	20%
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Micro project/Course based project: 20 marks

Course based task/Seminar/Quiz: 10 marks

Test paper, 1 no.: 10 marks

End Semester Examination Pattern:

There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 5 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student shall answer any five. Each question can carry 7 marks. Total duration of the examination will be 150 minutes.

MODEL QUESTION PAPER

ROBOTICS AND AUTOMATION

PART A

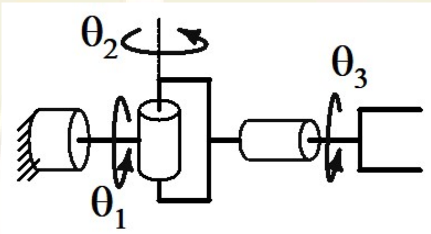
(Answer all the questions. Each question carries 5 Marks)

1. A frame {B} is rotated relative to a frame {A} about Z by 30^o and translated 10 units in X_A and 5 units in Y_A . Find ^AP where $^BP= [3,7,0]^T$.
2. Explain the joint parameters according to D-H convention.
3. Explain the concept of manipulator jacobians.
4. What is powered lead through programming?
5. Write any four applications of robots in industries

PART B

(Answer any 5 questions. Each carry 7 Marks)

6. Explain the working principle of laser range meter.
7. Assign frames and derive the forward kinematics for the following robot configuration

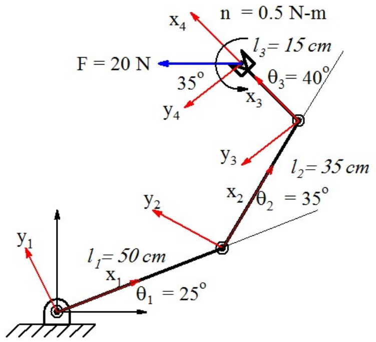


8. Calculate the inverse kinematics of a 3 link planar manipulator whose Forward kinematics and the desired position and orientation of the end effector are given by

$$^B_WT = \begin{bmatrix} C_{123} & -S_{123} & 0 & C_1L_1+L_2C_{12}+L_3C_{123} \\ S_{123} & C_{123} & 0 & L_1S_1+L_2S_{12}+L_3S_{123} \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 0.951 & 0.309 & 0 & 0.2116 \\ -0.309 & 0.951 & 0 & 0.4799 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

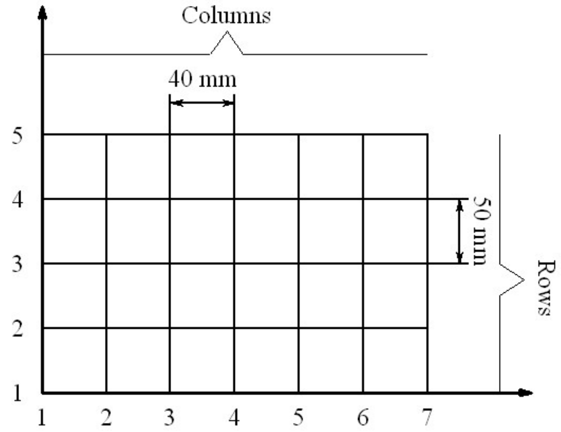
9. A 3 link planar robot is shown below. Calculate the forces and moments propagated from the tip to the base of the robot. Also determine the joint

torques.



10 A single-link robot with a rotary joint is motionless at θ = -5°. It is desired to move the joint in a smooth manner to θ = 80° in 4 seconds and stop smoothly. Compute the corresponding parameters of a linear trajectory with parabolic blends. Plot the position, velocity, and acceleration of the joint as a function of time

11 A robot is to be programmed to pick up parts from an input chute; and place them on a pallet with 35 positions. When a start signal is given, the robot begin picking up the parts and loading them into the pallet, continuing until all 35 positions on the pallet are filled. The robot then generate a signal to indicate that the pallet is full and wait for the start of the next cycle.



Pallet Configuration

12 What are required features for an arc welding robot?

Syllabus

MODULE	CONTENT	HOURS	SEMESTER EXAM MARKS (%)
I	Introduction to robotics-Classification and structure of robots, Drives systems: AC and DC servo motors, Stepper motors, Pneumatic and Hydraulic actuators, Sensors: Proximity sensors, range sensors, Encoders, Force and torque sensors, Vision sensors, basic control schemes, Spatial descriptions and transformations: Basic rotation matrices, general transformations, Workspace analysis, Euler angles	8	20
II	Forward Kinematics: DH Convention for affixing frames to links, Link parameters, Derivation of direct kinematic equations, Inverse manipulator kinematics, Solvability, algebraic and geometric solutions, Piper's solution when three axes intersect, Repeatability and accuracy	8	20
III	Velocities and static forces- Linear and rotational velocity of rigid bodies, Velocity propagation from link to link, Jacobians, Singularities, Static forces in manipulators, Jacobians in force domain, Cartesian transformation of velocities and static forces	8	20
IV	Trajectory generation: General considerations in path descriptions and generation, Joint space schemes, Cubic polynomials, Linear function with parabolic blends, Cartesian space schemes, Robot programming: Teach by showing, Textual Language Programming using AL, AML, VAL etc.,	8	20
V	Industrial applications: Spray painting, Spot welding, Arc welding, drilling, Assembly operations, loading unloading, Role of a robot in a manufacturing cell, Safety considerations.	8	20

Course Plan

No	Topic	No. of Lecture Hours
1	**Introduction to Robotics**	
1.1	Classification and structure of robots	1
1.2	Drives systems: AC and DC servo motors, Stepper motors, Pneumatic and Hydraulic actuators	1
1.3	Sensors: Proximity sensors, range sensors	1
1.4	Force and torque sensors, Vision sensors, encoders	1
1.5	Tactile sensors and basic control schemes	1
1.6	Basic rotation matrices, general transformations	2
1.7	Workspace analysis. Euler angles	1
2	**Forward and Inverse kinematics**	
2.1	DH Convention for affixing frames to links, Link parameters	2
2.2	Derivation of direct kinematic equations	2
2.3	Inverse manipulator kinematics, Solvability, algebraic and geometric solutions	2
2.4	Piper's solution when three axes intersect, Repeatability and accuracy	2
3	**Velocities and Static forces**	
3.1	Linear and rotational velocity of rigid bodies,	1
3.2	Velocity propagation from link to link	2
3.3	Jacobians, Singularities, Static forces in manipulators	2
3.4	Jacobians in force domain	1
3.5	Cartesian transformation of velocities and static forces	2
4	**Trajectory generation and Robot programming**	

4.1	General considerations in path descriptions and generation.	1
4.2	Joint space schemes, Cubic polynomials, Linear function with parabolic blends	2
4.3	Cartesian space schemes	2
4.4	Robot programming: Teach by showing,	1
4.5	Textual Language Programming using AL, AML, VAL etc.,(include sample programs)	2
5	**Industrial Applications of Robots**	
5.1	Spray-painting, Spot-welding robots	2
5.2	welding, drilling, Assembly operations using industrial robots	2
5.3	loading unloading, Role of a robot in a manufacturing cell	2
5.4	Safety considerations, precautions, and protective measures	2

Reference Books

1. John J Craig, Introduction to Robotics, Mechanics and Control, Third edition, Pearson Education International, 2005
2. Mark W. Spong & M. Vidyasagar, Robot Dynamics and Control, John Wiley & Sons, 2004
3. Mikell P. Groover et al, “Industrial Robots-Technology, Programming and Application”, McGraw Hill Publishing Company-2013.
4. Yoram Koran, “Robotics for Engineers”, McGraw-Hill International Student Edition, 2009

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221TME008	CAD/CAM	PROGRAME CORE	3	0	0	3

Preamble: Nil

Course Outcomes: The COs shown are only indicative. For each course, there can be 4 to 6 COs.

After the completion of the course the student will be able to

CO 1	Understand the basic concepts of CAD
CO 2	Impact general Awareness on components of geometric modelling.
CO 3	Identify the basic concepts of solid modelling and its applications
CO 4	Solve problems raised in engineering using CAD
CO 5	Apply knowledge in Assembling solid models in manufacturing process

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	✓	✓	✓		✓	
CO 2	✓	✓	✓		✓	
CO 3	✓	✓	✓			
CO 4	✓	✓	✓			
CO 5	✓	✓	✓			

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	20
Analyse	20
Evaluate	20
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Micro project/Course based project: 20 marks

Course based task/Seminar/Quiz: 10 marks

Test paper, 1 no: 10 marks

The project shall be done individually. Group projects not permitted. Test paper shall include minimum 80% of the syllabus.

End Semester Examination Pattern:

The end semester examination will be conducted by the University. There will be two parts; Part A and Part B. Part A contain 5 numerical questions (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students), with 1 question from each module, having 5 marks for each question. Students shall answer all questions. Part B contains 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student shall answer any five. Each question can carry 7 marks. Total duration of the examination will be 150 minutes.

Model Question paper

CAD/CAM

PART A

(Answer all the questions. Each question carries 5 Marks)

1. Compare conventional and Computer Aided design process
2. Explain the basic transformations in CAD
3. Describe the functions of user interface for solid modelling
4. Explain the parametric modelling Process.
5. List out the various mating conditions in assembly modelling and explain with neat sketches.

PART B

(Answer any 5 questions. Each carry 7 Marks)

6 Draw layout representing hardware details in a CAD work station and elucidate.

7 Find the coordinates of a reflected triangle having vertices (2,4), (4,3) and (3,7) about an arbitrary line represented by y= 2x+2. Plot the transformed triangle.

8 A square having coordinates (2,2), (5,2), (5,4) and (2,4) is to be rotated about the point (2,2) in clockwise direction at an angle 60° and after that it is scaled to 3 unit in X direction and 2 unit in Y direction. Find and plot the final coordinates of the geometry.

9 Describe Regularized Boolean set operations with examples.

10 Explicate any one hidden line removing algorithm with examples.

11 Define IGES? Describe its file structure.

12 Explain the top down assembly approach with an example.

Syllabus

MODULE	CONTENT	HOURS	SEMESTER EXAM MARKS (%)
I	Overview of cad systems: Conventional and computer aided design process, subsystems of CAD hardware and software, Analytical and Graphics packages, CAD workstations. Networking of CAD systems, generative, cognitive and image processing graphics static and dynamic data graphics. Transport of graphic data.	8	20
II	Output primitives (points, lines, curves etc.,), 2-D & 3-D transformation (Translation, scaling, rotation) windowing - view ports - clipping transformation. Introduction to curves - Analytical curves: line, circle and conics – synthetic curves: Hermite cubic spline- Bezier curve and B-Spline curve. Introduction to surfaces - Analytical surfaces: Plane surface, ruled surface, surface of revolution and tabulated cylinder – synthetic surfaces: Hermite bicubic surface- Bezier surface and B-Spline surface	8	20
III	Solid modelling: Regularized Boolean set operations - primitive instancing - sweep representations - boundary representations – constructive solid Geometry - comparison of representations - user interface for solid modelling.	8	20
IV	Visual Realism: Hidden – Line – Surface – solid removal algorithms shading – colouring. Introduction to parametric and variational geometry-based software's and their principles, creation of prismatic and lofted parts using these packages.	7	20
V	Assembly modelling: interferences of positions and orientation - tolerances analysis – mass property calculations - mechanism simulation. Graphics and computing standards– Open GL Data Exchange standards – IGES, STEP etc– Communication standards.	8	20

Course Plan (For 3 credit courses, the content can be for 40 hrs and for 2 credit courses, the content can be for 26 hrs. The audit course in third semester can have content for 30 hours).

No	Topic	No. of Lectures
1	**Overview of CAD systems**	
1.1	Overview of cad systems: Conventional and computer aided design process, subsystems of CAD hardware and software, Analytical and Graphics packages, CAD workstations.	3
1.2	Networking of CAD systems, generative, cognitive and image processing graphics static and dynamic data graphics	3
1.3	Transport of graphic data.	2
2	**Output primitives Curves and Surfaces**	
2.1	Output primitives (points, lines, curves etc.,), 2-D & 3-D transformation (Translation, scaling, rotation) windowing - view ports - clipping transformation.	3
2.2	Introduction to curves - Analytical curves: line, circle and conics – synthetic curves: Hermite cubic spline-Bezier curve and B-Spline curve	3
2.3	Introduction to surfaces - Analytical surfaces: Plane surface, ruled surface, surface of revolution and tabulated cylinder – synthetic surfaces: Hermite bicubic surface- Bezier surface and B-Spline surface.	2
3	**Solid modelling**	
3.1	Regularized Boolean set operations - primitive instancing.	2
3.2	Sweep representations - boundary representations.	2
3.3	Constructive solid Geometry - comparison of representations	2
3.4	User interface for solid modelling.	2
4	**Visual Realism**	
4.1	Hidden – Line – Surface – solid removal algorithms shading – colouring.	3
4.2	Introduction to parametric and variational geometry-based software's and their principles.	2
4.3	creation of prismatic and lofted parts using these packages.	2
5	**Assembly modelling**	

5.1	Assembly modelling: interferences of positions and orientation.	2
5.2	Tolerances analysis, mass property calculations, mechanism simulation.	2
5.3	Graphics and computing standards– Open GL Data Exchange standards – IGES, STEP etc– Communication standards.	4

Reference Books

1. David F. Rogers, James Alan Adams "Mathematical elements for computer graphics" second edition, Tata McGraw-Hill edition.2003
2. Donald Hearn and M. Pauline Baker "Computer Graphics", Prentice Hall, Inc., 1992.
3. Foley, Wan Dam, Feiner and Hughes – Computer graphics principles & practices, Pearson Education – 2003.
4. Ibrahim Zeid Mastering CAD/CAM – McGraw Hill, International Edition, 2007.
5. William M Neumann and Robert F.Sproull "Principles of Computer Graphics", McGraw Hill Book Co. Singapore, 1989.

PROGRAM ELECTIVE I

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221EME036	COMPOSITE MATERIALS	PROGRAMME ELECTIVE 1	3	0	0	3

Preamble: Nil

Course Outcomes: The COs shown are only indicative.

After the completion of the course the student will be able to

CO 1	Summarize the significance of advanced materials
CO 2	Compare the set of technological properties of the advanced materials with the conventional materials.
CO 3	Distinguish the construction, constituent's phases & characteristics of the composite materials.
CO 4	Extract the fabrication techniques of different types of composite materials
CO 5	Select and apply the appropriate polymer matrix composites material for recent industrial applications.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	✓	✓	✓		✓	
CO 2	✓	✓	✓		✓	
CO 3	✓	✓	✓			
CO 4	✓	✓	✓			
CO 5	✓	✓	✓			

Assessment Pattern

Bloom's Category	**End Semester Examination**
Apply	20%
Analyse	60%
Evaluate	20%
Create	

Mark distribution

Total Marks	**CIE**	**ESE**	**ESE Duration**
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer reviewed original publications (minimum
10 publications shall be referred): 15 marks
Course based task/Seminar/Data collection and interpretation: 15 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus): 10 marks

End Semester Examination Pattern:

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Model Question Paper

COMPOSITE MATERIALS

PART A

(Answer all the questions. Each question carries 5 Marks)

1. Classify composite materials based on reinforcement.
2. Differentiate short and continuous fibers.
3. What are the advantages of PMC'S over MMC's
4. Differentiate CVD & CVI
5. List down some of the applications of nano composites.

PART B

(Answer any 5 questions. Each carry 7 Marks)

6 Explain in details, the different types of reinforcements in Composite materials. List out the advantages and applications of each.

7 With the help of a neat sketch, explain the fabrication of Carbon – glass – carbon fiber reinforced epoxy hybrid composite.

8 Explain the process of rotational moulding with neat sketch.

9 With the help of neat sketch, explain hand layup and spray layup techniques of polymer matrix composites.

10 Explain the process of diffusion bonding in the manufacturing of MMC's.

11 Explain the environmental advantage of using natural fibers as the reinforcement.

12 Explain with neat sketch the manufacturing of a surface metal matrix composite.

Syllabus

MODULE	CONTENT	HOURS	SEMESTER EXAM MARKS (%)
I	Introduction to Composites: Matrices, Reinforcements, Classifications, Applications, Comparison with Metals and Importance over other materials, design fabrication and economic consideration, General requirements. Classification of composites based on reinforcement and matrix, Classification of Reinforcement, Form and functions of reinforcement, Functions of matrices. Dispersion strengthened, particle strengthened and fiber-reinforced composites.	8	20
II	Strengthening mechanisms, Aspect Ratio, Rule of Mixture, discontinuous and continuous fiber composites and their comparison, Characteristics and materials of reinforcements and matrices. Critical Fiber Length, Short and Continuous Fibres, Fibre Orientation. Major composite classes: polymer matrix, metal matrix, ceramic matrix, carbon-carbon, and intermetallic composites. Hybrid composites, Laminated composites. Examples of each class of composites.	7	20
III	Manufacturing of Polymer matrix composites (PMC)Hand and spray lay - up, injection molding, resin injection, filament winding, pultrusion, centrifugal casting, Rotational	8	20

	moulding and prepregs. Fibre/Matrix Interface. Measurement of interface strength. Characterization of systems; carbon fibre/epoxy, glass fibre/polyester, etc.		
IV	Fabrication of CMC's: Hot-Pressing, Infiltration, In Situ Chemical Reaction Techniques. CVD & CVI, Sol-gel. Fabrication of MMC'S: Liquid Infiltration-Casting, Solid State Processes-Diffusion Bonding & In Situ Technique.	8	20
V	Applications of advanced composite materials. Environmental effects in Composites, Green composites, Synthesis and Properties of Nanocomposites. Surface Composites & Surface metal matrix composites: Need, Synthesis, Properties, and applications	8	20

Course Plan

No	Topic	No. of Lectures
1	**Introduction to Composites**	
1.1	Matrices, Reinforcements, Classifications, Applications, Comparison with Metals and Importance over other materials, design fabrication and economic consideration, General requirements	2
1.2	Classification of composites based on reinforcement and matrix	2
1.3	Classification of Reinforcement, Form and functions of reinforcement, Functions of matrices	2
1.4	Dispersion strengthened, particle strengthened and fiber-reinforced composites.	2
2	**Major composite classes**	
2.1	Strengthening mechanisms, Aspect Ratio, Rule of Mixture, discontinuous and continuous fiber composites and their comparison, Characteristics and materials of reinforcements and matrices. Critical Fiber Length, Short and Continuous Fibers, Fiber Orientation.	2
2.2	Polymer matrix, metal matrix, ceramic matrix, carbon-carbon, and intermetallic composites.	3
2.3	Hybrid composites, Laminated composites. Examples of each class of composites.	2
3	**Manufacturing of Polymer matrix composites**	
3.1	Hand and spray lay - up, injection molding.	1
3.2	Injection molding, resin injection.	1
3.3	Filament winding, pultrusion, centrifugal casting, Rotational moulding and prepregs.	2
3.4	Fibre/Matrix Interface. Measurement of interface strength.	2
3.5	Characterization of systems; carbon fibre/epoxy, glass fibre/polyester, etc	2
4	**Fabrication of CMC’s**	
4.1	Hot-Pressing, Infilration, In Situ Chemical Reaction Techniques.	2
4.2	CVD & CVI, Sol-gel.	2
4.3	Liquid Infiltration- Casting	2
4.4	Solid State Processes-Diffusion Bonding & In Situ Technique.	2

5	**Applications of advanced composite materials**	
5.1	Environmental effects in Composites, Green composites.	2
5.2	Synthesis and Properties of Nanocomposites.	2
5.3	Surface Composites &.	2
5.4	Surface metal matrix composites Need, Synthesis, Properties, and applications.	2

Reference Books

1. Autar K. Kaw, Mechanics of Composite materials, CRC Taylor & Francis, 2nd Ed, 2005
2. Composite Material Science and Engineering, Krishan K. Chawla, Springer, 3e, 2012
3. Robert M. Jones, Mechanics of Composite Materials, Taylor & Francis, 1999.
4. Madhijit Mukhopadhay, Mechanics of Composite Materials & Structures, Universities Press,2004
5. Michael W, Hyer, Stress analysis of fiber Reinforced Composite Materials, Mc-Graw Hill International, 2009
6. Fibre Reinforced Composites, P.C. Mallik, Marcel Decker, 1993
7. Hand Book of Composites, P.C. Mallik, Marcel Decker, 1993

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221EME037	FINITE ELEMENT ANALYSIS	PROGRAMME ELECTIVE 1	3	0	0	3

Preamble: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	To familiarize computational procedures in linear finite element analysis.
CO 2	To understand the basic mathematics of finite element analysis and equip the students to formulate finite element procedures for engineering problems in structural, thermal and fluid flow domain.
CO 3	To impart knowledge in co-ordinate transformation and error estimation.
CO 4	To make the students aware of computational methods applicable for finite element analysis.
CO 5	To apply FEA in advanced Engineering problems.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	✓	✓				
CO 2	✓	✓				
CO 3	✓	✓				
CO 4	✓	✓			✓	
CO 5	✓	✓			✓	

Assessment Pattern

Bloom's Category	End Semester Examination (marks)
Apply	20
Analyse	40
Evaluate	
Create	

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	3 hours

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer reviewed original publications (minimum
10 publications shall be referred): 15 marks
Course based task/Seminar: 15 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus): 10 marks

End Semester Examination Pattern:

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Model Question Paper

FINITE ELEMENT ANALYSIS

PART A

(Answer all the questions. Each question carries 5 Marks)

1. Compare with figure CST element and LST element

2. Explain how the rise of temperature causes stress in a body?

3. Formulate the finite element equation for truss element?

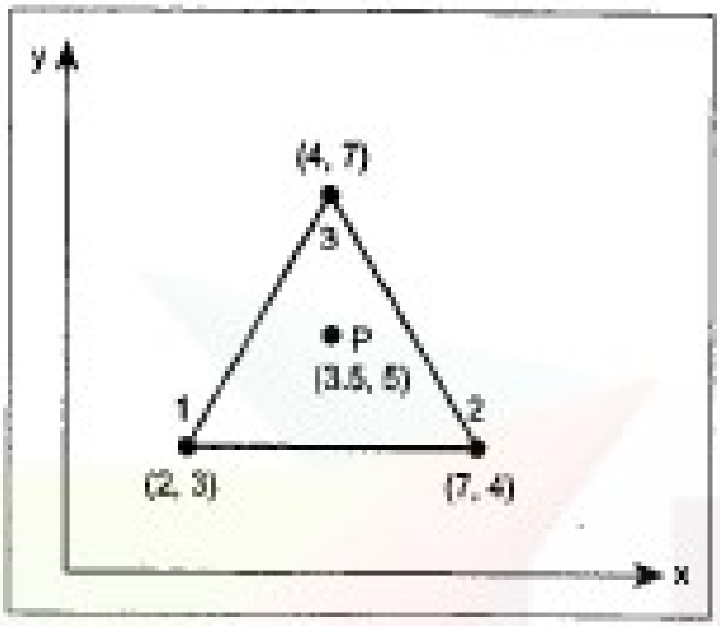
4. Write the steps for finding solution using Rayleigh-Ritz method?

5. Write the criteria of convergence of Newton-Raphson method?

PART B

(Answer any 5 questions. Each carry 7 Marks)

6. Determine the shape functions N1, N2 and N3 at the interior point P for the triangular element shown in Figure. $(x_1, y_1) = (2,3)$, $(x_2, y_2) = (7,4)$, $(x_3, y_3) = (4,7)$,



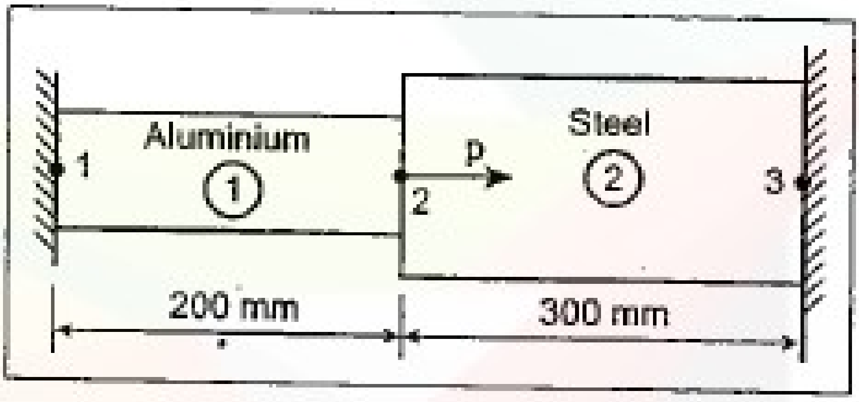
7. An axial load of 4 x10^5 N is applied at 30^0C to the rod as shown in Figure. The temperature is then raised to 60^0C. Calculate the following

a. Assemble the K and F matrices
b. Nodal displacements
c. Stresses in each material

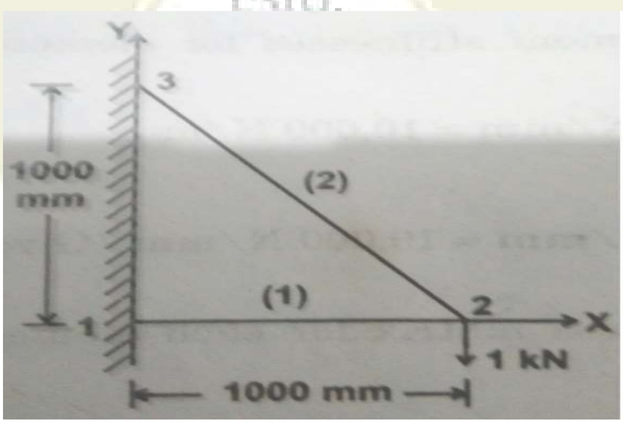
For Aluminum A_1= 1000 mm^2 For Steel A_2= 1500 mm^2

E_1= 0.7 × 10^5 N/mm^2 E_2= 2 × 10^5 N/mm^2

α_1 = 23 ×10^{-6} A_2 = 12 ×10^{-6}

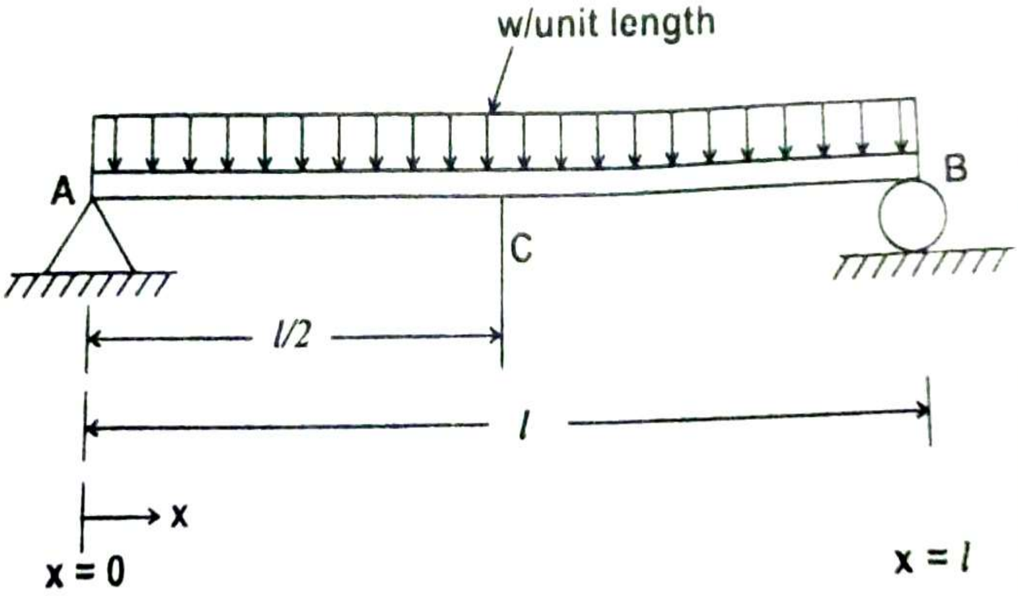


8. A truss structure is subjected to a load of 1 KN as shown in Figure. Calculate the nodal displacements and forces if the element stiffness of the truss is 10 kN/mm



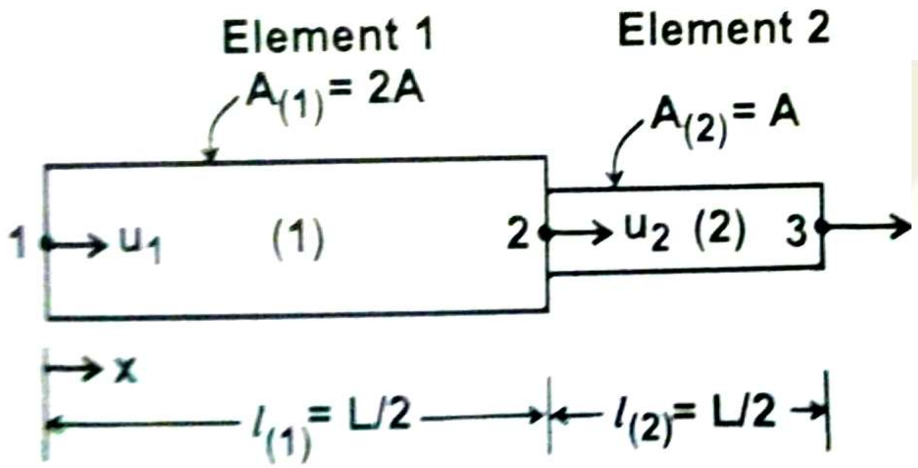
9. For a simply supported beam of span length l subjected to uniformly

distributed load throughout its length as shown in Figure, Find the deflection at the centre of the beam using one term trigonometric trial function in Rayleigh – Ritz method



10 Explain any four weighted residual methods

11 Find the natural frequencies of longitudinal vibration of the unconstrained stepped bar as shown in Figure?



12 Find the positive root of x^4-x= 10 correct to three places using Newton-Raphson method

Syllabus

MODULE	CONTENT	HOURS	SEMESTER EXAM MARKS (%)
I	FEA introduction: Discretization- Co-ordinates- Stiffness Matrix-Review of computational procedures with 1-D elements –Interpolation and shape functions – 2-D elements – Plane stress and plane strain analysis – CST and LST elements	**8**	**20**
II	Heat transfer and fluid flow problems – Choice of interpolation functions – Numerical integration. Axi–Symmetric problems, Modelling considerations – Symmetry – Applications – Iso-parametric formulation – 1-D and 2-D elements	**8**	**20**
III	Analysis of trusses- Coordinate transformation – Transformation of characteristic matrix–Lagrange multiplier and penalty function methods– Error – Sources of error –Convergence–Error estimates.	**8**	**20**
IV	Boundary value problems – Weak and strong forms – Functional –Euler-Lagrange equations – Rayleigh-Ritz method-Weighted-residual methods – Galerkin, Least-square and collocation methods – Galerkin finite element formulation – Applications to structural, Thermal and fluid flow problems.	**8**	**20**
V	Finite element formulation for non-linear problems – Solution methods– Method of false position- Newton-Raphson method – Modified Newton-Raphson method – Convergence criteria – Applications- FEA in vibration analysis–Fluid structure interaction–Thermo-mechanical problems and contact problems.	**8**	**20**

Course Plan

No	Topic	No. of Lecture Hours
1	**FEA Procedure**	
1.1	FEA introduction:	1
1.2	Discretization, Co-ordinates- (Local, Global, Natural)	1
1.3	Stiffness Matrix	1
1.4	Review of computational procedures with 1-D elements	1
1.5	Interpolation and shape functions	1
1.6	2-D elements	1
1.7	Plane stress and plane strain analysis	1
1.8	CST and LST elements	1
2	**Numerical integration and modelling consideration**	
2.1	Heat transfer and fluid flow problems	1
2.2	Choice of interpolation functions	1
2.3	Numerical integration	2
2.4	Axi–Symmetric problems	1
2.5	Modelling considerations	2
2.6	Iso-parametric formulation of 1-D and 2-D elements	1
3	**Coordinate transformation and error estimation**	
3.1	Analysis of trusses	1
3.2	Coordinate transformation	1
3.3	Transformation of characteristic matrix	1
3.4	Lagrange multiplier and penalty function methods	1
3.5	Error –Sources of error	1
3.6	Convergence	1
3.7	Error estimates.	2
4	**Finite element formulation**	
4.1	Boundary value problems	1
4.2	Weak and strong forms	1
4.3	Functional –Euler-Lagrange equations	1
4.4	Rayleigh-Ritz method	1
4.5	Weighted-residual methods	1
4.6	Galerkin, Least-square and collocation methods	1
4.7	Galerkin finite element formulation – Applications to structural, Thermal and fluid flow problems.	2

5	**Solution methods and advanced applications**	
5.1	Finite element formulation for non-linear problems, – Solution methods	1
5.2	Method of false position	1
5.3	Newton-Raphson method	1
5.4	Modified Newton-Raphson method	1
5.5	Convergence criteria	1
5.6	Applications of FEA in vibration analysis	1
5.7	Fluid structure interaction	1
5.8	Thermo-mechanical problems and contact problems.	1

Reference Books

1. R. D. Cook, D. S. Malkus, M. E. Plesha, R. J. Witt, Concepts & Applications of Finite Element Analysis, John Wiley & Sons, Fourth Edition, 2007
2. D. V. Hutton, Fundamentals of Finite Element Analysis, Tata McGraw Hill, 2005.
3. S. S. Rao, The Finite Element Method in Engineering, Butterworth Heinemann,5/E, 2010
4. J. N. Reddy, An Introduction to the Finite Element Method, McGraw Hill International, Third Edition, 2009
5. K. J. Bathe, Finite Element Procedures in Engineering Analysis, Prentice Hall of India, 2014.
6. O. C. Zienkiewicz, R. L. Taylor, The Finite Element Method, McGraw Hill, 7/E, 2013.
7. Dr. Sudhir K. Pundir, Numerical methods in science and Engineering, CBS publishers and distributers

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221EME038	DESIGN FOR MANUFACTURING	PROGRAMME ELECTIVE 1	3	0	0	3

Preamble: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Recognize the need to transform an industrial scenario from the traditional approach of no interaction between design and manufacturing engineers towards DFM.
CO 2	Design formed metal components with their manufacturing requirements in mind.
CO 3	Design machined components with their manufacturing requirements in mind.
CO 4	Design castings & non-metallic parts with their manufacturing requirements in mind.
CO 5	Design weldments with their assembly requirements in mind.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1			✓	✓		✓
CO 2			✓	✓		✓
CO 3			✓	✓		✓
CO 4			✓	✓		✓
CO 5			✓	✓		✓

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	20
Analyse	20
Evaluate	20
Create	-

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer reviewed original publications (minimum
10 publications shall be referred): 15 marks
Course based task/Seminar: 15 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus): 10 marks

End Semester Examination Pattern:

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Model Question Paper

DESIGN FOR MANUFACTURING

PART A

(Answer all the questions. Each question carries 5 Marks)

1. Describe the important factors to be considered while analysing the alternative methods for production?
2. Illustrate the process of Extrusion and comment on the economic production quantities for Extrusion?
3. Explain the typical applications of Automatic - Screw – Machine parts?
4. Illustrate the typical characteristics of Sand-Cast parts?
5. Explain the common in-process industrial cleaning operations?

PART B

(Answer any 5 questions. Each carry 7 Marks)

6 Discuss the processes of training and indoctrination with respect to managing the DFM in an engineering industry?

7 Explain the significance of Concurrent Engineering approach in managing the DFM?

8 Illustrate the important design recommendations for Powder Metallurgy parts?

9 For a design engineer, identify the important points for consideration applicable to machined, moulded, cast, formed, or stamped gears? Explain in details the important design recommendations?

10 Explain the Thermoset-moulding processes and summarize the important design recommendations for Thermosetting-Plastic parts?

11 Describe the important design recommendations for industrial cleaning processes?

12 Summarize the various industrial cleaning processes and their applications?

Syllabus

MODULE	CONTENT	HOURS	SEMESTER EXAM MARKS (%)
I	Economics of process selection – General design principles for manufacturability – History of Design for Manufacturability (DFM) – Managing DFM – Evaluating design proposals – Economical use of raw materials: Design recommendations for utilizing ferrous metals, nonferrous metals and non-metallic materials.	8	20
II	**Formed Metal Components**: Process description and Design recommendations for Metal extrusions, Metal stampings, Fine-blanked parts, Four-slide parts, Springs and wire forms, Spun-metal parts, Cold-headed parts, Cod extruded parts, Rotary-swaged parts, Tube and section bends, Roll-formed sections, Powder metallurgy parts, Forging, Electroformed parts, Metal injection-moulded parts.	8	20
III	**Machined Components**: General guidelines for Designing for Machining – Process description and Design recommendations for parts cut to length, Screw machine products, Other turned parts, Machined round holes, Parts produced on Milling, Planning, Shaping and Slotting machines, Screw threads, Broached parts, Internally ground parts, Cylindrically ground parts, Flat-ground surfaces, Honed, Lapped and Superfinished parts, Parts by Electrical Discharge Machining, Electrochemically machined parts, Gears - Designing parts for economical Deburring.	8	20
IV	**Castings**: Process description and Design recommendations for castings made in sand moulds, Permanent-mould castings, Centrifugal castings, Plaster-mould castings, Ceramic-mould castings, Investment castings, Die castings. **Non-metallic Parts**: Process description and Design recommendations for Thermosetting-	8	20

	plastic parts, Injection-moulded thermoplastic parts, Structural-foam-moulded parts, Rotationally moulded plastic parts, Blow-moulded plastic parts, Reinforced-Plastic/Composite parts, Plastic profile extrusions, Thermoformed-plastic parts, Welded plastic assemblies, Rubber parts, Ceramic and glass parts.		
V	**Assemblies:** Design for Assembly (DFA) – Process description and Design recommendations for Arc weldments and other weldments, Resistance weldments, Soldered and brazed assemblies, adhesively bonded assemblies. **Finishes:** Designing for cleaning - Process description and Design recommendations for Polished and plated surfaces, Hot-dip metallic coatings, Thermal-sprayed coatings, Vacuum-metallized surfaces, Heat treatments, Organic finishes. DFM for low quantity production – Guidelines.	**8**	**20**

Course Plan

No	Topic	No. of Lectures
1	**Design For Manufacturability (DFM)**	
1.1	Economics of process selection	1
1.2	General design principles for manufacturability, History of Design for Manufacturability (DFM)	1
1.3	Managing DFM, Evaluating design proposals – Economical use of raw materials	1
1.4	Design recommendations for utilizing ferrous metals	2
1.5	Design recommendations for utilizing nonferrous metals	2
1.6	Design recommendations for utilizing non-metallic materials.	1
2	**Process description and Design recommendations for Formed Metal Components**	
2.1	Process description and Design recommendations for Metal extrusions	1
2.2	Process description and Design recommendations for Metal stampings, Fine-blanked parts,	1
2.3	Process description and Design recommendations for Four-slide parts, Springs and wire forms	1
2.4	Process description and Design recommendations for Spun-metal parts, Cold-headed parts	1
2.5	Process description and Design recommendations for Cold extruded parts, Rotary-swaged parts,	1
2.6	Process description and Design recommendations for Tube and section bends, Roll-formed sections	1
2.7	Process description and Design recommendations for Powder metallurgy parts, Forging, Electroformed parts,	1
2.8	Process description and Design recommendations for Metal injection-moulded parts.	1
3	**Process description and Design recommendations for Machined Components**	
3.1	General guidelines for Designing for Machining	1
3.2	Process description and Design recommendations for parts cut to length, Screw machine products,	1
3.3	Process description and Design recommendations for Other turned parts, Machined round holes,	1
3.4	Process description and Design recommendations for	1

	Parts produced on Milling, Planning, Shaping and Slotting machines	
3.5	Process description and Design recommendations for Screw threads, Broached parts, internally ground parts, cylindrically ground parts,	1
3.6	Process description and Design recommendations for Flat-ground surfaces, Honed, Lapped and Superfinished parts,	1
3.7	Process description and Design recommendations for Parts by Electrical Discharge Machining, electrochemically machined parts,	1
3.8	Process description and Design recommendations for Gears; Designing parts for economical Deburring.	1
4	**Process description and Design recommendations for Castings & Non-metallic Parts**	
4.1	Process description and Design recommendations for castings made in sand moulds, Permanent-mould castings	1
4.2	Process description and Design recommendations for Centrifugal castings, Plaster-mould castings	1
4.3	Process description and Design recommendations for Ceramic-mould castings, Investment castings, Die castings.	1
4.4	Process description and Design recommendations for Thermosetting-plastic parts, Injection-moulded thermoplastic parts,	1
4.5	Process description and Design recommendations for Structural-foam-moulded parts, rotationally moulded plastic parts,	1
4.6	Process description and Design recommendations for Blow-moulded plastic parts, Reinforced-Plastic/Composite parts,	1
4.7	Process description and Design recommendations for Plastic profile extrusions, Thermoformed-plastic parts,	1
4.8	Process description and Design recommendations for Welded plastic assemblies, Rubber parts, Ceramic and glass parts.	1
5	**Design For Assembly (DFA) & Finishes**	
5.1	Design For Assembly (DFA)	1
5.2	Process description and Design recommendations for Arc weldments and other weldments,	1

5.3	Process description and Design recommendations for Resistance weldments, Soldered and brazed assemblies	1
5.4	Process description and Design recommendations for Adhesively bonded assemblies.	1
5.5	Designing for cleaning - Process description and Design recommendations for Polished and plated surfaces,	1
5.6	Process description and Design recommendations for Hot-dip metallic coatings, Thermal-sprayed coatings, Vacuum-metallized surfaces,	1
5.7	Process description and Design recommendations for Heat treatments, Organic finishes	1
5.8	DFM for low quantity production – Guidelines.	1

Reference Books

1. "Design for Manufacturability Handbook", JAMES G. BRALLA, 2nd Edition, McGraw Hill, 1998

2. "Product Design for Manufacture and Assembly", GEOFFREY BOOTHROYD, PETER DEWHURST, WINSTON A. KNIGHT, CRC Press; 3rd edition, 2010

3. "Design for Manufacturing and assembly", O. Molloy, S. Tilley and E.A. Warman, First Edition, Chapman &Hall, London, UK, 1998

4. "Engineering Design", G. E. Dieter and L. C. Schmidt, Fourth edition, McGraw-Hill companies, New York, USA, 2009

PROGRAM ELECTIVE II

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221EME042	PRODUCTION AND OPERATIONS MANAGEMENT	PROGRAMME ELECTIVE 2	3	0	0	3

Preamble: Nil

Course Outcomes: After the completion of the course the student will be able to

CO 1	Develop manufacturing planning and control system and an appropriate forecasting strategy for atypical manufacturing industry.
CO 2	Design an appropriate SOP and MPS for an organization
CO 3	Develop an appropriate MRP and ERP strategies for an organization
CO 4	Solve the company wide problems in plant layout, line balancing and quality.
CO 5	Design an ideal strategy to establish quality on a companywide basis.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	✓	✓	✓	✓		
CO 2	✓	✓	✓			
CO 3	✓	✓	✓	✓		
CO 4	✓	✓	✓	✓		
CO 5	✓	✓	✓			

Assessment Pattern

Bloom's Category	End Semester Examination
Apply	20%
Analyse	60%
Evaluate	20%
Create	-

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer reviewed original publications (minimum
10 publications shall be referred): 15 marks
Course based task/Seminar: 15 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus): 10 marks

End Semester Examination Pattern:

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Model Question Paper

PRODUCTION AND OPERATIONS MANAGEMENT

PART A (Answer all the questions. Each question carries 5 Marks)

1. Explain the importance of forecasting in manufacturing industry?

2. Discuss the need of a balance between demand and supply?

3. Clarify the term Economic Order quantity?

4. Explain how the calculation of bill of materials helps in manufacturing a product?

5. Summarize the benefits of QFD?

PART B (Answer any 5 questions. Each carry 7 Marks)

6. Company ABC manufacturing safety shoe has a forecast of 165 units every month. The demand for each moth is given in the following table. Calculate (i)

Mean Deviation (ii) Mean absolute deviation (iii) Mean square error and (iv) Mean absolute percentage error

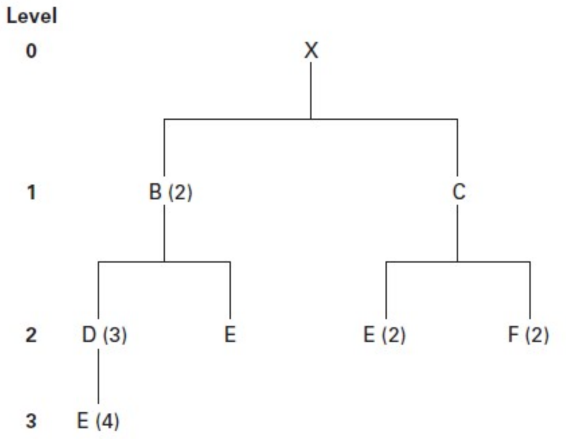
Month	1	2	3	4	5
Demand	150	160	165	175	180

7. Company EFG is manufacturing plastic chairs. Demand for each month is shown in the following table. A weight of 0.50 is assigned to the most recent demand value. A weight of 0.30 is assigned to the next most recent demand value and a weight of 0.20 is assigned to the oldest of the demand value included in the average. Calculate the weighted moving average

1	2	3	4	5	6
120	130	110	140	110	130

8. Differentiate between chase strategy, level strategy and mixed strategy

9. Utilize the information presented in Figure to compute the following:
   i. Compute the quantities of B, C, D, E, and F needed to assemble one X.
   ii. Compute the quantities of these components that will be required to assemble 10 Xs, taking into account the quantities on hand (i.e., in inventory) of various components:



Component	**On Hand**
B	4
C	10
D	8
E	60

10 Consider the following 2 machines and five jobs flow shop problem. Apply Johnson's algorithm to obtain optimal sequence which will minimize the makes span

Job(i)	Processing Time	
	Machine 1	Machine 2
A	6	8
B	11	6
C	7	3
D	9	7
E	5	10

11 Substantiate benchmarking as a potential manufacturing strategy

12 Demonstrate the concept of lean manufacturing.

Syllabus

MODULE	CONTENT	HOURS	SEMESTER EXAM MARKS (%)
I	Manufacturing Planning and Control (MPC) system framework -Matching MPC system with the needs of the firm -Demand management in MPC System -Nature and Use of Forecast -Demand patterns -Forecasting Models -Measures of Forecast accuracy	8	20
II	Sales and operation planning (SOP) process-Managerial inputs to SOP -Planning strategies -Master Production Scheduling Process -MPS Techniques -Time fencing and MPS stability	8	20
III	Bill of materials (BOM)- MRP Concept -Lot sizing methods in MRP- Enterprise Resource Planning (ERP)and functional units-Performance measures	8	20
IV	Single machine scheduling - Flow Shop scheduling, Johnson's problem - Computerized layout planning, ALDEP, CRAFT -Line balancing - TQM -TPM - Quality audits	8	20
V	Quality costs – Direct and indirect costs – SERVQUAL- Quality function deployment – Kaizen – Benchmarking – 5 S Principle –Elements of JIT manufacturing – Introduction to lean and agile manufacturing	8	20

Course Plan

No	Topic	No. of Lecture Hours
1	Manufacturing Planning and Control and Forecasting	
1.1	Manufacturing Planning and Control (MPC) system framework	1
1.2	Matching MPC system with the needs of the firm	1
1.3	Demand management in MPC System	1
1.4	Nature and Use of Forecast	1
1.5	Demand patterns	1
1.6	Forecasting Models	2
1.7	Measures of Forecast accuracy	1
2	Sales and operation planning and Master Production Schedule (MPS)	
2.1	Sales and operation planning (SOP) process	1
2.2	Managerial inputs to SOP	1
2.3	Planning strategies	3
2.4	Master Production Scheduling Process	1
2.5	MPS Techniques	1
2.6	Time fencing and MPS stability	1
3	Material Requirement Planning (MRP) and Enterprise Resource Planning (ERP)	
3.1	Bill of materials (BOM)	2
3.2	MRP Concept	1
3.3	Lot sizing methods in MRP	3
3.4	Enterprise Resource Planning (ERP)and functional units	1
3.5	Performance measures	1
4	Production management and quality systems	
4.1	Single machine scheduling.	1
4.2	. Flow Shop scheduling, Johnson's problem	1
4.3	Computerized layout planning ALDEP, CRAFT	2
4.4	Line balancing	1
4.5	TQM	1
4.6	TPM	1

4.7	Quality audits	1
5	Quality performance measures	
5.1	Quality costs – Direct and indirect costs	1
5.2	SERVQUAL	1
5.3	Quality function deployment	1
5.4	Kaizen	1
5.5	Benchmarking	1
5.6	5 S Principle	1
5.7	Elements of JIT manufacturing	1
5.8	Introduction to lean and agile manufacturing	1

Reference Books

1. Thomas E. Vollmann, William L. Berry, D Clay Whybark, and F. Robert Jacobs, Manufacturing Planning and Control for Supply Chain Management, Mc Graw Hill Int. Ed., 2010.
2. Edward A. Silver, David F. Pyke and Rein Peterson, "Inventory Management and Production Planning and Scheduling", 3rd Ed., John Wiley & Sons, 1998.
3. S N Chary, Production and Operations Management, Tata McGraw-Hill, 2012
4. R Panneerselvam, Production and Operations Management, PHI Learning pvt Ltd., 2012
5. Francis, R.L. and White, J.A., Facility Layout and Location: An Analytical Approach Prentice-Hall Inc., New Jersey, 2010.
6. Apple, J.M., Plant Layout and Material Handling, Kreiger Publishing, 3rd Edition, 2005
7. Dale H Besterield, Total quality Management, Pearson Education, 3rd Edition, 2011
8. William J Stevenson, Operations management, Tata McGraw Hill, 2014.

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221EME043	SOFT COMPUTING TECHNIQUES	PROGRAMME ELECTIVE 2	3	0	0	3

Preamble: Nil

Course Outcomes:

CO 1	Develop a Genetic Algorithm to optimize the given single objective optimization problem.
CO 2	Design a Genetic Algorithm to optimize the given multi-objective optimization problem.
CO 3	Solve a multi-variable single objective optimization problem using Simulated Annealing.
CO 4	Develop a Fuzzy Inference System (FIS) to model input-output relationship with respect to a given real life problem.
CO 5	Design an optimized Artificial Neural Network (ANN) model for establishing input-output relationship with respect to a given engineering problem.

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	✓		✓	✓	✓	✓
CO 2	✓		✓	✓	✓	✓
CO 3	✓		✓	✓	✓	✓
CO 4	✓		✓	✓	✓	✓
CO 5	✓		✓	✓	✓	✓

Assessment Pattern

Bloom's Category	End Semester Examination (marks)
Apply	20
Analyse	40
Evaluate	-
Create	-

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred): 15 marks
Course based task/Seminar: 15 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus): 10 marks

End Semester Examination Pattern:

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Model Question Paper

SOFT COMPUTING TECHNIQUES

PART A

(Answer all the questions. Each question carries 5 Marks)

1. How do you select a suitable scheme of computing (either soft computing or hard computing or hybrid computing) to solve a particular problem?

2. Define Pareto-optimal front of solutions in connection with multi-objective optimization?

3. Discuss the principle of Particle Swarm Optimization (PSO) algorithm as an optimizer? How does it differ from the Genetic Algorithm?
4. Explain the principle of Takagi and Sugeno's approach of Fuzzy Logic Controller (FLC)?

5. State the differences between Incremental and Batch modes of training of a neural network?

PART B

(Answer any 5 questions. Each carries 7 Marks)

6. A binary-coded Genetic Algorithm (GA) is to be used to solve an optimization problem involving one real and another integer variable. The real and integer variables are allowed to vary in the ranges of (0.2, 10.44) and (0, 63), respectively. Design a suitable GA-string to ensure a precision level of 0.01 for the real variable?

7. Use a binary-coded GA to minimize the function

$$f(x_1,x_2) = x_1 + x_2 - 2x_1^2 - x_2^2 + x_1x_2, \text{ in the range of } 0.0 \leq x_1,x_2 \leq 5.0.$$

Use a random population of size N = 6, tournament selection, a single-point crossover with probability $p_c = 1.0$ and neglect mutation. Assume 3 bits for each variable and thus, the GA-string will be 6-bits long. Show only one iteration.

8. Use Distance-based Pareto-GA (DPGA) to update non-dominated front of solutions for a few solution points: (2.0, 5.0), (6.5, 2.5), (8.0, 1.5), (3.2, 7.8) through hand-calculations in order to solve the two-objective optimization problem as given below.

$$\text{Minimize } f_1(x_1,x_2) = x_1 + x_2; \text{ Minimize } f_2(x_1,x_2) = \frac{1}{x_1} + \frac{1}{x_2}$$

$$\text{Subject to } \quad 1.0 \le x_1, x_2 \le 10.0$$

9. Use simulated annealing to solve the optimization problem given below.

$$\text{Minimize } y = E(X) = f(x_1,x_2) = (x_1 - 3)^2 + (x_2 - 5)^2$$

$$\text{Subject to } 0.0 \le x_1, x_2 \le 8.0$$

Assume, the initial temperature of molten metal $T_0 = 3600^o K$; initial solution selected at random $X_0 = \binom{1.0}{1.5}$ and termination criterion $\varepsilon = 0.002$. Let us assume the random numbers varying in the range of (0.0, 1.0) are as follows: 0.2,0.8,0.5,0.4,0.7,0.9,0.3,0.1,0.6,0.3,0.5,0.7,0.9,0.3,0.4,0.7,0.2,0.6, and so on. Show three iterations only.

10 Let us consider a fuzzy set A(x) in a discrete universe of discourse as follows:
$A(x) = \{(x_1, 0.2), (x_2, 0.25), (x_3, 0.3), (x_4, 0.4), (x_5, 0.6)\}$. Calculate its entropy value?

11 What is Fuzzy C-Means Clustering? Explain the algorithm for Fuzzy C-Means Clustering?

12 A Radial Basis Function Network (RBFN) is to be used to model input-output relationships of a manufacturing process having three inputs and one output. Fig. 1 shows the RBFN with one hidden layer containing three

neurons. The hidden neurons are assume to have Gaussian Transfer Functions of the form: $y = f(x) = \exp\left[-\frac{(x-\mu)^2}{2\sigma^2}\right]$ with the values of mean μ and standard deviation σ as follows: $(\mu_1 = 4.0, \sigma_1 = 0.4)$; $(\mu_2 = 4.5, \sigma_2 = 0.6)$; $(\mu_3 = 5.0, \sigma_3 = 0.8)$. Assume initial weights as $w_{11} = 0.2, w_{21} = 0.1, w_{31} = 0.3$. Use incremental training scheme with the help of a scenario: $x_{11} = 0.8, x_{12} = 1.5, x_{13} = 2.5$ and output O=0.5. Use back-propagation algorithm with a learning ratio $\eta = 0.2$. Calculate the updated values of $w_{11}, w_{21}, w_{31}, \mu s$ and σs. Show only one iteration.

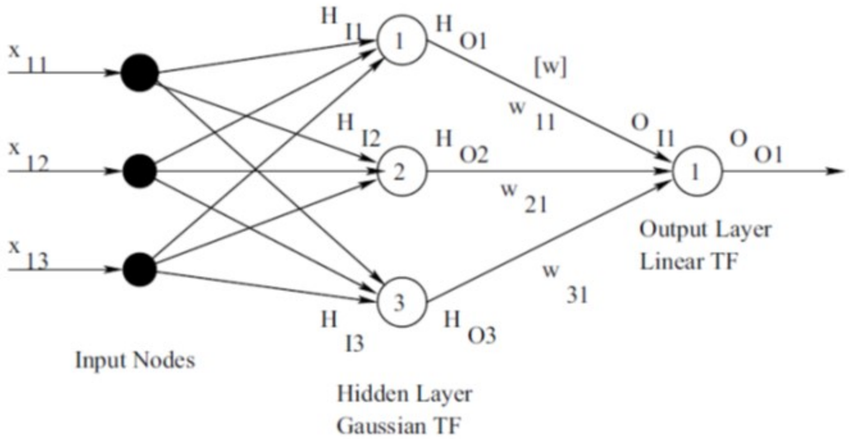


Fig. 1 A Radial Basis Function Neural network

Syllabus

MODULE	CONTENT	HOURS	SEMESTER EXAM MARKS (%)
I	Hard computing, Soft computing, Hybrid computing; Principle of optimization, Traditional methods of optimization; Genetic Algorithm (GA): Binary-coded GA, Parameters setting, Constraints handling, Real-coded GA, Micro-GA, Visualized interactive GA, Scheduling GA.	8	20
II	Multi-objective optimization: Different approaches – Weighted sum approach, Goal/Target programming, Vector Evaluated GA, Distance-based Pareto-GA, Non-dominated sorting GA.	8	20
III	Simulated Annealing (SA): Introduction, Working principle, Examples, Applications; Particle Swarm Optimization (PSO): Introduction, Algorithm, Examples, Comparison between GA and PSO.	8	20
IV	Fuzzy Logic: Crisp sets - Operations, Properties; Fuzzy sets – Operations, Properties; Measures of fuzziness and inaccuracy of fuzzy sets; Fuzzy logic controller – Mamdani approach, Takagi and Sugeno's approach, Hierarchical fuzzy logic controller, Sensitivity analysis; Fuzzy clustering – Fuzzy C-Means clustering, Entropy-based Fuzzy clustering.	8	20
V	Artificial Neural Network (ANN): Biological neuron, Artificial neuron, Static and dynamic neural networks, Supervised learning, Un-supervised learning, Incremental training, Batch mode of training; Multi-Layer Feed-Forward Neural Network (MLFFNN); Radial Basis Function Neural Network (RBFNN); Self-Organizing Map (SOM); Counter-Propagation Neural Network (CPNN); Recurrent Neural Network (RNN) – Elman network, Jordan network, Combined Elman and Jordan network; Introduction to Neuro-fuzzy systems - ANFIS.	8	20

Course Plan

No	Topic	No. of Lecture Hours
1	**Introduction to Genetic Algorithm**	
1.1	Hard computing, Soft computing, Hybrid computing	1
1.2	Principle of optimization	1
1.3	Traditional methods of optimization; Genetic Algorithm (GA)	1
1.4	Binary-coded GA	1
1.5	Parameters setting, Constraints handling	1
1.6	Real-coded GA, Micro-GA	1
1.7	Visualized interactive GA	1
1.8	Scheduling GA	1
2	**Multi-objective Genetic Algorithm**	
2.1	Multi-objective optimization	2
2.2	Different approaches – Weighted sum approach	1
2.3	Goal/Target programming	1
2.4	Vector Evaluated GA	1
2.5	Distance-based Pareto-GA	2
2.6	Non-dominated sorting GA	1
3	**Simulated Annealing (SA) and Particle Swarm Optimization (PSO)**	
3.1	Simulated Annealing (SA)	1
3.2	Introduction, Working principle	1
3.3	Examples, Applications	1
3.4	Particle Swarm Optimization (PSO)	1
3.5	Introduction, Algorithm	1
3.6	Examples	2
3.7	Comparison between GA and PSO	1
4	**Fuzzy Logic**	
4.1	Fuzzy Logic: Crisp sets, Operations, Properties	1
4.2	Fuzzy sets – Operations, Properties	1
4.3	Measures of fuzziness and inaccuracy of fuzzy sets	1
4.4	Fuzzy logic controller – Mamdani approach	1
4.5	Takagi and Sugeno's approach	1
4.6	Hierarchical fuzzy logic controller; Sensitivity analysis	1
4.7	Fuzzy clustering – Fuzzy C-Means clustering	1

4.8	Entropy-based Fuzzy clustering	1
5	**Artificial Neural Network (ANN)**	
5.1	Artificial Neural Network (ANN): Biological neuron	1
5.2	Artificial neuron, Static and dynamic neural networks	1
5.3	Supervised learning, Un-supervised learning	1
5.4	Incremental training, Batch mode of training	1
5.5	Multi-Layer Feed-Forward Neural Network (MLFFNN)	1
5.6	Radial Basis Function Neural Network (RBFNN)	1
5.7	Self-Organizing Map (SOM); Counter-Propagation Neural Network (CPNN)	1
5.8	Recurrent Neural Network (RNN) – Elman network, Jordan network, Combined Elman and Jordan network, Introduction to Neuro-fuzzy systems - ANFIS.	1

Reference Books

1. Dilip K. Pratihar, *Soft Computing: Fundamentals and applications,* Alpha Science International Ltd., Oxford, UK, 2014

2. Deb, Kalyanmoy, *Optimization for engineering design: Algorithms and examples.* PHI Learning Pvt. Ltd., 2012.

3. Deb, Kalyanmoy, *Multi-objective optimization using evolutionary algorithms.* John Wiley & Sons, 2001

4. Schalkoff ,R.J., *Artificial Neural Networks,* McGraw-Hill Companies Inc., 1997.

5. Sundareswaran, K, *A Learner 's Guide to Fuzzy Logic Systems,* Jaico Publishing House, 2005.

6. Randy L. Haupt & Sue Ellen Haupt, *Practical Genetic Algorithms*, Wiley-Interscience, 2nd edition, 2004.

7. Yegnanarayanan, B., *Artificial Neural Networks,* Prentice Hall of India, 1999

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221EME044	NANO AND MICRO MANUFACTURING	PROGRAMME ELECTIVE 2	3	0	0	3

Course Outcomes: After the completion of the course the student will be able to

CO 1	Identify the need and requirements of micro and nano manufacturing systems to address evolving challenges in materials and designs
CO 2	Understand some of the conventional and non-conventional micro-nano manufacturing systems
CO 3	Understand the concept of nano level manufacturing-Nano structured materials-Size effects. Synthesis of nano particles
CO 4	Understand various characterisation, quantification and imaging techniques needed for micro and nano manufacturing
CO 5	Understand various advanced finishing techniques for micro nano level manufacturing

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	✓		✓	✓		✓
CO 2	✓		✓	✓		✓
CO 3	✓		✓	✓		✓
CO 4	✓		✓	✓		✓
CO 5	✓		✓	✓		✓

Assessment Pattern

Bloom's Category	End Semester Examination (marks)
Apply	20
Analyse	40
Evaluate	-
Create	-

Mark distribution

Total Marks	CIE	ESE	ESE Duration
100	40	60	2.5 hours

Continuous Internal Evaluation Pattern:

Preparing a review article based on peer reviewed original publications (minimum 10 publications shall be referred): 15 marks
Course based task/Seminar: 15 marks
Test paper, 1 no. (Test paper shall include minimum 80% of the syllabus): 10 marks

End Semester Examination Pattern:

The end semester examination will be conducted by the respective College. There will be two parts; Part A and Part B. Part A will contain 5 numerical/short answer questions with 1 question from each module, having 5 marks for each question (such questions shall be useful in the testing of knowledge, skills, comprehension, application, analysis, synthesis, evaluation and understanding of the students). Students should answer all questions. Part B will contain 7 questions (such questions shall be useful in the testing of overall achievement and maturity of the students in a course, through long answer questions relating to theoretical/practical knowledge, derivations, problem solving and quantitative evaluation), with minimum one question from each module of which student should answer any five. Each question can carry 7 marks.

Model Question Paper

MICRO AND NANO MANUFACTURING

PART A

(Answer all the questions. Each question carries 5 Marks)

1. What is the need for precision manufacturing? Explain in the contexts of dimensions and tolerances?
2. Explain the method of making tools for micro milling
3. Describe Ion beam machining system with sketches?
4. With the help of schematic sketch, explain how PVD coating is deposited?
5. Explain the mechanism of material removal in magneto rheological abrasive flow finishing process?

PART B

(Answer any 5 questions. Each carries 7 Marks)

6 Compare top-down and bottom-up techniques of nano manufacturing with ONE example each.

7 List special features of diamond turning in comparison with conventional turning? What is the tool used in diamond turning

8 Prepare a schematic layout of focussed ion beam (FIB) machining? How FIB system can be used for imaging

9 Explain the synthesis of single walled carbon nanotubes?

10 How thin coatings can be deposited by physical vapor deposition? Explain the process with ONE example

11 Explain with sketch, Magneto Rheological Abrasive Flow Finishing (MRAFF) process, List process parameters affecting the finish

12 Explain the working principle of atomic force microscope (AFM) with sketch, How the tip of AFM is made

Syllabus

MODULE	CONTENT	HOURS	SEMESTER EXAM MARKS (%)
I	Introduction: Need for precision manufacturing. Classification of micro and nano manufacturing systems. Requirements of micro-machining systems – MEMS and NEMS devices, Top down and bottom-up approach for micro and nano manufacturing	8	20
II	Micro-machining methods: Micro turning, Diamond turning -drilling and milling -. Micro EDM and micro ECM, mechanism of material removal, difference between macro scale machining	8	20
III	Lithography, LIGA, Laser beam machining - Effect of process parameters, Heat affected zone, Electron beam machining - Ion beam machining, Principle of operation, Material removal mechanisms	8	20
IV	Nano structured material- thin wires-films-Quantum dots. plasma coating-CVD, PVD techniques and applications. Synthesis of carbon nanotubes	8	20
V	Advanced finishing techniques- Need for advanced finishing- Magneto Rheological finishing -Magneto Rheological Abrasive Flow Finishing Characterizations methods at micro and nano levels- Electron microscopy-SEM, STM-Atomic force microscopy-Confocal microscopy- Micro and nano hardness determination	8	20

Course Plan

No	**Topic**	**No. of Lectures**
1	**Introduction to precision engineering, MEMS, NEMS devices, Approaches to micro/nano manufacturing**	
1.1	Need for precision manufacturing, new materials, geometry, tolerances	1
1.2	Classifications of micro/nano manufacturing, Conventional, non conventional, thermal energy, electro chemical methods	2
1.3	Requirements of micro/nano manufacturing, characterization, metrology systems	2
1.4	Microelectromechanical systems and nanoelectromechanical devices	1
1.5	Top down and bottom-up approaches with case studies	2
2	**Mechanical and electric discharge type micro and nano manufacturing methods**	
2.1	Micro turning and diamond turning systems	2
2.2	Micro drilling and micro milling-tools and fabrication methods	2
2.3	Micro EDM, difference between EDM and micro EDM, Micro WEDM	2
2.4	Micro ECM, differences from ECM, features and tolerances, advantages	2
3	**Lithography and High energy beam micro/nano manufacturing methods**	
3.1	Lithography, LIGA	2
3.2	Laser beam machining, Types, Pulsed laser, Heat affected zone	2
3.3	Focused ion beam machining, principle, Uses and advantages	2
3.4	Micro Electron beam machining	2
4	**Nano structured materials and coatings, Methods of coating, Synthesis of CNT**	
4.1	Nano structured materials, Bulk and surface structures	2
4.2	Thin wires and films, quantum dots	2
4.3	Plasma coating methods CVD, PVD coatings	2
4.4	Synthesis of single and multi-walled carbon nano tubes	2

5	**Advanced finishing techniques and metrology**	
5.1	Introduction to Micro and Nano Finishing Processes	1
5.2	Abrasive flow machining, process, advantages	1
5.3	Magnetorheological Finishing (MRF) processes, Material removal mechanism	1
5.4	Magnetorheological Abrasive Flow Finishing (MRAFF) processes, Material removal mechanism	1
5.5	Micro and nano metrology, defining the scale, uncertainty	1
5.6	Scanning Electron Microscopy, Scanning tunnelling microscopy – description, principle of atomic force microscopy - description, different modes of operation application, confocal microscopy	2
5.7	Estimation of hardness at micro and nano level, depth sensing indentation methods and stiffness estimation	1

Reference Books

J. Mc Geough, Micromachining of engineering materials, CRC press, 1st Edition, 2002

2. N. Taniguchi, Nanotechnology: Integrated processing systems for ultra-precision and ultra-fine products, Oxford University Press Inc, 1996

3. V. K. Jain, Introduction to micro machining, Narosa publishing house, 2014

4. Mark J Jackson, Micro and Nano manufacturing, Springer, 2nd Edition, 2008

CODE	COURSE NAME	CATEGORY	L	T	P	CREDIT
221LME003	ADVANCED MANUFACTURING LAB 1	LABORATORY	0	0	2	1

Preamble: Nil

Course Outcomes:

After the completion of the course the student will be able to

CO 1	To gather knowledge on 2D drawing using any software package
CO 2	To gather knowledge on 3D modelling using any software package
CO 3	To impart gather knowledge on static Finite Element analysis
CO 4	To impart gather knowledge on dynamic Finite Element analysis
CO 5	To gather knowledge on assembling of various parts, fits tolerance, surface quality and measurements
CO 6	To gather knowledge onsynthesis of mechanism design for manufacturing systems and robotics:

Mapping of course outcomes with program outcomes

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6
CO 1	√	√	√	√	√	
CO 2	√	√	√	√	√	
CO 3	√	√	√	√	√	
CO 4	√	√	√	√	√	
CO 5	√	√	√	√	√	
CO 6	√	√	√	√	√	

Continuous Internal Evaluation (CIE) Pattern: Total Marks: 100

Attendance	15 marks
Regular class work/Modelling and Simulation Lab Record and Class Performance	60 marks
Continuous Assessment Test (Minimum 1 Test)	25 marks

Syllabus

1. Exercises on solid modelling: Introduction to computer graphics - viewing transformations, curves and surfaces generation, curve fitting and curve fairing techniques - 2D, wire frame
2. 3D shading - familiarity with Boolean operations - sweep, revolve, loft, extrude, filleting, chamfer, splines etc. - windowing, view point, clipping, scaling and rotation transformations using commercial solid modelling packages
3. Exercises on finite element analysis: Introduction to FEM - 1D, 2D and 3D elements - shape functions – pre-processing - boundary conditions, structured and free mesh generation - analysis - linear and non-linear analysis - static analysis - post processing - display, animation, extraction of nodal data - exercises on heat conduction and elasticity may be given using commercial FEM packages
4. Dynamic analysis using FE package-Modal and harmonic analysis. Impact analysis.
5. Exercises on Assembly and mechanism design: Assembling of various parts and tolerance analysis - synthesis and design of mechanisms - animations - exercises on various mechanisms like four bar linkages and its variations - cam and follower – Limits fits and tolerances-Surface Measurements-Parameters
6. Synthesis of mechanisms-Programming techniques for analytical synthesis-Robotic arm motion synthesis

No	**List of Exercise**	**Course Outcomes**
1	Preparation of 2D drawing using basic operations	**CO 1**
2	Preparation of 2D drawing using basic operations	**CO 1**
3	Preparation of 2D drawing using basic operations	**CO 1**
4	Preparation of 3D drawing using Boolean operations	**CO 2**
5	Preparation of 3D drawing using Extrude operations	**CO 2**
6	Preparation of 3D drawing using Mirror/copy operations	**CO 2**
7	Preparation of 3D drawing using rotation operations	**CO 2**
8	FE analysis static problems	**CO 3**
9	FE analysis static problems	**CO 3**
10	FE analysis static and thermal problems	**CO 3**
11	FE analysis static and thermal problems	**CO 3**
12	FE analysis dynamic problems	**CO 4**
13	FE analysis dynamic problems	**CO 4**
14	Exercises on limits fits and tolerances	**CO 5**

15	Exercises on surface measurements	**CO 5**
16	Exercise on synthesis of mechanisms involving linkages	**CO 6**

References:

1. ANSYS Software manual-ANSYS Inc

2. P.Radhakrishnan, Computer Numerical Control and Computer Aided Manufacture, New Age International Publishers, 2012

3. K. J. Bathe, Finite Element Procedures in Engineering Analysis, Prentice Hall of India, 2014